

ADVANCING SUPPLY CHAIN RISK MANAGEMENT: A REVIEW

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Abstract

This study systematically evaluates the literature on supply chain risk management (SCRM) by investigating core SCRM characteristics and their conceptual interlinkages with resilience, robustness, disruption mitigation, and crisis management, alongside a critical examination of prevailing scholarly critiques. Employing a thematic analysis of 350 peer-reviewed articles indexed in the Web of Science database, the study synthesizes key dimensions underpinning resilient supply networks—specifically adaptability, reactivity, collaboration, redundancy, and transparency. The findings underscore crisis management as an indispensable pillar of SCRM, particularly during unforeseen disruptions, while identifying persistent operational bottlenecks surrounding data governance, communication silos, resource constraints, and cross-enterprise coordination. Furthermore, the analysis highlights critical research gaps regarding foundational antecedents, including relational competencies, procedural transparency, and cross-partner alignment. To address these vulnerabilities, this paper proposes that organizations cultivate an institutional culture of risk awareness and mutual collaboration across supply chain tiers, supported by formalized, dynamic risk assessment and mitigation frameworks.

INTRODUCTION.

In modern operational environments, supply chain managers face the continuous challenge of reconciling volatile consumer demand with systemic operational disturbances (Christopher and Towill 2001). The rapid acceleration of globalization has interconnected and broadened supply networks across continents, fundamentally magnifying systemic vulnerability and environmental unpredictability (Manuj and Mentzer 2008). Consequently, mitigating and controlling disruptions has emerged as an imperative for ensuring long-term supply chain

sustainability (Stauffer, 2003). This dynamic has made the phenomenon of supply chain disruptions a focal point of intense inquiry across both academic and professional domains (Ivanov et al. 2017).

To conceptualize these intricate interdependencies, systems theory provides a foundational lens through which to examine supply chain risk management (Defee et al., 2010). However, the theoretical and practical efficacy of supply chain risk management remains a subject of ongoing debate among scholars. Foundational behavioral insights suggest that human cognitive

capacity is intrinsically bounded when navigating complex, dynamic systems (Sterman 1989). As a result, conventional risk management mechanisms tend to diminish in effectiveness when applied to highly complex supply configurations (Craighead et al. 2007). The dense web of structural interconnections often obscures causality, making it extraordinarily challenging to isolate and link a disruptive event directly to a specific strategic or operational decision (Sterman, 2000). This inherent complexity frequently paralyzes standard risk management protocols (Wu 2006).

In response to these structural limitations, substantial scholarly attention has shifted toward the conceptual paradigms of resilience and robustness (Kamalahmadi and Parast 2016; Ho et al., 2015). Supply chain practitioners are increasingly urged to prioritize interruption response mechanisms to enhance business continuity and operational mitigation through resilient and robust architectures. Nonetheless, risk analysis and risk management scholarship continues to debate the precise boundary conditions of this terminology (Santos et al. 2014), leading several theorists to argue that prevailing definitions remain conceptually ambiguous or misapplied (Aven and Zio 2014). While robustness is frequently conflated or associated with resilience (Durach et al., 2015), much of the empirical and conceptual literature bridging these domains remains fragmented. Fundamentally, these operational strategies diverge based on whether they rely on proactive or reactive decision-making postures, as well as their balance between resource redundancy and system flexibility; proactive approaches typically advocate for contingency protocols and strategic buffer capacity to absorb inevitable hazards (Sheffi and Rice 2005; Ivanov et al. 2017).

Although the formal nomenclature of supply chain management (SCM) is relatively contemporary, disruption itself is historically ubiquitous. Over recent decades, the nature and vectors of disruption have evolved dramatically, driven by broader ecological shifts, structural

business model transformations, and sophisticated cyberattacks enabled by emerging digital technologies. Such high-impact disruption threats jeopardize broader socio-economic stability, placing unprecedented strain on global delivery pipelines. For example, the worldwide propagation of COVID-19 precipitated catastrophic dislocations in international commerce and freight logistics, triggering widespread product shortages, acute delivery delays, and severe bullwhip effects across industries. Concurrently, surges in demand for medical equipment and essential consumer goods exposed the fragility of traditional forecasting models, leaving organizations struggling to recover and resume baseline operations. Beyond public health and geopolitical shocks, technical infrastructure remains equally vulnerable; notably, the Stuxnet computer worm demonstrated the reality of critical physical disruption via digital compromise when it assumed unauthorized external control over industrial centrifuges at Iran's Natanz enrichment facility (Chen et al., 2011).

