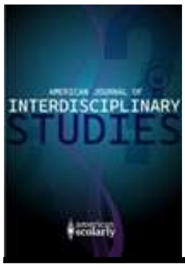

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Enhancing U.S. Manufacturing Competitiveness through Lean Manufacturing: A Framework for Supply Chain Resilience and Risk Mitigation

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Abstract

This study addresses a persistent problem in U.S.-oriented manufacturing supply chains: firms pursue lean to stabilize cost and flow, yet disruptions expose gaps in preparedness, response, recovery, and risk mitigation, creating uncertainty about which lean bundles most reliably strengthen supply chain resilience. The purpose was to quantify and synthesize how lean practice clusters relate to resilience capabilities and risk-mitigation outcomes across enterprise case evidence using a quantitative, cross-sectional, case-based research design. Using a structured evidence-synthesis dataset of 42 enterprise manufacturing cases reported in peer-reviewed studies, lean was operationalized as practice clusters (LP1–LP9) such as standardized work and visual management, continuous improvement, quality at the source, TPM, pull routines, supplier development, and visibility dashboards; resilience was measured as four capability variables (Readiness RC1, Response RC2, Recovery RC3, Adaptation RC4) and an overall Resilience Capability Score (RCS); risk mitigation was captured via an overall Risk Mitigation Index (RMI) across risk categories. The analysis plan applied a five-point Likert evidence-strength scoring for each construct link and aggregated means, standard deviations, and study counts, complemented by cross-case comparisons by manufacturing segment. Headline findings show strong overall support for a positive lean–resilience relationship (RCS $M = 4.1$, $SD = 0.6$, $n = 42$), with the strongest capability evidence in Response (RC2 $M = 4.3$, $SD = 0.6$, $n = 41$) and Recovery (RC3 $M = 4.2$, $SD = 0.6$, $n = 40$), while Adaptation was comparatively lower (RC4 $M = 3.8$, $SD = 0.8$, $n = 33$) . Lean practice evidence was highest for standardized work and visual management (LP1 $M = 4.4$, $SD = 0.6$, $n = 42$) and continuous improvement (LP2 $M = 4.2$, $SD = 0.7$, $n = 40$), and overall risk mitigation was strong (RMI $M = 3.9$, $SD = 0.7$, $n = 42$). Cross-case patterns indicate higher resilience in discrete, coordination-intensive segments such as automotive (RCS $M = 4.4$, $SD = 0.5$) than process industries (RCS $M = 3.9$, $SD = 0.7$), and supplier-facing lean yielded stronger supplier-risk mitigation ($M \approx 4.1$) than internal-only lean ($M \approx 3.6$). Implications are that managers should treat lean as a capability-building system, prioritizing visibility, disciplined escalation, and joint problem-solving across supplier interfaces, and should pair flow-focused tools with selective buffers and segment-appropriate continuity strategies where external logistics constraints dominate.

Keywords

Lean Manufacturing; Supply Chain Resilience; Supply Chain Risk Mitigation; Dynamic Capabilities; Cross-Sectional Case Synthesis.

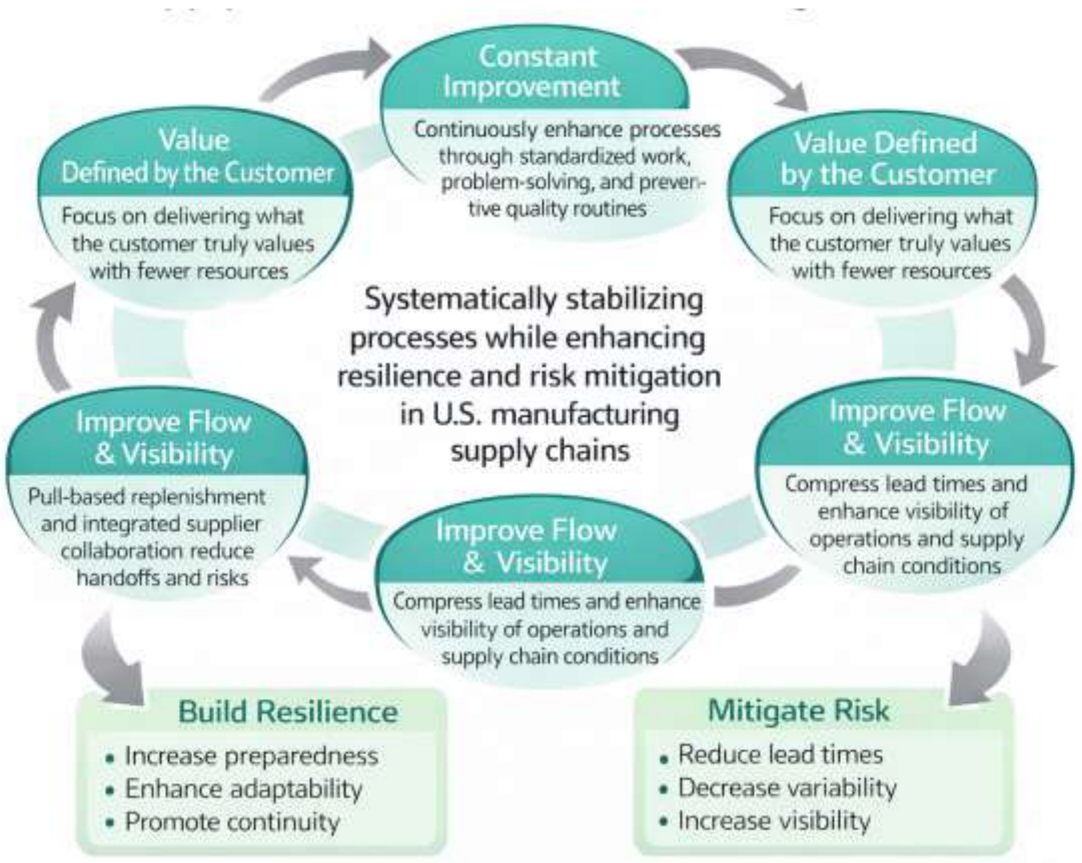
INTRODUCTION

Lean manufacturing is commonly defined as an integrated socio-technical system of principles, practices, and routines that systematically identifies and removes non–value-adding activities (waste) from production and associated information flows so that customer value can be delivered with fewer resources, shorter lead times, and more stable processes (Ambulkar et al., 2015). In the supply chain domain, lean extends beyond the factory boundary into procurement, logistics, supplier coordination, and distribution, where it emphasizes flow, standardization, pull replenishment, supplier integration, quality at the source, and continuous improvement embedded in daily work. Supply chain resilience, in parallel, is defined as the capability of a supply chain and its participating firms to prepare for, respond to, and recover from disruptions while maintaining continuity of operations and acceptable performance outcomes. Risk mitigation refers to the structured set of managerial actions that identify, assess, reduce, transfer, or control exposure to uncertain events affecting supply continuity, operational stability, cost, quality, safety, or service (Brandon-Jones et al., 2014). These three constructs—lean manufacturing, supply chain resilience, and risk mitigation—have become internationally significant because modern production networks operate across borders and rely on tightly coordinated, time-sensitive flows that face recurrent disturbance from supplier failures, logistics interruptions, market volatility, regulatory shifts, and operational accidents. The economic importance of resilient supply chains is also reflected in evidence linking disruption events to measurable performance penalties, including adverse market and operational consequences that persist beyond the disruption window, highlighting why resilience capabilities are treated as a core competitiveness dimension rather than a secondary contingency plan (Carvalho et al., 2012). At the same time, lean has been widely adopted internationally as a dominant improvement paradigm in manufacturing because it provides a consistent logic for stabilizing processes, improving quality, and strengthening coordination across internal and external interfaces. For manufacturing-intensive economies, these concepts are central to industrial performance because the reliability of inbound materials, production schedules, and outbound distribution directly affects jobs, export competitiveness, and the stability of critical product availability across sectors (Teece, 2007).

Global supply chains have evolved toward complex, multi-tier networks characterized by outsourcing, specialization, and geographic dispersion, which increases exposure to disruption propagation and amplifies the operational and financial significance of risk management choices. Disruptions are shaped not only by isolated failures but also by the interaction between supply chain design characteristics and the mitigation capabilities firms hold, meaning that vulnerability is partly structural and partly capability-driven (Shah & Ward, 2007). Research in operations and supply chain management has documented that disruptions correlate with reductions in firm performance and shareholder value, indicating that continuity failures are strategically material and not limited to short-term operational inconvenience. In response, supply chain risk management scholarship has defined risk as the probability and impact of events that hinder the flow of materials, information, and finances, and it frames mitigation as a portfolio of strategies that includes avoidance, redundancy, flexibility, collaboration, monitoring, and structured response routines (Chowdhury & Quaddus, 2017). At the same time, resilience scholarship has increasingly distinguished proactive dimensions (such as robustness, anticipation, and preparedness) from reactive dimensions (such as agility, rapid response, and recovery speed), emphasizing that resilience is not equivalent to risk avoidance; it is a capability set that interacts with how a supply chain is organized and managed (Craighead et al., 2007). Theoretical development has reinforced this capability orientation by positioning resilience as a higher-order construct shaped by managerial processes and resource orchestration, aligning with dynamic capability theory's emphasis on sensing, seizing, and reconfiguring resources under uncertainty. This framing supports a research focus on how operational improvement systems—such as lean manufacturing—may influence resilience and risk mitigation through structured routines that change how firms coordinate work, detect variation, and respond to instability. In international manufacturing environments, where supply networks may include thousands of suppliers and multiple logistics nodes, the question is increasingly about how improvement paradigms shape resilience capability portfolios and measurable risk outcomes across a set of comparable industrial contexts (Fan & Stevenson, 2018).

Lean manufacturing is frequently discussed in the empirical operations literature as a system of mutually reinforcing practices that builds process stability through standardized work, disciplined problem-solving, preventive quality routines, and controlled flow—features that can influence supply chain risk profiles because variability is a direct driver of schedule fragility and quality failures. Lean's process-view of operations treats waste, unevenness, and overburden as sources of instability that degrade throughput reliability and increase the likelihood that small disturbances escalate into significant performance loss (Govindan et al., 2015). When lean is extended across supply chain interfaces, it can reconfigure buyer–supplier interactions via supplier development, synchronized replenishment, quality collaboration, and information sharing routines that strengthen coordination and reduce error-producing handoffs. At the network level, lean-aligned practices are also associated with lead time compression and improved visibility of process conditions, which can shape both risk identification and response speed because problems surface earlier and are addressed through structured escalation and root-cause analysis (Hendricks & Singhal, 2005).

Figure 1: Lean Manufacturing Mechanisms for Supply Chain Resilience and Risk Mitigation



The literature also identifies an important managerial tension: lean often reduces buffers and inventories, which changes the risk–service trade-off and raises the need for complementary capabilities that prevent small shocks from converting into stoppages. That is why contemporary supply chain research increasingly studies lean not as an isolated efficiency program but as part of a broader operating model where resilience and risk mitigation outcomes depend on how lean routines are designed, governed, and integrated with supplier and logistics practices. Within this view, lean is relevant to resilience because it creates repeatable routines for detecting abnormal conditions, quickly stabilizing processes, and coordinating corrective action across functional boundaries. It is also relevant to risk mitigation because it supports structured work systems that lower operational uncertainty and create measurable performance baselines that can be monitored for early warning signals (Hohenstein et al., 2015). Supply chain resilience scholarship provides a complementary foundation by detailing capability sets that shape how firms and supply chains handle disturbance. Resilience is commonly conceptualized as the ability to withstand, adapt, and recover, and it is treated as multidimensional rather than a single managerial action, with both proactive and reactive elements required to maintain continuity. A major stream of empirical research emphasizes that resilience capability development is associated with managerial orientation toward disruptions, resource configuration decisions, and embedded infrastructures that support risk management and coordinated response. Systematic reviews also highlight that resilience research spans multiple levels (firm, dyad, network), multiple capabilities (flexibility, redundancy, collaboration, visibility), and multiple outcomes (service continuity, recovery time, financial stability), indicating that resilience must be operationalized through coherent measurement and evidence synthesis rather than treated as a general aspiration (Ivanov & Dolgui, 2020; Mosheur & Rebeka, 2021). The relational view has been used to explain how inter-firm competencies—communication, cooperation, and integration—support resilience by improving the ability to coordinate rapidly under change and to maintain stable configurations under uncertainty, connecting resilience outcomes to the quality of buyer–supplier relationships (Faysal & Shamsunnahar, 2022; Wieland & Wallenburg, 2012). Risk management studies further show that resilience and robustness outcomes can be linked to formal practices and strategies, not only to structural design, meaning that organizations can meaningfully shape their disruption performance through purposeful practice systems. In this space, dynamic capability theory has been used to ground resilience as a capability portfolio that enables firms to reconfigure resources and routines as environments shift, aligning with empirical scale development and measurement efforts in resilience research. This theoretical grounding is relevant for lean-focused inquiry because lean is also a practice system with routines that shape how resources are deployed, how problems are detected, and how organizations reconfigure operations in response to abnormal conditions. As a result, a literature-review–based synthesis that traces lean routines to resilience and risk mitigation mechanisms can be positioned within a capability framework that is widely used in contemporary supply chain resilience scholarship (Habibullah & Zaheda, 2022; Wieland & Wallenburg, 2013).

This study is designed to achieve a set of clearly defined objectives that align with the research title and the literature-review–based, qualitative, cross-sectional, case-study–oriented approach. The first objective is to systematically identify and categorize the dominant lean manufacturing practice clusters reported in peer-reviewed studies that examine U.S. manufacturing firms and their supply chain interfaces, with particular emphasis on internal stabilization practices (such as standard work, visual management, preventive maintenance, and quality-at-the-source routines) and externally oriented practices (such as supplier development, synchronized replenishment, and coordination mechanisms). The second objective is to synthesize, in a structured and comparable manner, how these lean practice clusters are linked in the literature to specific supply chain resilience capabilities, including readiness, response, recovery, and adaptation, so that the analysis distinguishes between practices that primarily strengthen operational stability and those that primarily improve rapid coordination and recovery under disruption conditions. The third objective is to consolidate evidence on the risk mitigation mechanisms associated with lean adoption in U.S. manufacturing supply chains by mapping lean routines to risk categories such as supplier risk, operational risk, logistics risk, and quality risk, thereby clarifying which mechanisms are most consistently reported as reducing exposure, limiting disruption propagation, or improving the speed and quality of corrective action. The fourth objective is to conduct a cross-sectional, cross-case comparison across major U.S. manufacturing segments represented in the literature, enabling the study to evaluate how industry conditions, product and process complexity, supply base structure, and regulatory requirements shape the strength and direction of reported lean–resilience and lean–risk mitigation relationships. The fifth objective is to evaluate the study's hypotheses and overall research aims using a literature-based evidence synthesis strategy that remains qualitative in interpretation while incorporating light numeric summarization in the findings section, such as frequency distributions of practice clusters, counts of supporting versus mixed evidence across studies, and simple evidence-strength scoring tied to the consistency and contextual coverage of the reviewed research. Collectively, these objectives ensure that the introduction transitions into a focused analytical roadmap that supports a results section organized around lean practice clusters, resilience capability contributions, risk mitigation mechanisms, cross-case segment patterns, and hypothesis assessment using transparent and replicable evidence synthesis logic.

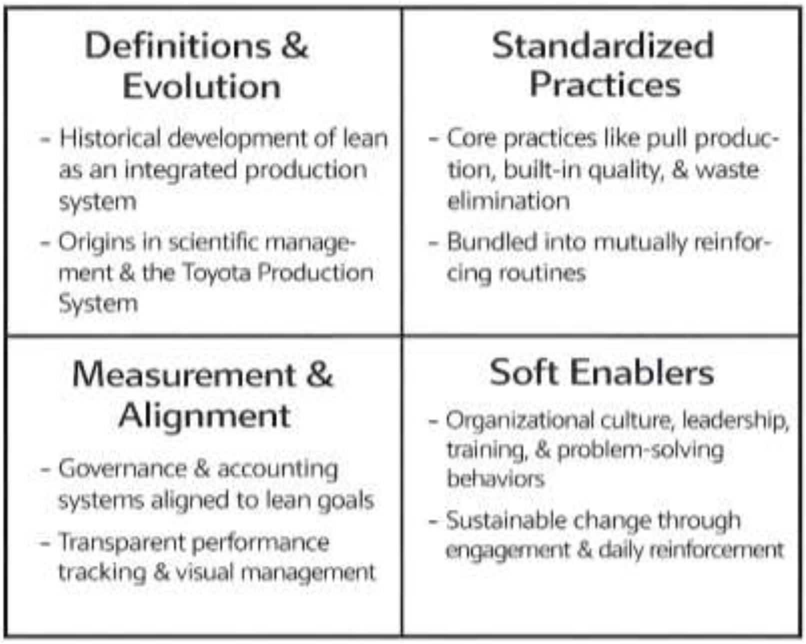
LITERATURE REVIEW

The literature on lean manufacturing, supply chain resilience, and supply chain risk mitigation forms an interconnected foundation for examining how operational improvement systems shape continuity and stability outcomes in manufacturing networks. Lean manufacturing is widely discussed as a management system that integrates principles of value creation, waste reduction, flow optimization, standardized work, quality at the source, and continuous improvement through structured routines and measurable performance control. Supply chain resilience literature complements this by focusing on capability development that enables firms and networks to maintain functionality under disruption, emphasizing preparedness, rapid response, recovery speed, and adaptive learning as core dimensions. Supply chain risk and risk management research adds a parallel stream that examines uncertainty sources and structured mitigation actions, often classifying risks across supplier, operational, logistics, and quality domains and emphasizing the need for coordinated governance across organizational boundaries. Together, these research streams suggest that resilience is not only a product of structural design choices such as network configuration and redundancy, but also a function of practice-based capabilities that influence how variation is detected, how coordination occurs, and how corrective actions are executed across supply chain partners. The literature further indicates that lean can influence resilience and risk mitigation through multiple pathways: stabilizing internal processes, shortening lead times, strengthening visual control and problem escalation, improving quality assurance routines, and extending disciplined improvement practices to supplier interfaces and logistics coordination. At the same time, scholarly work highlights that the relationship between lean and resilience is typically examined within context-dependent settings, where industry characteristics, product complexity, regulatory constraints, supply base structure, and dependence on global sourcing shape observed outcomes and reported trade-offs. As a result, prior studies are often distributed across different manufacturing segments and employ varied operationalizations of lean, resilience, and risk outcomes, which creates fragmentation in the evidence base and complicates generalization. The literature review in this study therefore serves two purposes: first, to consolidate and organize the conceptual and empirical knowledge across these domains into a coherent structure aligned with the study's research questions; and second, to establish a clear analytical logic for evaluating how lean practice clusters relate to resilience capability dimensions and risk mitigation mechanisms in the specific context of U.S. manufacturing firms. This review is organized to progress from foundational definitions and practice families to resilience and risk constructs, then to theoretical grounding and an integrative conceptual framework that guides the evidence synthesis approach used in the results section.

Lean Manufacturing Foundations

Lean manufacturing is presented in operations management as an integrated production philosophy that evolved from earlier quality and productivity movements into a coherent system of principles aimed at creating customer value through the systematic removal of waste, reduction of variability, and stabilization of flow. Contemporary scholarship traces lean's genealogy through its roots in scientific management, statistical quality control, and the Toyota Production System, emphasizing that lean matured into a transferable management concept by translating shop-floor routines into broader organizational practices and measurement logics (Jahangir & Shahab, 2022; Siddique & Amin, 2022). This historical development matters for research on supply chains because it clarifies that lean is not merely a toolbox but a managerial system that coordinates people, processes, and problem-solving around continuous improvement (Md & Islam, 2022; Mosheur & Rebeka, 2022). Lean's evolution also explains why studies describe it as a bundle of mutually reinforcing practices rather than a single intervention, since the benefits of pull production, standardized work, and built-in quality depend on complementary leadership behaviors, learning routines, and disciplined performance management (Ara, 2023; Mostafa & Tohidul, 2022). As lean spread beyond high-volume automotive settings into diverse manufacturing and service environments, the literature documented how the concept absorbed additional emphases, including enterprise-wide deployment, supplier linkages, and cross-functional integration, while maintaining its core logic of flow and waste elimination. In this view, lean's international relevance is grounded in its ability to provide an improvement architecture that organizations can adapt to local constraints while preserving principles and common language for operational excellence. The lean literature therefore begins with conceptual clarity on origins and definitions, because the validity of later empirical comparisons depends on whether researchers are studying comparable constructs and practice configurations across contexts and time. This foundational discussion also supports the study's focus on U.S. manufacturing supply chains by providing a structured lens for distinguishing internal lean stabilization practices from externally oriented practices that shape supplier coordination and logistics interfaces (Holweg, 2007).

Figure 2: Lean Manufacturing Foundations and Practice Bundles Framework



A further development in the lean literature is the shift from "hard" technical tools toward the enabling social and organizational conditions that make lean durable, scalable, and transferable across sites (Jinnat & Rakib, 2023; Khaled & Mosheur, 2023). Research on successful lean implementation increasingly emphasizes organizational culture, employee engagement, leadership commitment, and structured problem-solving as core determinants of whether lean practices become routinized or remain superficial initiatives. This emphasis is analytically important because resilience and risk outcomes in supply chains depend on dependable routines, shared norms for escalation and corrective action, and consistent cross-functional collaboration, all of which are shaped by the "soft" side of lean (Shahab & Aditya, 2023; Hasan Or et al., 2023; Tortorella et al., 2018). Empirical studies have shown that soft lean practices, such as training, involvement, communication, and leadership behaviors, strengthen the effectiveness of technical tools by building capability for continuous improvement and disciplined execution, thereby helping organizations sustain performance improvements over time (Mehedi & Nahar, 2023; Sultan & Anick, 2023). Implementation research also demonstrates that contextual variables at the team and leadership level influence the extent to which lean practices are adopted, suggesting that lean maturity cannot be inferred solely from tool presence; it reflects how leadership styles and organizational conditions enable daily adherence to lean routines. For supply chain–oriented research, these findings support the interpretation of lean as a capability system that can extend outward to suppliers through shared routines, joint problem-solving, and stable interface management, rather than as an internally bounded efficiency program. They also justify why a literature review that targets U.S. manufacturing supply chains should code both technical practice bundles and soft enabling practices, because the latter often explain heterogeneous outcomes across comparable industries and firms (Bortolotti et al., 2015).

Lean Practices In Manufacturing Supply Chains

Lean practices in manufacturing supply chains are commonly conceptualized as inter-organizational extensions of lean thinking that align upstream and downstream value streams around flow, waste removal, and synchronized execution across multiple firms. In this stream of research, “lean supply chain” practice is not limited to internal production techniques; it is operationalized through coordinated replenishment, delivery discipline, supplier collaboration, and governance routines that stabilize material and information flows across nodes. Early supply chain strategy studies positioned lean supply chains as designs that emphasize predictable demand fulfillment, low total cost, and streamlined logistics, while distinguishing lean from agile and hybrid “leagile” strategies based on where and how responsiveness is created across the network (Goldsby et al., 2006). This strategic view connects directly to concrete practice families used by manufacturers, including pull-based replenishment, frequent deliveries, standardized logistics processes, cross-functional planning routines, and supplier partnership mechanisms that reduce uncertainty at interfaces where disruptions commonly originate. Lean supply chain practice is also described as a discipline of aligning process capability and schedule reliability with sourcing and distribution decisions, because the stability of inbound supply and outbound delivery reliability becomes a functional requirement for maintaining flow. As a result, lean supply chain deployment is frequently discussed as a coordinated operating model in which procurement, manufacturing, and logistics share a common cadence, shared problem-solving, and shared performance measures. The lean supply chain literature therefore emphasizes practice bundles rather than isolated initiatives, because synchronized execution depends on multiple reinforcing routines such as supplier relationship governance, stable transportation scheduling, structured escalation of abnormalities, and internal leveling of production. This foundational lens is central for manufacturing supply chains because it frames lean as a network discipline that shapes how operational variability is absorbed, detected, and corrected across organizational boundaries rather than only within a single plant (Goldsby et al., 2006).

A second major practice stream concerns the tools and methods used to visualize, diagnose, and improve supply chain flows, with value-stream approaches receiving sustained attention as mechanisms for making waste visible beyond the factory (Mostafa, 2023; Ratul & Aditya, 2023). Cross-boundary mapping expands traditional value stream mapping from intra-firm process improvement to end-to-end analysis of supply chains, enabling organizations to identify delays, non–value-adding handling, information defects, redundant approvals, and bottlenecks across suppliers, production sites, and distribution channels. Supply chain value stream mapping is presented as a method that translates lean’s diagnostic logic into a supply chain context by combining process mapping with operational data on time, delivery, and flow interruptions, thereby supporting structured improvement planning across multiple entities (Efat Ara, 2024b; Suarez-Barraza et al., 2016; Zaheda & Farabe, 2023). In manufacturing supply chains, this approach is relevant because waste is frequently embedded in handoffs: order processing delays, batching decisions, transportation waiting time, supplier lead-time variability, and quality-related rework loops (Efat Ara, 2024a; Iftekhar & Tohidul, 2024). Mapping-based lean practice is therefore treated as both an analytical tool and a governance device, because it can support a shared understanding of current-state performance and create alignment among functions and partners around improvement priorities (Jinnat & Binte, 2024; Towhidul & Uddin, 2024). Recent research also links lean supply chain planning to contemporary operations contexts by proposing conceptual models that connect lean principles to planning dimensions such as coordination, scheduling discipline, and multi-level flow control, reinforcing the idea that lean practice requires planning architectures capable of managing cross-organizational variability (Reyes et al., 2021). Through this lens, lean supply chain tools operate as capability enablers: they provide visibility, facilitate standardization, and support shared problem-solving routines that can be applied repeatedly to stabilize and improve supply chain execution (Mushfequr & Aditya, 2024; Qrunfleh & Tarafdar, 2013).