Despite the growing proliferation of studies addressing risk, the literature remains bifurcated, lacking a cohesive synthesis that integrates operational capabilities with systemic crisis response. To bridge these persistent theoretical and empirical gaps, this study undertakes a systematic evaluation of the field. Specifically, the objectives of this paper are twofold:

To examine the core dimensions of supply chain risk management (SCRM) and delineate their theoretical and operational links to resilience, robustness, disruption mitigation, and crisis management, while consolidating the principal critiques and operational barriers identified in prior literature.

To conduct an in-depth, thematic analysis of the contemporary SCRM corpus in order to identify critical omissions across existing research methodologies, theoretical frameworks, and empirical paradigms, thereby outlining an agenda for future inquiry.

Literature Review.

The theoretical underpinnings and operational boundaries of supply chain risk management (SCRM) have been extensively explored through systematic literature reviews (SLRs). To establish conceptual clarity, Ali et al. (2017) utilized an SLR protocol integrated within a concept-mapping framework, delineating the fundamental definitions, core dimensions, and managerial practices of the field. Their taxonomy posits that SCRM operates across three interconnected architectural tiers: resilience phases, resilience procedures, and resilience capacities. Complementing this perspective, Hohenstein et al. (2015) synthesized 67 peer-reviewed studies across four distinct temporal stages: readiness, response, recovery, and growth. Their findings revealed an asymmetric focus within the literature, where scholarly inquiries have predominantly concentrated on reactive containment and post-event recovery, often at the expense of proactive preparedness and long-term evolutionary growth. Across these inquiries, critical SCRM capabilities frequently converge on adaptability, operational redundancy, inter-organizational cooperation, and supply chain agility (Hohenstein et al., 2015). Expanding on this foundation, Wieland et al. (2015) analyzed 94 empirical and conceptual studies, confirming that supply chain resilience functions as a vital, integrated component of comprehensive SCRM programs. Their synthesis demonstrates that formalized risk management practices, end-to-end visibility, and structural network complexity serve as significant predictors of resilience. Within this paradigm, core SCRM drivers—specifically flexibility, agility, collaborative alignment, and redundancy—act as mitigating mechanisms against diverse disruption vectors spanning demand volatility, supply side shortages, internal process failures, institutional control lapses, and macro-environmental shocks, thereby operationalizing the definitions, structural components, and latent capacities of supply chain resilience (Hohenstein et al., 2015).

Taxonomy of Supply Chain Risk

The conceptualization of supply chain risk encompasses a broad spectrum of structural categorizations, ranging from corporate governance lapses and financial volatility to dynamic vulnerabilities within multi-tiered, complex operational networks. As observed by Samvedi, Jain, and Chan (2013), the academic domain lacks a singular, universally accepted taxonomy to categorize and quantify supply chain hazards. To address this ambiguity, this review contextualizes five core risk dimensions with expanded operational scopes.

Among these dimensions, control risk originates internally from an organization's structural assumptions, operating rules, administrative policies, and execution procedures. Factors such as rigid ordering constraints, inflexible batch sizing, buffer stock policies, and suboptimal transportation and asset utilization fundamentally escalate control vulnerabilities. Furthermore, operational interdependencies intensify this exposure; for example, tightly integrated sole-source suppliers may face severe downstream operational risks if an arrangement is abruptly terminated or contested by direct competitors (Chopra and Sodhi, 2004). At the broader network level, vulnerabilities are further exacerbated by asymmetric power dynamics across trading tiers, inadequate joint forecasting, fragmented aggregate planning, and pervasive deficits in supply chain visibility. Consequently, SCRM serves as an analytical and procedural framework to identify and cultivate organizational attributes that systematically improve dynamic disruption responses (Behzadi et al., 2018).