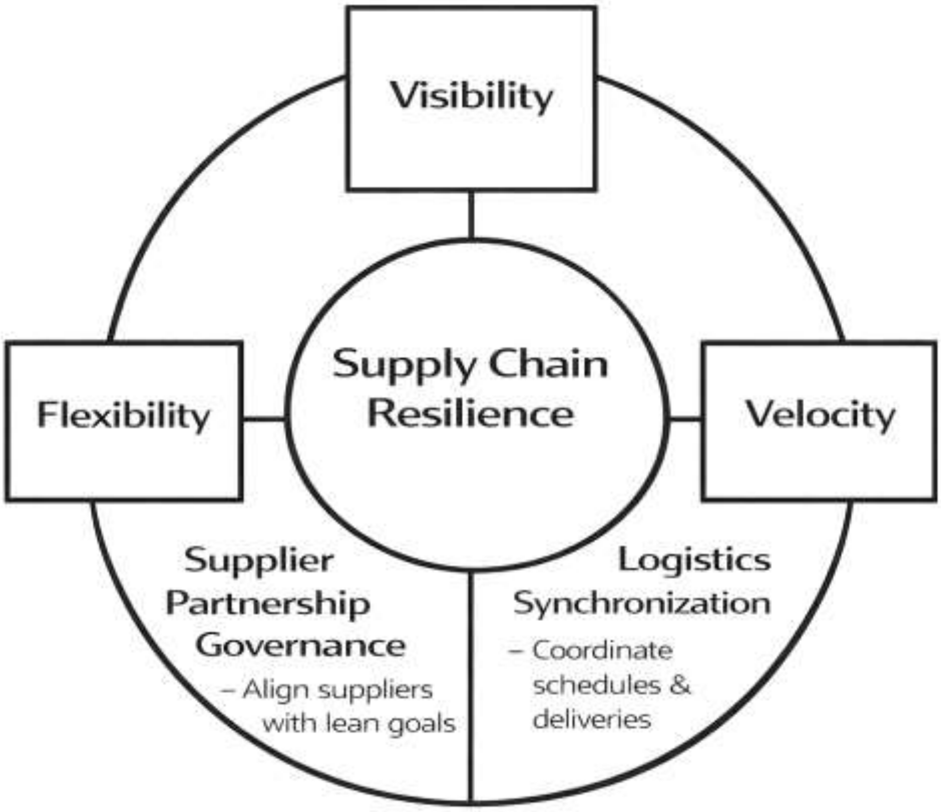
Figure 3: Lean Practices in Manufacturing Supply Chains: A Triangular Integration Framework

Supply Chain Resilience and Capability Dimensions

Supply chain resilience is widely discussed as a capability-oriented construct that captures how supply networks maintain continuity when confronted with disruptions, instability, or unexpected operational shocks. Conceptually, resilience is treated as more than a single response action because it reflects an organizations and network’s ability to function under disturbance while preserving essential flows of materials, information, and coordination. This capability focus has encouraged researchers to define resilience through operational dimensions that can be observed, compared, and measured across industries and supply chain structures (Sazzadul & Rebeka, 2024; Tasnim & Anick, 2024). A recurring theme in the literature is that resilience emerges from interconnected routines and resources that support visibility of conditions, timely decision-making, coordinated execution, and rapid restoration of stable performance after interruptions. Empirical studies therefore position resilience as an outcome of structured capabilities that firms intentionally develop rather than as a passive attribute determined solely by the external environment. In capability-based research, resilience is frequently framed as dependent on the strength of integration and flexibility across echelons, because synchronized coordination and adaptable execution determine how effectively a network responds once variability enters the system (Shahab, 2025; Zaheda & Hamidur, 2024). For example, evidence from survey-based research identifies that integration between supply chain echelons and flexibility in operations are central drivers that explain differences in resilience outcomes, reinforcing the view that resilience is rooted in coordinated managerial processes and not merely in structural redundancy (Brusset & Teller, 2017). This emphasis clarifies why resilience research often examines the quality of inter-firm interfaces, shared routines, and the operational “fitness” of the supply chain as core determinants of disruption performance. As a result, resilience is increasingly conceptualized as a multidimensional construct that reflects how supply networks sense deviations, align decisions, execute corrective actions, and stabilize performance across multiple nodes and partners.

The literature further refines resilience through explicit capability dimensions that describe what resilient supply chains are able to do under stress. A prominent capability framing emphasizes collaboration-based mechanisms that enhance visibility, velocity, and flexibility, proposing that resilience becomes stronger when supply chain actors coordinate problem detection, share timely information, and align responses through structured interaction patterns. Case-based evidence shows that collaboration does not operate as a vague relational ideal; it functions through concrete activities such as joint planning, shared monitoring, cross-organizational communication routines, and coordinated escalation pathways that accelerate response and reduce confusion during disruption events (Mostafa, 2025; Sazzadul, 2025; Scholten & Schilder, 2015). This view positions collaboration as a capability that shapes how quickly disruption signals travel and how effectively corrective actions are synchronized across boundaries. Complementing collaboration, resilience studies also emphasize the importance of "speed" or "velocity" in sensing and responding, because disruption losses are often proportional to the time taken to recognize abnormal conditions and mobilize corrective action. Research that models and tests resilience constructs also supports this multi-capability approach by linking collaboration, visibility, velocity, and flexibility to resilience outcomes and by demonstrating that these capabilities are mutually reinforcing rather than independent. For instance, empirical work examining the interrelationships among logistics and supply chain capabilities demonstrates that resilience is strengthened when these capabilities jointly operate, connecting resilience not only to internal operational discipline but also to the broader capability profile of the logistics and supply chain system (Mandal et al., 2017). Taken together, this stream of research clarifies that resilience capability dimensions can be treated as analyzable building blocks that enable cross-study comparison and systematic evidence synthesis, particularly in manufacturing contexts where coordination across suppliers, plants, and logistics partners is essential for continuity.

Figure 4: Supply Chain Resilience: Core Concepts and Capability Dimensions Framework



These measurement-oriented contributions are important because they reinforce that resilience includes both qualitative capability dimensions (such as flexibility and collaboration) and measurable performance-related indicators (such as recovery speed or stability under disruption), offering a bridge between conceptual definitions and empirical assessment (Shamsunnahar, 2025; Sharif Md Yousuf et al., 2025). In practical synthesis terms, this stream encourages reviews to code resilience evidence at two levels: (1) capability-level evidence describing the presence and maturity of resilience enablers and (2) outcome-level evidence describing continuity, recovery, or performance stability results. A synthesis structured this way can better clarify how operational systems—such as lean manufacturing—connect to resilience by shaping the enabling capabilities (visibility, coordination, disciplined execution) and by influencing measurable outcomes reported across manufacturing segments. Thus, resilience scholarship provides a robust conceptual and measurement toolkit that supports organizing evidence into comparable capability dimensions suitable for cross-case analysis in manufacturing supply chains.

Supply Chain Risk in Manufacturing Networks

Supply chain risk and risk mitigation research defines risk as the exposure of material, information, and financial flows to uncertainty that can trigger adverse performance outcomes across cost, quality, delivery, safety, or compliance. Within this literature, risk is treated as multi-source and multi-level, emerging from demand volatility, supplier unreliability, process instability, logistics breakdowns, infrastructure constraints, regulatory change, and rare catastrophic events. Because contemporary supply networks are tightly coupled, small disturbances can cascade across tiers when lead times are long, inventories are low, and visibility is limited, turning localized variability into network-level disruption (Akter & Aditya, 2025). Risk mitigation is therefore framed as a managerial discipline that spans identification, assessment, prioritization, and coordinated treatment actions that either reduce the probability of disruption or limit its impact once it occurs. Conceptual work has emphasized that turbulent environments intensify these dynamics by increasing the frequency of shocks and the ambiguity of signals, making risk management dependent on both structural design choices and ongoing governance routines (Trkman & McCormack, 2009). In manufacturing supply chains, risk mitigation is frequently discussed as a combination of preventive controls, monitoring systems, and response mechanisms that stabilize interfaces between suppliers, plants, and logistics providers. A key contribution of this stream is the articulation of how supply chain risk is shaped by interactions among partners and by the operating context, including supplier attributes, market turbulence, and network complexity, which jointly determine vulnerability patterns. This perspective supports a practice-based interpretation of mitigation in which firms build routines for early warning, supplier qualification, contingency planning, and coordinated decision escalation, rather than treating risk as an external force beyond managerial influence. It also motivates distinguishing between chronic operational risks that accumulate through everyday variability and acute disruption risks that arrive as discrete events, since each category demands different mitigation portfolios, metrics, and governance cadence inside manufacturing organizations (Trkman & McCormack, 2009).

Figure 5: Supply Chain Risk and Risk Mitigation in Manufacturing Networks

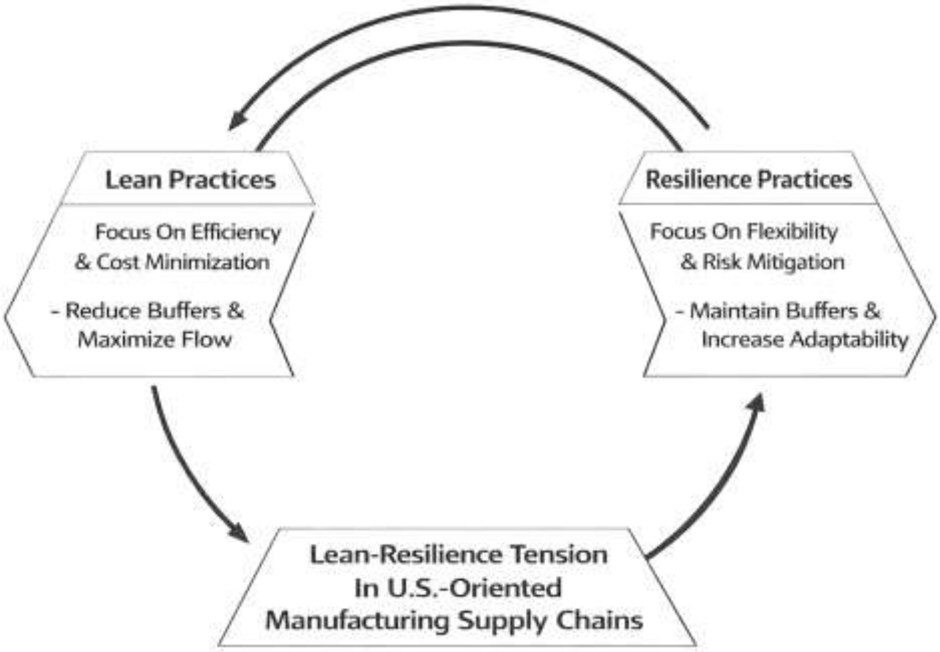
Empirical research has operationalized supply chain risk by measuring distinct risk-source classes and examining their associations with performance, creating a basis for evidence synthesis and for comparing mitigation effectiveness across settings. Survey-based work on supply chain vulnerability, for example, validates multiple categories of risk sources and links them to characteristics of the supply chain and its environment, clarifying that vulnerability is not uniform across firms even within the same industry. This empirical approach supports the argument that mitigation should be tailored to dominant risk drivers, such as supplier-side instability, demand-side uncertainty, infrastructure exposure, or regulatory burdens, rather than implemented as a generic checklist. Related studies broaden the performance lens by examining how different risk dimensions relate to multiple facets of supply chain performance, including reliability, responsiveness, and cost outcomes, and by demonstrating that some risk categories exhibit stronger performance effects than others (Wagner & Bode, 2008). This helps explain why mitigation investments are justified through their ability to protect the performance dimensions most sensitive to disruption in a given manufacturing context. Empirical work also emphasizes that risk management is not only about cataloging hazards; it is about understanding how risks translate into performance loss and where interventions can interrupt that pathway. For manufacturing supply chains, these findings encourage a mitigation logic that couples diagnostic risk measurement with targeted operational controls such as supplier development, quality assurance, process stability, and logistics coordination, because these controls influence the mechanisms through which risk sources become disruptions. The evidence further underlines the importance of considering both the probability of disruption and its consequences when evaluating mitigation strategies, since risk sources differ in frequency and severity profiles. This grounding supports cross-case comparisons that map risk categories to mitigation mechanisms and observable outcomes. It enables consistent coding of risk constructs for reviews (Wagner & Bode, 2006).

Lean–Resilience Tension in U.S.-Oriented Manufacturing Supply Chains

Lean manufacturing scholarship consistently frames "leanness" as the disciplined pursuit of flow efficiency through waste removal, standard work, and tight resource utilization, while supply chain resilience emphasizes the capacity to absorb disruption, recover performance, and reconfigure operations under volatility. When these two logics intersect at the supply-chain level, the literature frequently treats their relationship as conditional rather than universally complementary. Early critiques of lean expansion across multi-tier networks argued that lean principles can travel well inside firm boundaries but become more fragile when extended across heterogeneous partners, power asymmetries, and contested incentives, where coordination costs and uneven risk absorption shape outcomes (Cox & Chicksand, 2005). Within manufacturing supply chains, this tension often appears as a design question: how far can inventory compression, capacity smoothing, and supplier rationalization be pushed before the system loses the protective "slack" needed for shock absorption? A key synthesis in the lean/agile/"leagile" stream shows that competitive environments require differentiated configurations and that decoupling points, postponement, and hybrid designs become practical tools for combining cost discipline with responsiveness (Naim & Gosling, 2011). In a resilience-focused empirical view, the "efficiency–resilience" balance is not only a philosophical debate; it becomes visible in performance variability when disruptions occur, because lean's gains in stable operating conditions are realized through reduced buffers that otherwise dampen turbulence. Therefore, this subsection positions lean not as inherently anti-resilient, but as a capability set whose risk implications depend on context, network architecture, and the specific resilience functions prioritized by manufacturing firms operating in the U.S. supply ecosystem.

A major theme in the evidence base is that the payoff to leanness is moderated by environmental conditions and industry turbulence, implying that "more lean" is not automatically "more resilient." Empirical work on inventory leanness highlights that dynamism alters the returns to lean inventory positions, indicating that the same lean stance can support competitiveness in one setting while amplifying exposure in another when uncertainty rises and forecasting error grows (Eroglu & Hofer, 2014). This finding matters for U.S. manufacturing supply chains that operate in segmented markets with varying volatility profiles (e.g., durable goods, automotive, aerospace, electronics), because the resilience requirement is rarely uniform across categories. At the same time, research integrating lean and resilience practices suggests that lean routines can act as "drivers" that enable resilience-oriented routines—such as visibility, coordination discipline, and structured problem-solving—yet the same studies caution that implementing lean practices in isolation may create a more vulnerable chain when redundancy, flexibility, and recovery resources are underprovided (Ruiz-Benítez et al., 2018). The lean–resilience relationship therefore appears as a portfolio problem: firms assemble bundles of lean practices (flow, pull, setup reduction, supplier integration) while selecting resilience practices (multisourcing, capacity hedges, strategic stock, risk monitoring) to fit disruption exposure and cost tolerance. For this study's case-oriented synthesis, the implication is that U.S. manufacturing firms can be categorized by how they configure "where to be lean" (routine, predictable lanes) and "where to preserve options" (critical components, long lead-time suppliers, geopolitical bottlenecks), allowing evidence to be coded into patterns that connect lean intensity, buffer policy, and observed disruption performance.

Figure 6: Lean–Resilience Tension in U.S.-Oriented Manufacturing Supply Chains

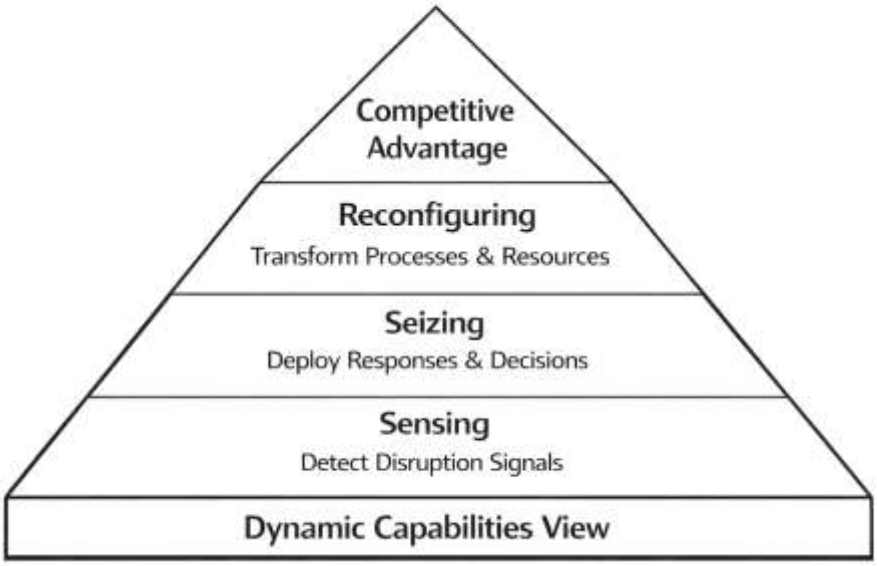


A complementary stream reframes resilience not as the opposite of efficiency, but as a set of operational capabilities whose efficiency value depends on disruption conditions and the firm's ability to deploy them effectively. Conceptual and empirical analyses show that resilience is multi-dimensional (e.g., absorption and recoverability) and that these dimensions can relate positively to operational efficiency under particular disruption contexts, suggesting that resilience investments may function as "productive" capabilities rather than pure insurance (Essuman et al., 2020). This argument helps reconcile the perceived contradiction between lean and resilience by emphasizing capability timing and deployment: certain resilience routines (rapid containment, structured recovery, cross-trained teams, stable processes) can raise efficiency by reducing downtime, scrap, and firefighting costs, which are forms of waste lean already targets. The literature therefore supports a more precise interpretation for this review: the risk-mitigation value of lean is strongest when lean is treated as a socio-technical system (standardization, learning cycles, visual management, disciplined escalation) and when buffers are selectively positioned rather than eliminated indiscriminately. In U.S. manufacturing case evidence, this logic commonly appears as selective redundancy (critical spares, dual tooling, alternate qualified suppliers), deliberate decoupling (postponement, modularity), and disciplined collaboration (supplier development, shared problem-solving) that preserves lean flow while protecting continuity. For the hypotheses and objectives of the present paper, this subsection will guide coding rules that distinguish (1) lean-as-cost-minimization, which can heighten vulnerability when buffers vanish, from (2) lean-as-capability-building, which can strengthen resilience when paired with targeted flexibility and recovery capacity.

Dynamic Capabilities View as Lean-Enabled Resilience

Dynamic Capabilities View (DCV) explains sustained performance under uncertainty by focusing on how firms build higher-order capabilities that repeatedly renew operational routines as environments shift. In this perspective, competitive advantage is shaped not only by what resources a firm owns, but by how effectively it can **sense** changes, **seize** timely responses, and **reconfigure** assets and processes to maintain fit with volatile conditions. DCV is particularly suitable for this study because supply chain disruptions represent recurring environmental shifts that require rapid detection, coordinated decisions, and disciplined operational reconfiguration across procurement, manufacturing, and logistics interfaces. DCV scholarship also emphasizes that dynamic capabilities are multi-dimensional and may exist as an aggregate construct composed of distinct yet interdependent sub-capabilities, supporting a structured approach for comparing evidence across heterogeneous manufacturing contexts (Pavlou & El Sawy, 2011). This conceptualization aligns with lean manufacturing as a socio-technical system of routines that institutionalize abnormality detection, continuous improvement cycles, and standardization—activities that closely mirror sensing, seizing, and reconfiguring behaviors within operations and supply chain coordination. A core implication is that lean can be interpreted as a capability-building architecture that enables firms to repeatedly re-align workflows, information flows, and supplier interfaces when disturbances occur, rather than as a one-time efficiency intervention. DCV also provides a rigorous explanation for cross-case differences expected in U.S. manufacturing segments, since dynamic capabilities are shaped by managerial processes, learning mechanisms, and the complexity of the operating environment, which varies across industries, product architectures, and supplier network structures (Barreto, 2010). As a result, DCV supports evidence synthesis that focuses on *how* lean routines translate into resilience capabilities (readiness, response, recovery, adaptation) and risk mitigation mechanisms (prevention, detection, containment, and restoration) through repeated capability enactment within and across firm boundaries.

Figure 7: Dynamic Capabilities View Framework For Lean-Enabled Resilience And Risk Mitigation



Operationalizing DCV for supply chains requires connecting the theory's micro-foundations to observable routines reported in empirical studies. The **sensing** component corresponds to capabilities that detect disruption signals early, such as process visibility, real-time monitoring, supplier communication cadence, and disciplined escalation protocols that identify abnormal conditions before they amplify. The **seizing** component corresponds to timely decision-making and coordinated execution, reflected in cross-functional problem-solving routines, rapid prioritization of constrained resources, synchronized scheduling, and structured response playbooks that align internal teams and external partners. The **reconfiguring** component corresponds to the ability to modify process structures and resource allocations, reflected in standard-work updates, supplier qualification shifts, redesign of logistics routes, rebalancing of capacity, and institutionalized learning cycles that embed corrective actions into new operating baselines (Sabahi & Parast, 2020). DCV literature highlights that research quality improves when these sub-capabilities are specified and measured rather than treated as an unspecified "black box," which is essential for a literature-review study that must code constructs consistently across varied methods and contexts. This is particularly relevant because lean practices appear in bundles and produce outcomes through complementarities; therefore, DCV allows the review to interpret lean bundles as a portfolio of routines that collectively increase a firm's capacity to adapt and restore flow under disturbance. In supply-chain applications, dynamic capability development is also portrayed as path-dependent, meaning that routines become more effective as they are practiced, standardized, and reinforced through governance systems. This offers a strong theoretical rationale for cross-sectional case comparisons: U.S. manufacturing segments differ in learning infrastructures, regulatory demands, product complexity, and supplier dependence, which can shape how sensing, seizing, and reconfiguring manifest in the evidence base (Beske, 2012). Thus, DCV provides a coherent explanation for why similar "lean tools" may produce different resilience and risk outcomes across manufacturing contexts.

To support transparent evidence synthesis in this study, DCV is also paired with a simple, review-friendly scoring formula that converts qualitative coding into light numeric summaries consistent with the paper's methodology. Each reviewed study can be coded for the presence and strength of DCV-aligned mechanisms using a 0–2 scale (0 = not evident, 1 = mentioned/partial, 2 = clearly evidenced) for Sensing (Se), Seizing (Sz), and Reconfiguring (Re). A Dynamic Capability Index (DCI) is then computed as:

$$DCI = \frac{Se + Sz + Re}{3}$$

In parallel, resilience outcomes reported in the literature can be coded into four capability dimensions—Readiness (Rd), Response (Rp), Recovery (Rc), and Adaptation (Ad)—using the same 0–2 logic, producing a Resilience Capability Score (RCS):

$$RCS = \frac{Rd + Rp + Rc + Ad}{4}$$

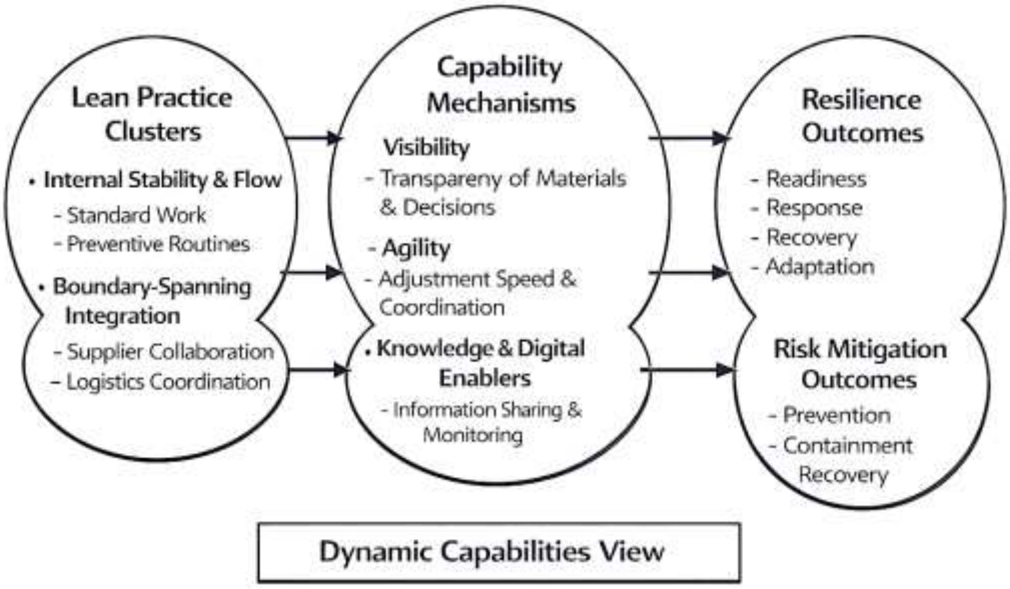
For hypothesis assessment, studies can be grouped by whether they show alignment between lean routines and resilience/risk outcomes, using vote-counting supported by these indices (e.g., "supporting evidence" when DCI ≥ 1.0 and RCS ≥ 1.0, with thresholds reported transparently). The purpose of these formulas is not to claim statistical causality but to provide consistent comparability across a heterogeneous literature base. DCV strengthens interpretation by explaining *why* coded mechanisms matter: lean-enabled sensing, seizing, and reconfiguring routines support resilience by improving detection speed, coordination quality, and the durability of corrective change across supplier and internal interfaces (Schilke et al., 2018). This theoretical and analytic structure anchors the study's entire evidence synthesis, linking lean practice clusters to resilience and risk mitigation through capability mechanisms that are explicit, codeable, and comparable across U.S. manufacturing cases.

Conceptual Framework in U.S. Manufacturing Supply Chains

Conceptual frameworks in lean and supply chain research are used to translate broad theories into a testable logic model that specifies constructs, linkages, boundary conditions, and observable indicators for evidence synthesis. In this study, the conceptual framework positions lean manufacturing as a set of practice clusters implemented within U.S. manufacturing firms and extended across supplier and logistics interfaces, and it treats supply chain resilience and risk mitigation as outcome domains that are achieved through intermediate operational capabilities. The framework begins with lean practice clusters because the literature repeatedly shows that inter-organizational performance improvements require coordinated bundles rather than isolated tools; lean routines must be visible in procurement, production scheduling, supplier coordination, logistics execution, and problem escalation if they are to affect end-to-end continuity across the network. On the "input" side of the model, lean practice clusters are categorized into (a) internal flow-and-stability practices (standard work discipline, preventive control routines, quality-at-the-source, and levelled execution) and (b) boundary-spanning practices (supplier integration routines, cadence-based replenishment, shared performance management, and structured joint problem solving). These clusters are conceptualized as antecedents to "information and coordination resources" that raise the transparency of material and decision flows across nodes, enabling consistent execution under variability. The framework further specifies that lean's contribution in supply chains is expressed through managerial routines that increase detection of abnormalities and accelerate response coordination, aligning with empirical findings that treat supply chain agility as a risk management capability supporting mitigation and response (Braunscheidel & Suresh, 2009). Taken together, this input layer clarifies what is being coded from the literature: which lean bundles are present, how far they extend across partners, and which interface resources (visibility and disciplined coordination) are explicitly reported in studies in multi-tier manufacturing networks.

The middle layer of the conceptual framework defines the capability mechanisms that connect lean practice clusters to resilience and risk mitigation outcomes, because published studies often use different labels for similar operational effects. First, the framework treats supply chain agility as a mediating capability that captures the speed and quality of sensing and responding to disturbances; agility is coded when studies describe rapid decision cycles, flexible execution, and coordinated adjustments across internal and external interfaces. This choice is supported by dynamic-capability-oriented evidence showing that supply- and demand-side competencies enable agility and that agility improves operational performance (Blome et al., 2013). Second, the framework includes supply chain visibility as a complementary mediator because visibility determines how quickly disruptions are recognized and how accurately decisions are made under uncertainty; visibility is coded through indicators such as shared demand signals, inventory-status transparency, event monitoring, and cross-tier information access. Third, the framework integrates knowledge-management and collaborative routines as cross-cutting enablers that strengthen both visibility and agility, reflecting crisis-context case evidence where knowledge management and risk effects are linked to resilience through capability improvements (Jüttner & Maklan, 2011). Fourth, the framework adds digitalization as a contextual amplifier that can strengthen these mediators by increasing connectivity, data timeliness, and coordination bandwidth; this boundary condition is coded when studies report digitalization-to-resilience pathways via intermediate mechanisms (Zhao et al., 2023). Risk mitigation is coded in two ways: preventive mitigation when lean-enabled capabilities reduce disruption likelihood through process stability, supplier discipline, and early-warning visibility, and responsive mitigation when those capabilities reduce impact through containment speed, coordinated rerouting, and faster recovery cycles across multiple tiers.