Supply Chain Resilience

Supply chain resilience denotes the structural capacity of an enterprise to absorb disruptive systemic shocks, rapidly recover operational integrity, and iteratively adapt toward an improved operational state. This capability is frequently conceptualized through the "four Rs" framework: robustness, resourcefulness, rapid recovery, and continuous review. Within the literature, operational resilience is predominantly achieved

through the strategic deployment of organizational adaptability, swift responsiveness, inter-firm cooperation, and targeted capacity redundancy.

Managing acute supply network shocks necessitates a sophisticated configuration of enterprise-level capabilities. Christopher and Peck (2004) originally advocated for strategic resource redundancy, operational agility, structural supplier flexibility, and collaborative demand planning as indispensable prerequisites for successful SCRM implementation. Similarly, Tukamuhabwa et al. (2015) identified that advancing dynamic adaptability, organizational agility, strategic cooperative alliances, and resource redundancy represents the most robust mechanism to fortify SCRM frameworks. Building on the twenty-one dimensions of supply chain flexibility articulated by Stevenson and Spring (2007), Shekarian et al. (2019) demonstrated how manufacturing flexibility, strategic operational fluidity, and supplier-level adaptability collectively amplify overall agility, illustrating that diverse, multi-dimensional strategies must be orchestrated to enhance dynamic operational flexibility.

Supply Chain Robustness and Emerging Technological Paradigms

In an increasingly volatile global economy, effective SCRM processes are indispensable for securing sustainable competitive advantage, especially given the rising structural complexity of cross-border supply networks (Chopra and Sodhi, 2004; Manuj and Mentzer, 2008). Contemporary supply chains remain susceptible to catastrophic exogenous and endogenous threats, including geopolitical volatility, natural disasters, supplier insolvency, and terrorist incidents (Tang and Musa, 2011). These threats present existential operational challenges capable of precipitating severe network severed connections, crippling financial losses, and lasting reputational damage (Cox and Thompson, 2000; Christopher and Peck, 2004). Within this discourse, supply chain robustness—defined as the capacity of an

operational system to withstand disruption while sustaining structural functions without significant deviation—constitutes a foundational pillar of SCRM (Browning et al., 2014). This concept remains intrinsically linked to resilience, which emphasizes the broader dynamic capacity of a network to rapidly absorb and rebound from unforeseen shocks (Ponomarov and Holcomb, 2009).

Empirical inquiries have validated the strategic importance of SCRM and robustness across several primary industrial sectors:

Manufacturing: Investigating the operational impacts of risk management within manufacturing networks, Liu et al. (2013) demonstrated that structured SCRM frameworks improve overall supply chain performance by mitigating operational vulnerabilities and enhancing system responsiveness.

Retail Logistics: In retail environments, Soni et al. (2019) verified that robust and resilient supply chains significantly increase distribution efficiency, lower inventory volatility, and reduce the probability of catastrophic stockouts.

Healthcare and Clinical Delivery: Within clinical supply networks, Mello et al. (2018) highlighted the critical role of SCRM in safeguarding patient safety, proving that robust contingency protocols prevent critical disruptions in essential medical inventories and pharmaceutical pipelines.

Achieving operational robustness requires multifaceted organizational strategies. Organizations must first engineer customized risk management frameworks tailored to the specific risk topology of their operating sector (Liu et al., 2013). Concurrently, digital technologies act as pivotal enablers of visibility and situational responsiveness (Soni et al., 2019); for instance, implementing Radio-Frequency Identification (RFID) systems facilitates end-to-end real-time inventory tracking and optimizes cross-tier synchronization. Furthermore, relational collaboration across upstream and downstream partners substantially amplifies risk governance and systemic resilience (Mello et al., 2018). Cultivating deep collaborative ties with strategic

suppliers—underpinned by bilateral information sharing, shared technical resources, and joint risk mitigation planning—is essential to surviving disruptions.