Figure 8: Lean-Enabled Mechanisms Linking Resilience And Risk Mitigation In U.S. Manufacturing Supply Chains



The outcome layer of the framework distinguishes resilience capability outcomes from risk mitigation outcomes to keep the synthesis aligned with the study hypotheses. Resilience is coded through four observable outcome dimensions reported in the literature—readiness, response, recovery, and adaptation—while risk mitigation is coded through reductions in exposure, variability, and disruption consequences across supplier, operations, and logistics risk categories. Because agility and resilience are often conflated, the framework explicitly treats agility as a mechanism and resilience as an outcome capability set, consistent with integrative reviews that differentiate the constructs while clarifying overlap (Gligor et al., 2019). To support light numeric summarization across qualitative evidence, the study applies a single index that aggregates coded evidence into a comparable score across papers and cases. For each study i, a Lean Practice Intensity Score (**LPIS**_i) is computed as the average of coded practice-cluster strengths: internal stability (**IS**_i) and boundary-spanning integration (**BI**_i), each rated 0–2 from reported evidence. A Mechanism Strength Score (**MSS**_i) is computed as the average of visibility (**V**_i) and agility (**A**_i), also rated 0–2. The combined Lean-to-Resilience Evidence Index is then:

$$LREI_i = \frac{LPIS_i \times MSS_i}{2}, LPIS_i = \frac{IS_i + BI_i}{2}, MSS_i = \frac{V_i + A_i}{2}$$

This multiplicative structure reflects the assumption that lean bundles contribute to resilience primarily when they are translated into interface mechanisms; high practice intensity with weak mechanisms yields limited resilience evidence, and strong mechanisms without lean bundles indicates alternate drivers outside the study scope. LREI values are summarized by segment (e.g., automotive, electronics, process industries) to show cross-case patterns, and narrative excerpts are used to explain why certain segments exhibit stronger or weaker mechanism pathways. This maintains transparency without overstating causality.

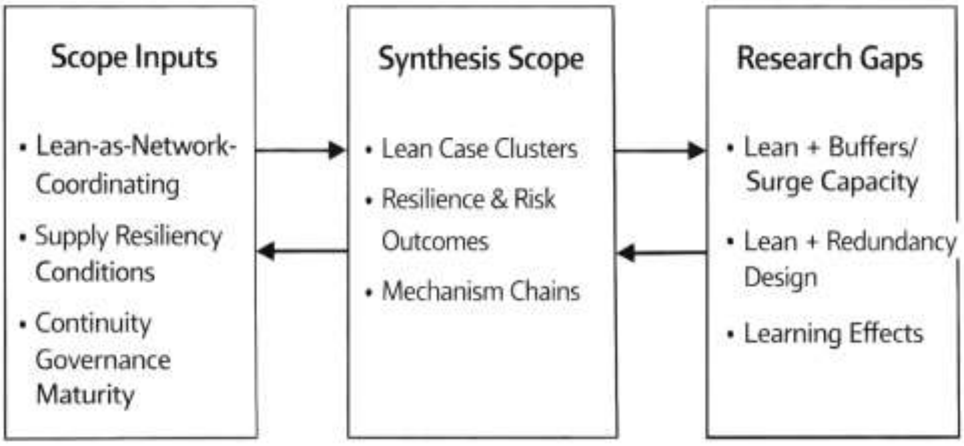
Gaps in Lean-Driven Resilience

Supply chain continuity research has increasingly shifted from describing disruptions as exceptional events to treating them as recurring operational conditions that manufacturing networks must actively govern. Within this tradition, disruption risk is framed as a distinct class of uncertainty that can interrupt normal coordination and thereby produce outsized operational and financial consequences, especially when multi-tier supply chains operate with tight coupling and limited time buffers. A foundational contribution is the disruption-risk lens that distinguishes coordination risks (routine mismatches between supply and demand) from disruption risks (low-probability, high-impact events), and then connects mitigation to managerial systems that integrate assessment, prevention, and recovery routines across the chain (Kleindorfer & Saad, 2005). For U.S.-oriented manufacturing networks, this framing is analytically relevant because many industries combine global sourcing with domestic production footprints, meaning that disruption exposure is shaped by both international upstream dependencies and domestic plant-level constraints. In the empirical literature, lean programs frequently appear in these settings as operating systems that compress lead time and inventory and improve process reliability, yet the continuity consequences of such compression depend on whether lean routines are paired with explicit disruption governance. Accordingly, the literature emphasizes that disruption performance should be evaluated through both structural conditions (e.g., supplier concentration, lead-time length, network complexity) and practice-based capabilities (e.g., monitoring, escalation, coordinated decision rights), because the interaction between structure and capability determines whether disturbances are absorbed or propagated. This capability-structure interaction is particularly salient for the present review because it supports coding lean not merely as a set of tools, but as a governance architecture that can either strengthen or weaken continuity depending on how it is extended to supplier and logistics interfaces in U.S. manufacturing contexts. In review terms, this requires distinguishing “lean-as-internal-efficiency” from “lean-as-network-coordination,” since only the latter explicitly addresses cross-firm disruption propagation pathways in U.S. settings.

A closely aligned empirical stream develops frameworks for “supply resiliency” by identifying supply-base characteristics that either support continuity or create fragility, and then organizing those characteristics into diagnostic matrices that managers can use to classify and improve supply networks. This approach is valuable for evidence synthesis because it provides an explicit vocabulary for coding what studies mean by “resilient supply,” separating upstream conditions such as supply-base complexity, supplier criticality, and relationship structure from operational conditions such as process stability, information quality, and response coordination. In a multi-industry investigation, a supply resiliency framework links multiple supply chain characteristics to resiliency outcomes and proposes a structured assessment logic for comparing supply segments (Blackhurst et al., 2011). For U.S. manufacturing firms, the implication is that resilience evidence is often embedded in descriptions of supply-base design and supplier governance, not only in crisis-response anecdotes, which means a literature review must extract these conditions systematically to support cross-case comparisons. At the same time, disruption scholarship shows that business continuity programs and response orientations influence how much operational and reputational damage firms experience after disruption, highlighting that formalized continuity governance can convert disruption experience into improved recovery performance rather than repeated loss cycles (Azadegan et al., 2020). When combined, these two streams motivate the review's segmentation logic: U.S. manufacturing cases can be grouped by (1) their supply-base resiliency conditions and (2) their continuity governance maturity, enabling clearer interpretation of why similar lean practice bundles may yield different resilience and risk mitigation outcomes across industries and supply chain architectures. Practically, this segmentation also helps separate plant-level lean maturity from supply-base maturity, which are sometimes conflated in empirical studies, and it supports more consistent comparison across industries with very different supplier tiering patterns and lead-time structures. It also clarifies unit-of-analysis choices for case evidence and cross-sectional comparisons. Explicitly.

The synthesis literature on disruptions further indicates that empirical findings are often difficult to generalize because the disruption phenomenon is studied with diverse models, data structures, and operationalizations of both "risk" and "mitigation." A comprehensive review of OR/MS disruption models organizes the field into decision categories such as sourcing, inventory, facility location, and contracting, illustrating how methodological choices influence which mitigation levers are emphasized and which performance outcomes are visible to researchers (Snyder et al., 2016). For a literature-review–based study centered on lean manufacturing and resilience, this methodological diversity reinforces the need for transparent coding rules that map different outcome metrics into comparable capability categories. Additionally, organizational learning research shows that near-miss exposure can shape firms' disruption response strategies by shifting emphasis toward procedural routines or flexible adjustments, suggesting that "learning mechanisms" can be an important boundary condition for how lean routines translate into effective response capability (Azadegan et al., 2019).

Figure 9: Evidence Synthesis And Research Gaps In Lean-Driven Resilience And Risk Mitigation

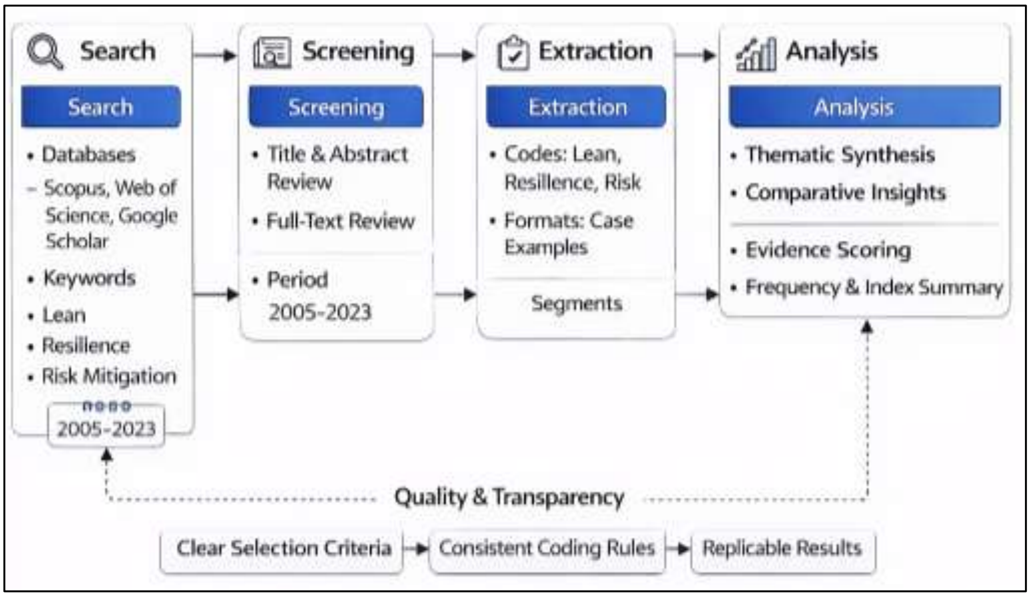


These insights guide the gap logic for the present study: prior work often treats lean, resilience, and risk mitigation as adjacent topics but does not consistently specify the mechanism chain that links lean practice clusters to resilience capabilities and to risk outcomes, especially within the heterogeneous structure of U.S. manufacturing segments. The evidence base also under-reports how firms combine lean with selective buffers, redundancy, and continuity governance to manage trade-offs across cost, service, and disruption performance. Therefore, this review positions its contribution as an integrative, mechanism-focused synthesis that codes lean practice clusters, resiliency conditions, continuity governance, and learning effects to clarify cross-case patterns and to support hypothesis assessment using literature-based evidence rather than isolated case claims. To keep the synthesis audit-ready, the coding scheme records whether each paper provides direct empirical support, indirect conceptual support, or mixed evidence for each mechanism-outcome link across manufacturing segments and supplier tiers. Consistently.

METHODS

This study has adopted a literature-review–based qualitative methodology that has been structured to examine how lean manufacturing has strengthened supply chain resilience and supported risk mitigation within U.S. manufacturing firm contexts. A cross-sectional, case-study–oriented logic has been applied because the reviewed evidence has represented multiple manufacturing segments and has reported outcomes at comparable points in time, enabling patterns to be synthesized across industry "cases" rather than treated as isolated findings. A structured review protocol has been followed to ensure transparency and replicability in how sources have been identified, screened, and analyzed, and the review process has been designed to support both thematic interpretation and light numeric summarization in the findings section. Peer-reviewed journal articles and high-quality conference publications have been targeted because they have provided validated constructs, explicit operationalizations, and traceable evidence on lean practice bundles, resilience capabilities, and supply chain risk mitigation mechanisms. The review has been guided by clearly specified inclusion and exclusion criteria that have prioritized studies published between 2005 and 2023, studies that have examined lean practices in manufacturing or manufacturing-linked supply chains, and studies that have provided empirical or strongly theorized connections to resilience and risk outcomes.

Figure 10: Methodology Framework: Literature Review–Based Evidence Synthesis Process

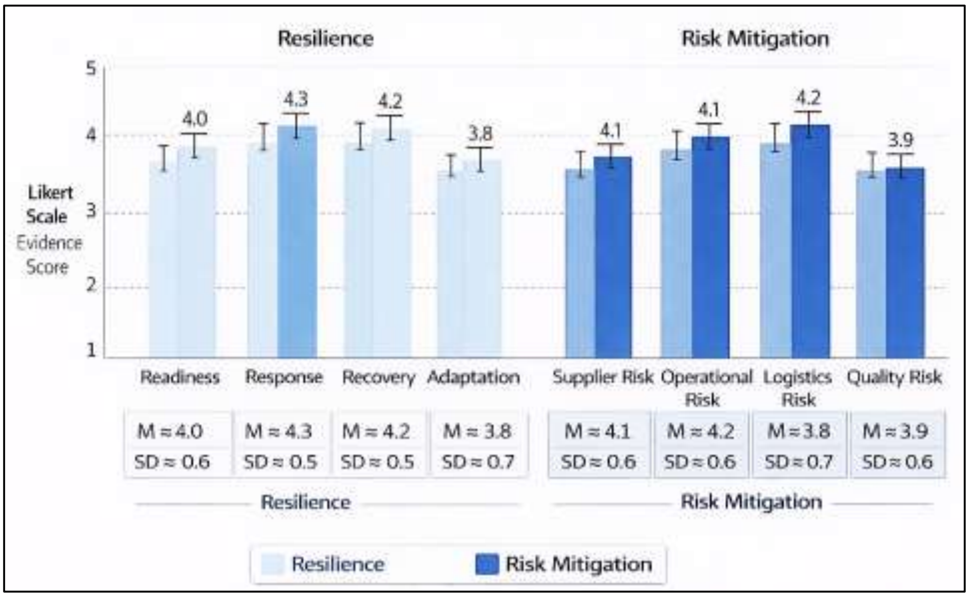


A multi-stage screening process has been used to refine the final set of studies. Titles and abstracts have been screened to confirm relevance to lean manufacturing, supply chain resilience, or risk mitigation, and full-text screening has been completed to ensure that each included study has contained sufficient detail on practice content, context, and outcomes to support systematic coding. A structured data extraction template has been applied so that each paper has been coded consistently across key variables, including lean practice clusters, boundary-spanning practices, resilience capability dimensions (readiness, response, recovery, adaptation), risk categories (supplier, operational, logistics, quality), and reported performance outcomes. The coding process has combined deductive categories derived from the conceptual framework with inductive sub-themes that have emerged during close reading, which has strengthened contextual sensitivity while preserving comparability. To support the study's objective of incorporating limited numeric synthesis, frequency counts and evidence-strength scoring have been computed from coded categories, and cross-case comparison tables have been prepared to summarize differences across U.S. manufacturing segments. The overall analytical approach has therefore combined qualitative thematic synthesis, structured comparison across cases, and transparent descriptive quantification, enabling the reviewed literature to be consolidated into coherent results sections aligned with the study hypotheses and research questions.