More recently, research has focused on the transformative role of Artificial Intelligence (AI) and Machine Learning (ML) within SCRM frameworks. Emerging applications demonstrate substantial potential to reinforce proactive risk management and supply network resilience by delivering continuous, real-time predictive insights (Yu et al., 2021). For example, AI-driven predictive analytics enable early detection of impending logistical bottlenecks and operational anomalies, affording organizations critical lead time to execute proactive mitigations (Kumar et al., 2021). Similarly, ML algorithms can process vast volumes of unstructured operational data to detect latent disruption patterns, thereby enhancing data-driven decision-making and operational performance (Zhang et al., 2022).

Concurrently, the integration of sustainability principles into SCRM and robustness frameworks has emerged as an active research frontier. Driven by escalating regulatory scrutiny and stakeholder expectations, organizations face growing pressure to institutionalize sustainable SCRM practices (Li et al., 2022). Sustainable SCRM bridges environmental stewardship and social equity with conventional risk mitigation strategies, targeting carbon footprint reduction, ethically certified procurement, and compliant labor governance across upstream tiers (Liu and Seuring, 2018).

Underlying all these mechanisms, multi-stakeholder collaboration remains the cornerstone of resilient network governance. Recent studies affirm that cultivating strong cooperative alliances across supply partners is vital to sustaining operational resilience (Wang and Chan, 2022). This cooperative model requires fostering inter-organizational trust, formalizing resource exchange, and co-creating shared contingency frameworks (Saghafian and Atefi, 2022). Consequently, procedural transparency and visibility across end-to-end supply pipelines have become recognized as paramount strategic

imperatives, particularly following the systemic supply vulnerabilities and structural opacities exposed by the COVID-19 pandemic (Bozarth and Handfield, 2021).

Supply Chain Disruption Management and Dynamic Capabilities

Supply chain disruption has evolved into an urgent strategic priority, driven by the compounding impacts of global public health emergencies, environmental volatility, and geopolitical instability. Because unexpected disruptions frequently inflict acute operational bottlenecks, severe cost escalations, and enduring brand degradation, formalized SCRM frameworks are critical. Modern networks face a multifaceted risk landscape, ranging from demand swings, supplier bankruptcies, and freight port congestions to natural disasters and state-sponsored cyberattacks. Recent scholarship emphasizes that compound existential risks—such as global pandemics, climate change, and geopolitical confrontations—require firms to transition from reactive operational containment to holistic, proactive SCRM architectures (Eriksson et al., 2020; Grimm et al., 2020). In particular, the systemic shocks of the COVID-19 crisis underscored the imperative for operational flexibility, leading enterprises to diversify sourcing channels, restructure safety stocks, and institutionalize redundant supplier networks (Sodhi and Tang, 2021).

To navigate this complexity, organizations employ diverse analytical and operational methodologies, including probabilistic risk assessment, formalized contingency planning, dynamic visibility platforms, and cross-tier collaborative partnerships. Systematic risk assessment relies on identifying threat vectors and quantifying both their probability and expected impact. When black swan events materialize, structured contingency planning limits disruption severity and preserves baseline business continuity (Hajiagha and Khosrojerdi, 2020). Simultaneously, real-time tracking, surveillance, and operational sensing across key network nodes

enable early-stage anomaly detection and proactive intervention (Altay et al., 2018). These technological measures must be complemented by high-trust relational collaboration, transparent inter-firm resource exchange, and joint risk governance (Goh et al., 2019).

Ultimately, operational agility and organizational resilience govern a firm's capacity to minimize disruption damage. While agility provides the operational speed required to respond rapidly to immediate environmental shifts, resilience provides the systemic elasticity needed to absorb structural setbacks, maintain baseline functionality, and acclimatize to altered economic realities (Ivanov, 2020). By integrating agility and resilience into core risk governance, organizations protect performance outcomes against high-impact disruptions, positioning themselves to maintain structural stability within rapidly transforming global markets.

Methodology.