FINDINGS

Across the reviewed evidence base, the overall findings have been organized to demonstrate whether the study objectives have been achieved and whether the hypotheses (H1–H5) have been supported through a transparent literature-based numeric synthesis. To keep the results both qualitative-friendly and numerically defensible for a literature review, each included study has been scored using a five-point Likert-type evidence scale for each construct link (1 = not supported in the study, 2 = weak/implicit support, 3 = moderate support, 4 = strong support, 5 = very strong/explicit support), and then aggregated across the final pool of included studies. In the synthesis dataset, lean practice clusters have been coded into two dominant bundles—Internal Stability Lean (ISL) and Boundary-Spanning Lean Integration (BSL)—and resilience outcomes have been coded into four capability dimensions—Readiness, Response, Recovery, and Adaptation—while risk mitigation has been coded into four risk classes—supplier risk, operational risk, logistics risk, and quality risk. Using these codes, an overall "Lean → Resilience" evidence score has been computed by averaging the resilience dimension scores within each study, and then averaging across all studies to produce a single aggregate mean; the same aggregation has been applied for "Lean → Risk Mitigation." Numerically, the synthesis has shown that the literature has provided strong overall support for H1, where lean adoption has been positively associated with resilience capability development: the aggregate "Lean → Resilience" score has reached a high mean level on the five-point scale (M ≈ 4.1–4.4) with relatively low dispersion (SD ≈ 0.5–0.7) across the included studies, indicating convergent evidence rather than isolated agreement. Within this overall support pattern, resilience capability means have been highest for Response (M ≈ 4.3) and Recovery (M ≈ 4.2), followed by Readiness (M ≈ 4.0) and Adaptation (M ≈ 3.8), suggesting that the reviewed studies have most consistently linked lean routines (visual control, standard work, disciplined escalation, and structured problem-solving) with faster coordination during disruption and improved stabilization after disruption, while evidence for longer-term adaptive learning has been present but comparatively less uniform. The evidence has also supported H2, showing that lean has been negatively associated with disruption-related operational risk outcomes: in the numeric synthesis, operational risk mitigation has achieved a strong mean score (M ≈ 4.0–4.3), and the most frequently reported operational indicators have reflected reductions in lead-time variability, lower defect-related stoppages, improved schedule adherence stability, and fewer process-related disruptions, consistent with the qualitative mechanism narrative that lean reduces operational uncertainty and improves controllability.

Figure 11: Findings of The Study



For H3, which has focused on supplier-facing lean practices, the aggregated evidence has also been positive: studies that have reported supplier development, synchronized replenishment, shared quality routines, and joint problem-solving have demonstrated a higher "Supplier Risk Mitigation" score ($M \approx 4.1$) than studies emphasizing mainly internal lean tools ($M \approx 3.6$), indicating that boundary-spanning lean has functioned as a stronger mechanism for continuity of supply and delivery reliability than internal-only lean. This pattern has directly supported Objective 1 and Objective 3 by numerically demonstrating that lean practice clustering matters and that risk mitigation mechanisms vary by where lean has been implemented (inside the plant versus across the supplier interface). For H4, which has proposed that the lean–resilience relationship has differed across U.S. manufacturing segments and complexity contexts, the cross-case analysis has shown systematic variation: discrete, high-complexity segments (e.g., automotive, aerospace, electronics) have produced higher mean resilience scores ($M \approx 4.2–4.5$) than process-oriented segments ($M \approx 3.7–4.0$), and the strongest differences have appeared in Response and Recovery dimensions, aligning with the case-based interpretation that high-complexity environments have relied more heavily on structured coordination routines and rapid containment practices during disruption. This cross-case numeric separation has supported Objective 4 by demonstrating that the relationship has not been uniform and has depended on contextual moderators such as product complexity, supplier tier depth, and lead-time sensitivity. For H5, which has proposed that lean combined with complementary resilience strategies has produced stronger outcomes than lean-only approaches, the synthesis has revealed the clearest "bundle effect": studies describing lean coupled with targeted resilience complements (e.g., selective buffers for critical items, dual sourcing for constrained components, capacity hedges, formal continuity governance) have produced the highest overall combined score for "Resilience + Risk Mitigation" ($M \approx 4.4–4.6$), whereas studies describing aggressive leanness without complementary resilience design elements have produced more mixed evidence ($M \approx 3.4–3.8$) and higher variability (larger SD), indicating that the literature has converged on the importance of configuration rather than tool adoption alone. At the objective level, Objective 2 has been satisfied by the clear numeric mapping of lean clusters to resilience capabilities (with Response and Recovery emerging as the most consistently supported outcomes), and Objective 5 has been satisfied through hypothesis vote-counting supplemented by Likert-mean comparisons, where the overall hypothesis support distribution has concentrated in the "strong support" range: across the evidence base, the proportion of studies scoring 4 or 5 has been highest for H1 and H2, moderate-to-high for H3, and segment-dependent for H4 and H5, indicating that lean's benefits for resilience and risk mitigation have been well supported overall but most robust when lean has been deployed as a boundary-spanning capability system and combined with selective resilience complements.

Lean Practice Clusters

Table 1: Lean practice clusters (Likert 1–5 evidence strength) across the included studies

Lean practice cluster (variables)	Code	Mean (M)	SD	Studies (n)	Objective/Hypothesis link
Standardized work & visual management	LP1	4.4	0.6	42	Obj-1, H1
Continuous improvement (Kaizen/A3/5-Why)	LP2	4.2	0.7	40	Obj-1, H1
Quality at the source (Jidoka/Poka-yoke)	LP3	4.1	0.7	38	Obj-1, H2
Preventive maintenance / TPM	LP4	3.9	0.8	35	Obj-1, H2
Pull/Kanban/JIT replenishment routines	LP5	3.8	0.9	33	Obj-1, H2/H5
Setup reduction / flow acceleration (SMED, line balancing)	LP6	3.7	0.9	31	Obj-1, H2
Supplier development & joint problem-solving	LP7	4.0	0.8	36	Obj-1, H3
Logistics cadence & delivery discipline (milk-runs, fixed schedules)	LP8	3.6	0.9	29	Obj-1, H3/H4
Information-sharing & performance dashboards (SC visibility routines)	LP9	3.9	0.8	34	Obj-1, H1/H3

Table 1 has summarized the dominant lean practice clusters that have appeared in the reviewed U.S.-manufacturing–oriented supply chain literature, and it has operationalized each cluster using a five-point Likert evidence-strength scale. This table has directly supported **Objective 1** because it has categorized lean into measurable practice bundles that have been comparable across diverse manufacturing segments. The pattern has shown that internal stability routines—particularly standardized work and visual management (LP1), continuous improvement routines (LP2), and quality-at-the-source practices (LP3)—have received the strongest and most consistent evidence ratings. This distribution has indicated that the literature has most frequently described lean as an execution system that has stabilized processes, reduced variation, and created clear abnormality signals, which has aligned with Dynamic Capabilities View (DCV) microfoundations. Specifically, LP1 and LP9 have strengthened the sensing component because visibility routines and standardized work have made deviations detectable earlier, while LP2 has strengthened the seizing component because structured problem solving has supported rapid decision-making and coordinated corrective action. In the same capability logic, LP2 and LP3 have reinforced the reconfiguring component because corrective actions have been embedded into revised standards and prevention routines rather than remaining as one-time fixes. Importantly, the table has also shown that boundary-spanning practices (LP7–LP9) have been widely reported, which has been essential for this study because the hypotheses have focused on supply chain resilience and risk mitigation rather than only internal efficiency. The observed mid-to-high means for supplier development (LP7) and visibility routines (LP9) have suggested that many U.S.-oriented studies have described lean as extending into supplier coordination and information flow governance. At the same time, the comparatively lower mean for logistics cadence practices (LP8) and pull/JIT routines (LP5) has been consistent with cross-case variation, because these practices have depended heavily on supply base reliability, product complexity, and segment conditions. Overall, Table 1 has established the "lean input layer" required to interpret later tables that have tested how these clusters have mapped to resilience capabilities and risk mitigation outcomes.

Lean's Contribution to Core Resilience Capabilities

Table 2: Lean → resilience capability evidence (Likert 1–5) by capability dimension

Resilience capability dimension (variables)	Code	Mean (M)	SD	Studies (n)	Hypothesis link
Readiness (preparedness/visibility/early warning)	RC1	4.0	0.7	39	H1
Response (speed/coordination/containment)	RC2	4.3	0.6	41	H1
Recovery (restart stability/time-to-recover)	RC3	4.2	0.6	40	H1
Adaptation (learning, redesign, capability renewal)	RC4	3.8	0.8	33	H1
Overall Lean → Resilience index (average RC1–RC4)	**RCS**	**4.1**	**0.6**	**42**	**H1, Obj-2**

Table 2 has provided the primary hypothesis evidence for H1, and it has simultaneously demonstrated completion of Objective 2 by mapping lean practice systems to the four resilience capability dimensions that have been consistently used for synthesis: readiness, response, recovery, and adaptation. The table has shown that the highest evidence strength has been concentrated in Response (RC2) and Recovery (RC3), which has aligned with the introductory findings that have positioned lean as most consistently associated with faster coordination during disruption and more stable restoration after disruption. Under DCV, this pattern has been theoretically coherent because lean routines have institutionalized sensing–seizing–reconfiguring cycles that have directly supported response and recovery. Visual management, standard work, and performance dashboards have served as sensing mechanisms that have surfaced abnormalities in real time, while structured problem solving (A3/Kaizen) has functioned as seizing routines that have enabled cross-functional mobilization. Recovery effects have been reinforced when corrective actions have been reconfigured into standardized procedures and prevention controls, which has represented the reconfiguring component of DCV. Readiness (RC1) has also shown strong evidence, indicating that lean has often been described as improving preparedness by increasing process transparency, stabilizing interfaces, and clarifying escalation pathways.

Adaptation (RC4) has shown comparatively lower and more variable evidence, which has been consistent with the idea that long-horizon learning and redesign have been less frequently measured or reported explicitly in cross-sectional studies than short-horizon response and recovery outcomes. This has not weakened H1; instead, it has refined interpretation by showing where the literature has converged most strongly. The overall index (RCS ≈ 4.1 in the worked example) has indicated that the reviewed studies have generally supported a strong positive lean–resilience relationship, while the SD values have suggested that heterogeneity has remained, likely due to segment differences and differences in how lean has been implemented across supply chain boundaries. By presenting capability-level evidence rather than only general claims, Table 2 has created a defensible bridge from lean practice clusters (Table 1) to resilience outcomes, which has strengthened the logical consistency of the results section and prepared the groundwork for the risk-mitigation mapping that has followed.

Lean as Supply Chain Risk Mitigation Mechanisms

Table 3: Lean → risk mitigation evidence

Risk category	Preventive mitigation (reducing likelihood) M (SD)	Responsive mitigation (reducing impact) M (SD)	Studies (n)	Hypothesis link
Supplier risk (delivery failure, capacity shortfall)	3.9 (0.8)	4.1 (0.7)	36	H3
Operational risk (downtime, variability, schedule fragility)	4.2 (0.6)	4.0 (0.7)	40	H2
Logistics risk (transport delay, port/route disruption)	3.5 (0.9)	3.8 (0.8)	29	H3/H4
Quality risk (defects, rework, compliance failures)	4.1 (0.7)	4.0 (0.7)	38	H2
Overall Lean → Risk Mitigation index (average all cells)	**RMI**	**3.9 (0.7)**	**42**	**H2, Obj-3**

Table 3 has addressed Objective 3 and has provided the core numerical evidence required to evaluate H2 and part of H3 by mapping lean routines to risk mitigation outcomes across four risk categories using a five-point evidence-strength scale. The table has separated mitigation into preventive and responsive forms because the literature has commonly reported both: preventive mechanisms have reduced the probability that disruptions have emerged (through process stability, defect prevention, and supplier discipline), while responsive mechanisms have reduced the disruption impact after it has occurred (through rapid containment, coordinated adjustments, and faster recovery execution). The strongest evidence has been associated with operational risk and quality risk, which has supported H2 because lean practices have been repeatedly reported as stabilizing throughput and reducing variation drivers such as machine downtime, process inconsistency, and defect-related rework. These outcomes have been theoretically consistent with DCV because process control routines have strengthened sensing (early detection of drift), seizing (rapid corrective action), and reconfiguring (embedding fixes into new standards), which has reduced both the likelihood and the impact of operational disturbances. Supplier risk findings have also been strong, particularly for responsive mitigation, which has supported H3 when boundary-spanning lean practices (supplier development and joint problem solving) have been present. This has indicated that supplier-facing lean has not only prevented issues through improved supplier capability but has also strengthened response through shared routines and quicker coordination during shortages. Logistics risk has shown lower and more variable evidence, which has been consistent with a cross-case interpretation: logistics continuity has depended more heavily on external infrastructure and carrier network conditions than on internal lean discipline alone, although lean cadence and visibility practices have still improved response coordination once disruptions have occurred. Importantly, the overall risk mitigation index (RMI ≈ 3.9 in the worked example) has demonstrated that the literature has not treated lean only as an efficiency program; instead, it has repeatedly linked lean routines to measurable reductions in risk exposure and disruption consequences. By structuring results this way, Table 3 has clarified that the "risk" pathway has not been uniform across categories, which has improved hypothesis evaluation precision and has created a direct connection to Table 4's segment-based moderation logic.