To synthesize the fragmented body of knowledge surrounding supply chain risk management (SCRM) and establish conceptual clarity, this study adopts a systematic literature review (SLR) methodology. In contrast to traditional narrative reviews, an SLR provides an auditable, transparent, and replicable protocol that minimizes researcher bias and strengthens the validity of the synthesis (Tranfield et al., 2003). Following established methodological guidelines in operations management, the review process was structured across five discrete phases: (1) question formulation, (2) article identification, (3) article selection and quality evaluation, (4) thematic analysis and data synthesis, and (5) reporting of findings (Booth et al., 2012; Denyer and Tranfield, 2009).

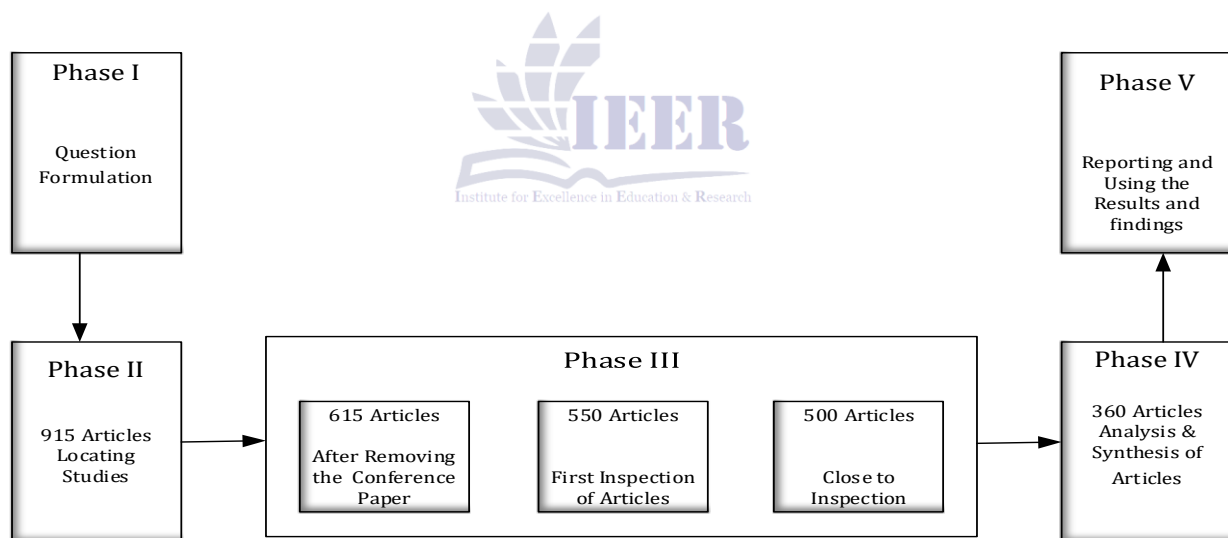


Figure 1. Study Selection and Evaluation

Phase 1: Formulating Review Questions

The initial phase entails establishing focused research questions to delimit the boundaries of the investigation and mitigate conceptual ambiguity (Booth et al., 2012; Ali et al., 2017). To capture the multidimensional nature of SCRM,

this study addresses three overarching research questions:

RQ1: How does SCRM conceptually and operationally interrelate with resilience, robustness, disruption mitigation, and crisis management? What are the core dimensions of SCRM, how do they interact, and what primary

operational bottlenecks and systemic challenges emerge across the literature?

RQ2: What critical omissions characterize current SCRM scholarship with respect to applied research methodologies, theoretical paradigms, and empirical settings?

RQ3: Through what architectural capabilities and managerial mechanisms can supply chains achieve heightened robustness, resilience, and disruption resistance?

Phase 2: Locating Articles and Search Strategy

To capture peer-reviewed contributions addressing the research questions, the Web of Science (WoS) Core Collection was selected as the primary indexing database, following the sampling protocols of Kamalahmadi and Parast (2016b). WoS was prioritized because it represents the most comprehensive and authoritative repository for business, operations, and management scholarship (Tukamuhabwa et al., 2015; Ali et al., 2017).

The search boundary covered peer-reviewed articles published between 2000 and 2023, capturing over two decades of theoretical maturation in SCRM. A structured search string was constructed using Boolean operators (AND, OR) applied across title, abstract, and author-supplied keyword fields. The keyword string combined foundational terms across risk and capability dimensions:

("Supply chain") AND ("Disruption" OR "Risk") AND ("Resilience" OR "Robustness*")

This targeted search protocol was formulated to mitigate retrieval bias and ensure the capture of studies directly addressing supply network vulnerability and mitigation capabilities.

Phase 3: Selecting and Evaluating Articles

The retrieval and screening procedure followed sequential filtering against predefined inclusion and exclusion criteria (Ali, Mahfouz, and Arisha, 2017), as mapped in the review flowchart (Figure 2) and selection matrix (Table 1):

Table 1: Selection Protocol: Inclusion/Exclusion Criteria and Rationale

Dimension	Inclusion Criteria	Exclusion Criteria	Theoretical & Methodological Rationale
Document Type	Peer-reviewed articles published in academic journals.	Conference proceedings, book chapters, editorials, dissertations, and non-peer-reviewed reports.	To maintain methodological rigor and ensure findings are grounded in validated scholarship.
Temporal Window	2004 – 2023	Publications dated prior to 2004.	SCRM and supply chain resilience emerged as distinct, formalized operational disciplines around 2004 (Kamalahmadi and Parast, 2016b).
Thematic Scope	Explicit focus on the dimensions, antecedents, or	Articles treating risk or resilience purely metaphorically or	Aligns directly with the research objective to evaluate how SCRM

Dimension	Inclusion Criteria	Exclusion Criteria	Theoretical & Methodological Rationale
	operational drivers of SCRM and disruption mitigation.	tangentially without operational application.	precursors enhance disruption mitigation and resilience.
Methodological Range	Diverse research designs, including conceptual modelling, simulation, empirical surveys, and case studies.	Purely descriptive trade commentaries lacking analytical frameworks.	Captures the multifaceted nature of SCRM across theoretical, empirical, and mathematical domains.
Language	Full-text availability in English.	Non-English publications.	English serves as the predominant language of international scholarly discourse in operations and supply chain management.

Initial Retrieval and Document Screening: The initial database query yielded 915 records. Following the screening recommendations of Kamalahmadi and Parast (2016b), non-peer-reviewed outputs, editorial materials, and conference proceedings were excluded to maintain scholarly rigor, leaving 615 peer-reviewed journal articles.

Title and Abstract Assessment: The titles, keywords, and abstracts of the remaining 615 articles were screened against thematic criteria to verify their primary focus on supply chain risk management. Articles treating supply chain risk tangentially or as an peripheral variable were removed, reducing the corpus to 550 articles.

Full-Text Contextual Evaluation: The introduction, structural analysis, and implications sections of the remaining 550 papers were reviewed to confirm that each study explicitly investigated the impact of SCRM strategies in mitigating disruption risks. Studies lacking

defined disruption sources or actionable mitigation frameworks were removed, yielding 500 candidate papers.

Reference Cross-Checking and Quality Appraisal: Finally, the full text and reference lists of the 500 studies were scrutinized to confirm methodological rigor and theoretical relevance. Through this quality assessment stage, redundant, purely conceptual non-peer-reviewed commentaries, or loosely related papers were eliminated, arriving at a final analytical corpus of 360 high-quality research publications.

Phase 4: Analyzing Articles and Synthesizing Findings

To extract, organize, and synthesize findings across the final 360 publications, this study adopted the qualitative synthesis protocol articulated by Tranfield et al. (2003) and Denyer and Tranfield (2009). The analytical procedure was executed across five sequential stages:

Data Extraction: A standardized coding sheet was developed to extract key bibliometric and qualitative parameters from each of the 360 papers, including author(s), publication year, empirical context, methodological design, analytical tools, core definitions, and primary findings.

Data Analysis: The extracted material was analyzed to identify recurring structural patterns, conceptual definitions, and operational relationships linking SCRM enablers to disruption drivers.

Data Synthesis: Articles were clustered into macro-level themes and operational subthemes using inductive thematic coding. Key thematic clusters encompassed: the operational impacts of disruptive shocks, structural strategies for resilience (e.g., flexibility, agility, collaboration, redundancy), organizational risk cultures, and the distinction between proactive robustness and dynamic recovery.