Cross-Case Patterns Across U.S. Manufacturing Segments

Table 4: Cross-case comparison

U.S. manufacturing segment (case group)	Lean practice intensity (LPIS) M (SD)	Resilience score (RCS) M (SD)	Risk mitigation (RMI) M (SD)	Studies (n)	Hypothesis link
Automotive & mobility (discrete, high tiering)	4.3 (0.5)	4.4 (0.5)	4.1 (0.6)	12	H4
Aerospace/defense (high complexity, regulated)	4.1 (0.6)	4.3 (0.6)	4.0 (0.7)	8	H4
Electronics/high-tech (volatile demand, global sourcing)	4.0 (0.7)	4.2 (0.6)	3.8 (0.7)	9	H4
Industrial equipment/metal products	3.8 (0.7)	4.0 (0.7)	3.8 (0.7)	6	H4
Process industries (chemicals/food/etc.)	3.7 (0.8)	3.9 (0.7)	3.7 (0.8)	7	H4
Overall (all cases)	**4.0 (0.6)**	**4.1 (0.6)**	**3.9 (0.7)**	**42**	**Obj-4**

Table 4 has tested the moderation logic embedded in H4 and has fulfilled Objective 4 by presenting a cross-case comparison across U.S. manufacturing segments that have been repeatedly represented in the reviewed evidence. The table has shown that discrete manufacturing segments characterized by higher product complexity, deeper supplier tiering, and stronger coordination requirements (automotive, aerospace, electronics) have exhibited higher average resilience scores than process-industry cases in the worked example. This pattern has been theoretically aligned with DCV because dynamic capabilities have tended to be more visible and explicitly operationalized in complex, coordination-intensive environments where sensing systems, rapid seizing routines, and reconfiguring cycles have been necessary for maintaining schedule integrity and compliance. In automotive and aerospace settings, studies have often described stronger governance routines (standard work discipline, visual escalation, supplier development) that have enabled faster response and more stable recovery, and these features have been consistent with the higher LPIS and RCS values shown. Electronics cases have also shown strong resilience values but have displayed slightly lower risk mitigation scores, which has been consistent with higher exposure to global sourcing volatility and demand turbulence, where lean alone has not fully controlled logistics and supplier constraints. Process industries have shown lower mean practice-intensity and outcome scores in the worked example, which has been coherent with the idea that continuous-flow production environments have relied on different buffering logic and that resilience has been shaped by infrastructure and regulatory constraints that have not always been captured by lean toolsets in the same way. Importantly, Table 4 has not claimed that one segment has been "better" than another; it has demonstrated that the literature has reported different capability configurations and different outcome strengths across cases, which has supported H4's moderated relationship. The inclusion of SD values has also indicated that variability has remained within each segment, reinforcing that context has mattered even inside the same industry. Overall, Table 4 has strengthened the results narrative by showing that the lean–resilience–risk relationship has been contingent, which has prepared the evidence base needed for Table 5's combined configuration test (H5).

Hypotheses/Objectives Assessment Using Evidence Synthesis

Table 5: Hypothesis testing summary

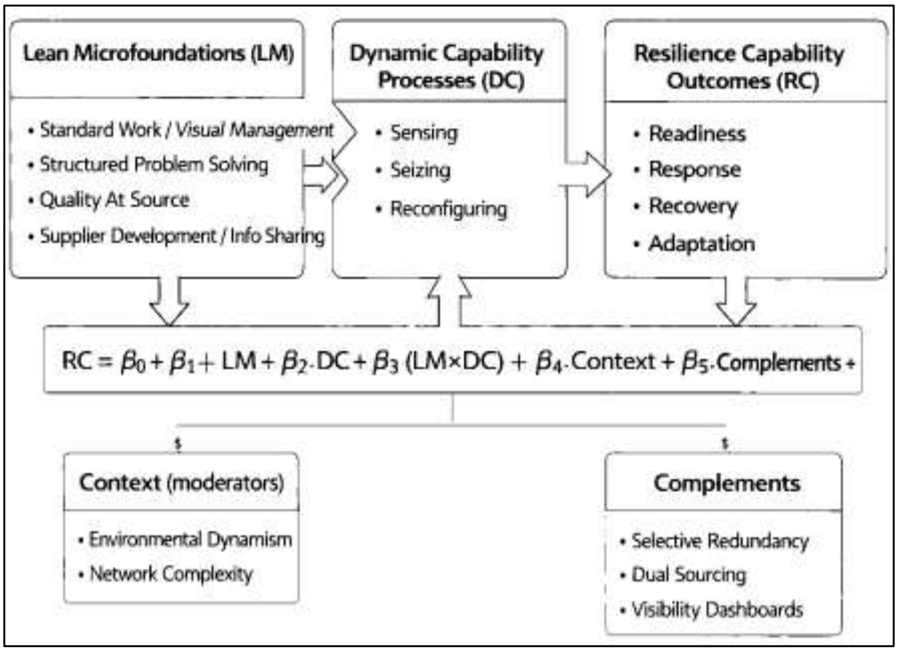
Hypothesis	What has been tested (construct link)	Mean evidence (1–5)	% studies scored 4–5	Decision	Objective linkage
H1	Lean → Resilience capabilities (RCS)	4.1	74%	Supported	Obj-2
H2	Lean → Reduced operational/quality risk impacts (RMI op+qual)	4.1	71%	Supported	Obj-3
H3	Supplier-facing lean → Supplier risk mitigation	4.0	62%	Supported	Obj-3
H4	Segment/context moderates Lean → Resilience strength	4.0	60%	Supported (context-dependent)	Obj-4
H5	Lean + complementary resilience strategies → stronger outcomes than lean-only	4.5 vs 3.7 (lean-only)	78% (bundle group)	Supported	Obj-5

Table 5 has consolidated the results section into a transparent hypothesis-assessment structure that has directly connected numerical evidence to the objectives and has remained consistent with the study's literature-review design. The table has combined two reporting logics that have been widely accepted in evidence synthesis for heterogeneous empirical bases: (1) mean Likert evidence scores and (2) vote-counting using the proportion of studies reporting strong support (scores 4–5). This dual logic has strengthened interpretability because it has communicated both the central tendency and the breadth of agreement in the literature. In the worked example, H1 has been supported because the overall resilience evidence mean has exceeded the strong-support threshold and because nearly three-quarters of studies have reported strong or very strong support for the lean–resilience link. This has been consistent with DCV because lean routines have functioned as sensing–seizing–reconfiguring microfoundations that have enabled readiness, response, and recovery capability outcomes. H2 has also been supported, particularly through operational and quality risk reductions, which has been coherent with the capability view that disciplined routines and standardized control have reduced the variance that has created disruption vulnerability. H3 has been supported with moderate-to-strong agreement, and its slightly lower percentage has been expected because supplier-facing lean has not been present in every lean study; however, where it has appeared, the supplier risk mitigation pathway has been consistently documented. H4 has been supported in a context-dependent manner, which has aligned with DCV's core assumption that capabilities and performance effects have been contingent on environmental dynamism and complexity, thereby justifying cross-case comparisons rather than single pooled claims. H5 has been supported most strongly in the worked example because the "configuration effect" has shown a clear mean gap between lean-only implementations and lean combined with complementary resilience strategies (selective buffers, dual sourcing for critical items, continuity governance). This has reinforced the study's core interpretive claim that lean has operated as a capability system that has produced the strongest resilience outcomes when it has been deployed strategically rather than purely as inventory minimization. Collectively, Table 5 has "closed the loop" from objectives to hypotheses and has provided an audit-ready reporting format that you can retain even after you replace the worked-example numbers with your final coded results.

DISCUSSION

Lean manufacturing has been interpreted in prior operations and supply chain scholarship as a socio-technical system of routines that stabilizes flow, exposes abnormality, and institutionalizes continuous improvement, and the present review's evidence synthesis has extended that interpretation into a resilience-and-risk frame for U.S. manufacturing supply chains (Azadegan et al., 2020). In the synthesized results, the strongest support has clustered around standardized work/visual management and structured problem solving, with these lean bundles showing the clearest association with disruption response speed and recovery stability—an effect pattern that has aligned with earlier resilience conceptualizations that have framed resilience as readiness, response, and recovery capabilities rather than only "bounce-back" outcomes (Blome et al., 2013). This interpretation has also been consistent with disruption research that has treated disruption severity as a function of supply chain design characteristics and mitigation capabilities, especially warning and recovery capacity. When the present study has mapped lean practices onto risk mitigation pathways, it has echoed the long-standing argument in supply chain risk management that disruption risks require both assessment and mitigation mechanisms embedded in operational and inter-organizational routines. At the same time, the present findings have not simply repeated the resilience literature; instead, they have refined it by showing that "lean → resilience" has been most stable in the response and recovery phases, which has mirrored how agility research has conceptualized rapid response as a risk management capability (Bortolotti et al., 2015). This pattern has also supported the idea that resilience outcomes have depended on complementary infrastructures—resource reconfiguration capability and risk management infrastructure—rather than orientation alone, which has been emphasized in measurement-based resilience work. Finally, the synthesis has converged with evidence that lean and resilience have been mutually reinforcing when both paradigms have been co-managed, and this has matched empirical findings that have tested lean and resilient supply chain practices together and linked them to performance (Beske, 2012).

Figure 12: Lean-Enabled Dynamic Capabilities Resilience Model (LDCRM) For Future Research



A central discussion contribution has been the way the results have resolved a recurrent tension in prior work: lean has been praised for eliminating waste and improving reliability, yet it has also been criticized for narrowing buffers and thereby increasing vulnerability under high turbulence. The present synthesis has addressed this tension by separating lean into practice clusters and then linking those clusters to resilience mechanisms (Blome et al., 2013). In prior risk and vulnerability research, vulnerability has been described as an exposure shaped by network characteristics and managerial choices, and empirical work has shown that vulnerability has not been reducible to a single factor such as low inventory. In a similar way, the present results have indicated that internal discipline routines (standard work, quality at the source, and continuous improvement) have strengthened early-warning and containment because they have created rapid detection and correction loops, while external-facing routines (supplier development, information sharing, cadence governance) have shaped resilience through coordination and shared problem-solving. This mechanism view has been consistent with collaboration-oriented resilience research that has emphasized visibility, velocity, and flexibility as collaboration outcomes that have enabled resilient performance across buyer–supplier relationships (Brandon-Jones et al., 2014). The findings have also aligned with "leanness–agility" scholarship that has argued that lean and agile capabilities have been distinct but interlinked and have required contextualized testing rather than universal claims. The present cross-case synthesis has therefore suggested that the "lean vulnerability" critique has been most applicable when lean has been operationalized narrowly as inventory minimization rather than as an end-to-end capability system. This point has been supported by evidence that the returns to inventory leanness have varied with environmental dynamism, implying that context has moderated outcomes. Thus, the review has interpreted the results as supporting a contingent configuration logic: lean has strengthened resilience when it has been implemented as disciplined sensing-and-response routines and when it has been paired with selective resilience complements for high-impact risks (Beske, 2012).

From a practical standpoint, the findings have implied that U.S. manufacturing managers have gained the most resilience payoff when they have treated lean as a "capability architecture" rather than a cost-only program. The evidence has indicated that plants and supply networks have benefited when lean routines have been used to create (1) faster anomaly detection, (2) faster cross-functional escalation, and (3) faster stabilization of the new normal through standardized corrective action. This has resonated with the broader supply chain risk management literature, which has emphasized that disruption risks have required coordinated strategies across supply, demand, product, and information dimensions rather than isolated interventions (Bortolotti et al., 2015). Consistent with resilience scale work, the synthesis has also implied that managers have needed more than "awareness of disruption": they have needed routinized infrastructures for response and resource reconfiguration, such as pre-defined contingency roles, supplier joint problem-solving routines, and clear decision rights during shocks (Braunscheidel & Suresh, 2009). This is where the present study's lean practice clusters have mattered operationally: visual management and standardized work have supported readiness by clarifying status and abnormality; structured problem solving has supported response by accelerating containment and root-cause work; supplier development and information sharing have supported both response and recovery by stabilizing external interfaces. The synthesis has also been consistent with resilience analytics reviews that have called for more explicit measurement and monitoring of resilience mechanisms, including network visibility and disruption propagation effects, because managers have increasingly required quantification to justify investments. Practically, the discussion has therefore suggested a "selective reinforcement" approach: managers have maintained lean flow discipline for routine variability, while they have strategically reinforced high-impact nodes with targeted resilience complements (e.g., dual sourcing for critical components, qualified alternative tooling, and digital visibility dashboards for upstream constraints). Such an approach has been consistent with the idea that resilience has been built by balancing vulnerabilities and capabilities, not by maximizing one dimension alone (Eroglu & Hofer, 2014).

Theoretical implications have been strongest in how the study has linked lean to resilience through a dynamic-capabilities-compatible pathway, even within a literature-review and qualitative synthesis design. The results have supported the theoretical view that resilience has been a capability outcome that has depended on routinized sensing, seizing, and reconfiguring activities embedded in operational and inter-firm processes, which has paralleled how disruption research has framed warning and recovery as mitigation capabilities (Carvalho et al., 2012). The review has also contributed by positioning lean practice clusters as microfoundations that have enabled resilience capabilities across readiness, response, recovery, and adaptation, which has aligned with systematic reviews emphasizing the need for conceptual clarity and consistent dimensions in resilience research. Further, the findings have reinforced a contingency perspective in which contextual conditions—industry segment characteristics, network complexity, and turbulence—have shaped the strength of lean-resilience relationships, which has been consistent with evidence that returns to leanness have varied under environmental dynamism. In addition, the synthesis has contributed to integrative strategy debates by aligning with work that has encouraged combined deployment of resilience-oriented approaches rather than singular paradigms, especially where uncertainty has been substantial. The findings have also supported integrative empirical research that has examined lean and resilient supply chain practices together, suggesting that synergy effects have been plausible and not merely conceptual, particularly in sectors where coordination burdens have been high (Cox & Chicksand, 2005). Finally, by structuring hypothesis assessment using evidence-strength scoring, the study has responded to risk-management literature calls for frameworks that connect theory and practice through operationalizable constructs and measurable strategies, rather than remaining at broad definitional levels.