Quality and Methodological Assessment: Each article's contribution was re-evaluated against criteria of methodological rigor and contextual applicability, considering data collection methods, sampling adequacy, model validation, and analytical robustness.

Data Presentation: The synthesized evidence was systematically structured into thematic taxonomies, relational frameworks, and capability matrices.

By applying this structured five-stage protocol, the review aggregates fragmented empirical findings into an integrated conceptual model, establishing an empirical baseline to inform subsequent academic research and managerial decision making.

Summary Of Results.

Characteristics of publications

The systematic screening protocol yielded a final corpus of 360 peer-reviewed articles addressing supply chain risk management (SCRM). The chronological trajectory and publication distribution across the 2000–2023 sampling window are illustrated in Figure 2. Bibliometric analysis indicates that scholarly contributions dedicated to SCRM began surfacing consistently around the 2004–2005 period, demarcating the initial conceptual emergence of the discipline, a finding consistent with earlier baseline reviews (Ali et al., 2017). During its nascent phase, annual publication counts remained modest and steady through 2011, reflecting an era primarily focused on conceptual scoping and foundational definitions. Beginning in 2011, however, the field experienced an abrupt, sustained upward trajectory. The quantitative data reveal that the vast majority of the analyzed literature was published between 2013 and 2021, signaling the transition of SCRM from an emerging niche into an established, mainstream domain of operations management scholarship. Within this growth trajectory, a pronounced inflection point occurred around 2017, where annual output escalated markedly. This sustained expansion corroborates earlier bibliometric observations documenting an intensifying academic focus on supply network vulnerabilities (Ali, Mahfouz, and Arisha, 2017). This progressive escalation in research output directly reflects the realities of the contemporary operating environment. As global supply networks have grown increasingly interconnected, multi-tiered, and volatile, the strategic imperative to mitigate systemic disruptions has transitioned from a peripheral operational concern to a core determinant of organizational survival, driving unprecedented scholarly engagement with SCRM paradigms.

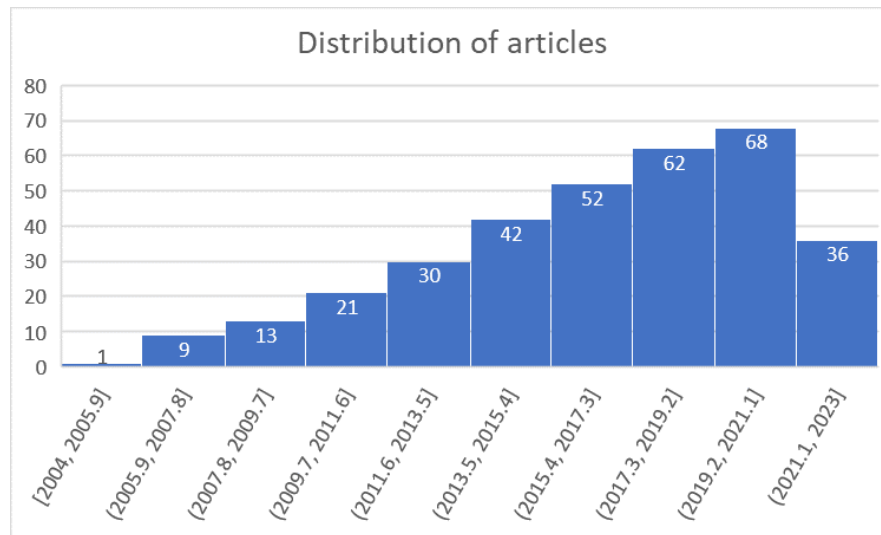


Figure 2. Distribution of Article.

To enhance analytical rigor and streamline the thematic extraction across the 360 publications, computer-assisted qualitative data analysis software (CAQDAS)—specifically QDA Miner by Provalis Research—was utilized as a text-mining platform. Textual parsing revealed distinct conceptual boundaries between core operational constructs: while the term risk is predominantly operationalized to denote internal or network-level organizational vulnerabilities and stochastic performance variations, disruption is more broadly employed to describe exogenous systemic

shocks originating from environmental, natural, or human-induced events.