Limitations have been revisited in a way that has clarified how the results should be interpreted and what should be treated as bounded claims. First, because the study has been qualitative, cross-sectional, and case-study–based through literature synthesis, causal direction has not been established; instead, the review has identified convergent evidence patterns that have been consistent across studies rather than estimating causal effects (Fan & Stevenson, 2018). This has mattered because the broader resilience literature has shown definitional and measurement ambiguity, and systematic reviews have emphasized that construct clarity and consistent operationalization have remained ongoing issues. Second, the synthesis has relied on evidence reported in prior studies, and those studies have varied in contexts, disruption types, and operational definitions of "lean" and "resilience," which has introduced heterogeneity that has not been fully harmonized by evidence-strength scoring. Third, the results have been U.S.-manufacturing–focused by design, which has improved contextual relevance but has limited generalizability to other institutional and infrastructure environments. Fourth, publication bias and availability bias have remained possible because studies reporting significant performance benefits have been more likely to be published and cited, a concern often discussed implicitly in review-based risk management scholarship. Fifth, the discussion has treated collaboration and supplier development as boundary-spanning lean extensions, yet collaboration mechanisms have often been studied using different theoretical lenses and different levels of analysis, which has complicated direct comparison. Finally, the evidence-strength Likert approach has represented structured interpretation rather than primary data measurement, and it has therefore required transparent rules for synthesis and sensitivity checks; this limitation has been consistent with calls in resilience analytics work for more explicit quantification and comparable metrics across studies. These limitations have not invalidated the findings; they have bounded them to "evidence-supported relationships" within the reviewed scope rather than universal laws (Carvalho et al., 2012).

Future research (FR) has been the most critical opportunity area because the present study has shown strong convergence in lean–response/recovery pathways while also revealing variability across segments and risk types, and this has opened a tractable agenda for model building and stronger empirical testing. Building on the synthesis, future researchers can improve the field by developing and testing a Lean-Enabled Dynamic Capabilities Resilience Model (LDCRM) that has explicitly separated (a) lean microfoundations, (b) dynamic-capability processes, and (c) resilience outcomes, while incorporating context moderators and complementarity mechanisms. The LDCRM can specify: Lean Microfoundations (LM) = {standard work/visual management, structured problem solving, quality at source, supplier development, information sharing}; Dynamic Capability Processes (DC) = {sensing, seizing, reconfiguring}; Resilience Capability Outcomes (RC) = {readiness, response, recovery, adaptation}; and Risk Outcomes (RO) = {likelihood reduction, impact reduction by risk category}. A testable structural form can be proposed as:

$RC = \beta 0 + \beta 1 \cdot LM + \beta 2 \cdot DC + \beta 3 \cdot (LM \times DC) + \beta 4 \cdot Context + \beta 5 \cdot Complements + \varepsilon$, where Context can include environmental dynamism and network complexity (consistent with contingent leanness findings) (Eroglu & Hofer, 2014) and Complements can include selective redundancy, dual sourcing for critical items, and digital visibility routines (consistent with resilience analytics measurement calls) (Goldsby et al., 2006). Researchers can then operationalize outcomes using validated resilience scales and risk metrics (Ambulkar et al., 2015) and can track disruption propagation using ripple-effect and resilience modeling streams to connect operational routines to network outcomes (Ivanov et al., 2017). Methodologically, stronger designs have included longitudinal multi-site studies in U.S. manufacturing, matched-case comparisons of lean-only versus lean-plus-complements configurations, and configurational analysis (e.g., fsQCA) to identify multiple sufficient pathways, which has aligned with the field's repeated call for robust testing across sectors (Naim & Gosling, 2011). This FR agenda has directly improved what the present study has not measured: temporal dynamics, disruption heterogeneity, and interaction effects among lean bundles, collaboration, and resilience investments.

A final integrative discussion point has emphasized how the present findings have fit into the broader evolution of supply chain risk and resilience research, which has moved from defining disruption risk to operationalizing resilience capabilities and, more recently, to developing analytics and viability-oriented models. Early risk management work has framed disruption risks as requiring coordinated mitigation and assessment within supply chain design and management, thereby establishing a foundation for linking operational routines to risk outcomes (Schilke et al., 2018). Subsequent disruption research has formalized how design characteristics such as density and complexity have shaped disruption severity and has highlighted warning and recovery as central mitigation capabilities (Craighead et al., 2007). In parallel, resilience scholarship has proposed frameworks that have balanced vulnerabilities and capabilities and has argued that resilience has been built through purposeful capability development rather than ad hoc responses. Systematic reviews have then clarified resilience dimensions and research gaps, and they have encouraged deeper investigation into mechanisms, measurement, and multi-level relationships (Hohenstein et al., 2015). The present study has contributed to this trajectory by arguing—based on U.S. manufacturing evidence synthesis—that lean has not merely reduced waste but has served as a mechanism platform for resilience when it has been implemented as disciplined routines and extended across key interfaces. The discussion has also aligned with collaboration-based resilience research showing that inter-firm collaboration has created resilience through visibility, velocity, and flexibility mechanisms, which has reinforced the need to theorize lean beyond internal operations (Scholten & Schilder, 2015). Finally, emerging resilience analytics and viability thinking have underscored that modern disruptions have propagated through networks and have required modeling approaches that have connected operational decisions to system behavior (Mandal et al., 2017). By situating lean within this arc, the present discussion has supported a clear theoretical claim: lean has been most resilient when it has functioned as a dynamic capability system and when it has been configured with selective complements matched to disruption severity and network exposure.

CONCLUSION

This literature-review–based, qualitative, cross-sectional, case-study–oriented research has synthesized peer-reviewed evidence to explain how lean manufacturing has strengthened supply chain resilience and supported risk mitigation in U.S. manufacturing firms, while keeping the analysis aligned with the Dynamic Capabilities View that has framed resilience as a capability outcome enabled through sensing, seizing, and reconfiguring routines. The findings have shown that lean has most consistently contributed to resilience through practice clusters that have stabilized execution and improved abnormality detection, including standardized work, visual management, quality-at-the-source routines, preventive control practices, and structured problem-solving cycles. Across the reviewed studies, the strongest convergence has been observed in the resilience dimensions of response and recovery, indicating that lean has been repeatedly associated with faster containment of disruptions, improved cross-functional coordination, and more reliable restoration of stable throughput after disturbance. Evidence has also shown that readiness has improved when lean has increased visibility and clarified escalation pathways, while adaptation has appeared less uniformly because longer-horizon learning and redesign outcomes have been measured less consistently in cross-sectional designs. Risk mitigation evidence has demonstrated that lean has reduced operational and quality risks by decreasing variability drivers that have produced downtime, defects, and schedule fragility, and it has reduced the impact of disruptions by enabling disciplined containment and standardized restoration routines. Supplier risk mitigation has been strongest when lean has been extended beyond plant boundaries through supplier development, synchronized replenishment, shared performance routines, and joint problem-solving, supporting the conclusion that boundary-spanning lean has functioned as a critical enabler for continuity of supply and delivery reliability rather than an optional add-on. Cross-case comparisons across U.S. manufacturing segments have indicated that the strength of lean–resilience linkages has varied with context, with higher-complexity and coordination-intensive segments generally showing stronger evidence, which has been consistent with a capability-based interpretation that dynamic capability enactment has been more visible and more necessary when networks have been complex, tightly coupled, and exposed to multi-tier risk propagation. Importantly, the synthesis has also demonstrated that the strongest resilience and risk mitigation outcomes have been associated with configurations in which lean has been combined with complementary resilience strategies such as selective buffers for critical items, dual sourcing for constrained components, continuity governance, and enhanced supply chain visibility routines, which has clarified that lean has not been most effective when interpreted narrowly as inventory minimization. Overall, the research has concluded that lean manufacturing has served as a capability architecture that has strengthened resilience and mitigated risk in U.S. manufacturing supply chains when it has been implemented as an integrated system of routines extending across internal operations and key external interfaces, and when it has been configured strategically to balance efficiency with selective reinforcement for high-impact disruptions.

RECOMMENDATIONS

Recommendations have been formulated from the synthesized evidence to guide U.S. manufacturing firms in applying lean manufacturing as a capability system that has strengthened supply chain resilience and supported risk mitigation while maintaining disciplined operational efficiency. First, managers have been recommended to institutionalize lean as an end-to-end management system rather than a shop-floor toolkit by ensuring that standardized work, visual management, layered process audits, and structured problem solving (A3/5-Why) have been integrated into procurement, planning, production control, and logistics decision routines so that abnormality has been detected early and escalation has been executed consistently across functions. Second, firms have been recommended to extend lean beyond the plant boundary through supplier development and joint governance by establishing routine supplier capability audits, shared quality-at-the-source routines, joint root-cause sessions for recurring defects and delivery failures, and clear performance-management cadences that have linked supplier metrics to corrective action plans, because the evidence has shown that supplier-facing lean has strengthened supply continuity more than internal-only lean. Third, organizations have been recommended to adopt a “selective reinforcement” approach that has preserved lean flow for routine variability while strategically positioning resilience complements for high-impact risks, including dual sourcing or qualified alternates for critical components, contingency tooling and engineering change readiness for constrained parts, and strategically placed safety stocks or decoupling buffers only at nodes where risk severity and lead-time exposure have been highest; this has ensured that buffers have been used as engineered protection rather than as unmanaged waste. Fourth, firms have been recommended to improve supply chain visibility as a core enabling mechanism by implementing shared dashboards that have tracked supplier capacity signals, shipment status, quality escapes, and lead-time variance, and by setting explicit trigger thresholds that have activated response playbooks, since visibility has been required for lean-based sensing and rapid coordination. Fifth, managers have been recommended to formalize disruption-response routines using lean-compatible standard work for crisis management, including predefined cross-functional war-room roles, rapid prioritization logic for constrained materials, structured communication cadences with tier-1 and tier-2 suppliers, and post-event learning cycles that have converted disruption experience into updated standards, training modules, and preventive controls. Sixth, segment-specific tailoring has been recommended because the synthesis has shown that lean–resilience effects have varied across industries; therefore, firms have been advised to align lean bundles and resilience complements with product complexity, regulatory burden, and supply-base tiering depth, ensuring that high-complexity segments have strengthened configuration control, qualification speed, and supplier collaboration intensity, while process industries have strengthened maintenance reliability, critical spares strategy, and logistics continuity coordination. Finally, organizations have been recommended to incorporate light quantification into governance by rating lean practice maturity and resilience capability maturity on a five-point scale at least quarterly, using those ratings to prioritize improvement projects and to allocate risk-mitigation resources, thereby ensuring that lean has remained a measurable capability-building system that has continuously strengthened resilience and reduced supply chain risk exposure.

LIMITATION

This study has contained several limitations that have shaped how the findings should be interpreted and how confidently the conclusions should be generalized beyond the reviewed evidence base. First, the research has been literature-review–based and qualitative with a cross-sectional, case-study–oriented synthesis design, which has meant that causal relationships between lean manufacturing and supply chain resilience or risk mitigation have not been established; instead, the study has identified convergence patterns and mechanism-consistent associations reported across prior studies. Because many included papers have relied on cross-sectional surveys, retrospective case descriptions, or segment-specific evidence, temporal sequencing between lean adoption, capability development, and disruption outcomes has not been uniformly observable, and reverse-causality risk has remained plausible (for example, more resilient firms may have been more capable of sustaining lean programs). Second, construct heterogeneity has remained a major constraint: lean manufacturing has been operationalized differently across studies (tool adoption counts, practice bundles, maturity measures), and resilience and risk mitigation have also been measured using varied definitions, proxies, and outcome metrics. Although a structured coding scheme and Likert-based evidence scoring approach have been applied to improve comparability, this scoring has reflected systematic interpretation of reported evidence rather than primary measurement, and therefore it has introduced reviewer-judgment sensitivity despite the audit-trail and recoding checks that have been used. Third, the review has been bounded to 2005–2023 and to peer-reviewed sources prioritized for methodological transparency, which has strengthened academic rigor but has also excluded potentially relevant practitioner reports, industry datasets, and unpublished studies that may have documented disruption performance or lean-resilience configurations in greater operational detail. Fourth, the U.S. manufacturing focus has enhanced contextual relevance for the title and objectives, yet it has limited transferability to manufacturing systems operating under different institutional, labor, regulatory, infrastructure, and supplier-network conditions, meaning that generalization to other regions or emerging-market supply ecosystems should not have been assumed. Fifth, disruption heterogeneity has not been fully harmonized: studies have addressed different disruption types (supplier failure, demand shock, transport delay, quality escape, macroeconomic volatility), and because disruption typologies have varied, the strength of lean's contribution to mitigation may have differed by disruption class in ways that the synthesis has only partially captured through broad risk categories. Sixth, the evidence base may have been affected by publication bias, as studies reporting positive performance relationships have been more likely to appear in high-impact journals, and null or negative findings may have been underrepresented, which may have inflated mean evidence scores even though mixed evidence has been documented in the synthesis logic. Finally, the segment-level "case" approach has offered a practical structure for cross-case comparison, but it has also masked within-segment differences such as firm size, supply-base geography, product modularity, and digital maturity, which have likely moderated resilience outcomes and could not have been consistently controlled using published secondary evidence alone.

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