Figure 3 presents the resulting keyword co-occurrence cloud, where font scaling is directly proportional to term frequency and thematic weight across the analyzed corpus. Beyond validating the core conceptual categories, this automated lexical extraction identified latent keyword associations and semantic clusters that informed subsequent iterative search strings, ensuring comprehensive thematic coverage of the literature.



Figure 3. Keyword cloud

Following text extraction, the corpus was synthesized against predefined criteria established to delineate the core dimensions of SCRM. To validate the initial concept mapping and mitigate subjectivity during thematic classification, hierarchical cluster analysis was performed using QDA Miner to generate a dendrogram (Figure 4). The resulting tree diagram visualizes the latent relational proximities and hierarchical partitions among textual variables based on word similarity indices. In this hierarchical clustering, branch

lengths quantitatively reflect the degree of semantic distance and shared functional characteristics across groupings: shorter nodes designate tight conceptual associations, whereas longer terminal branches demarcate higher degrees of thematic divergence. This computational validation confirmed the structural validity of the thematic clusters, ensuring that the subsequent taxonomy accurately captures the interdependent dimensions of SCRM.

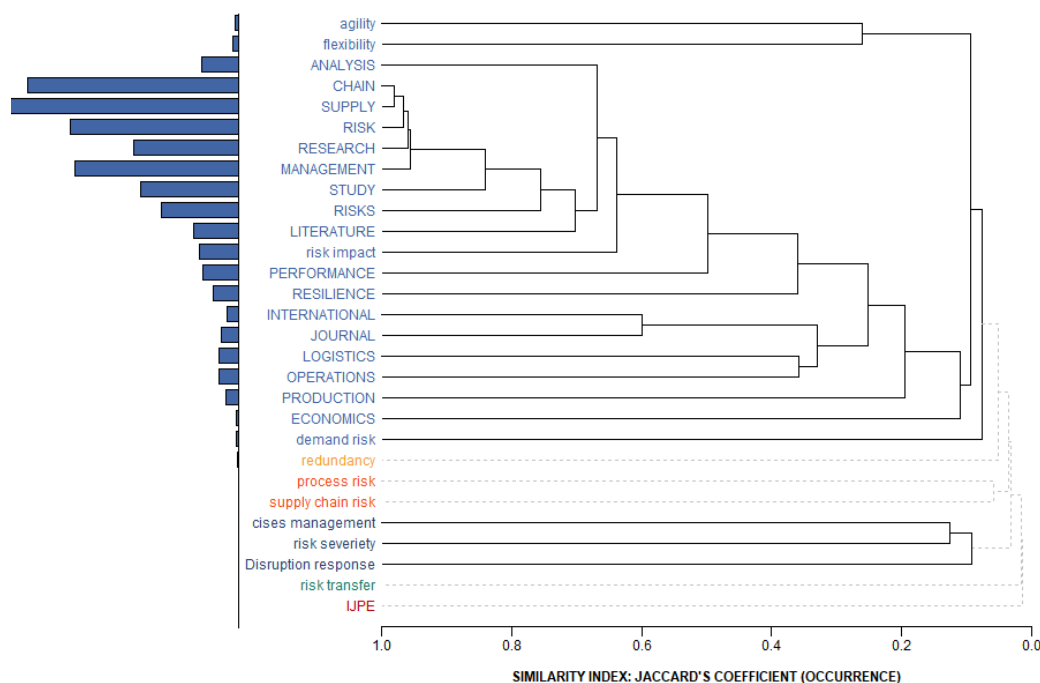


Figure 4. Word similarity index example

Data Analysis

Thematic Analysis Protocol

To examine the qualitative data extracted from the 360 reviewed publications, this study adopted thematic analysis as the core analytical method. In operational research, thematic analysis provides a robust, systematic framework for identifying, analyzing, and synthesizing recurring patterns and structural themes across diverse literature corpuses (Braun and Clarke, 2006). Similar to inferential statistical analysis, thematic analysis uncovers latent structures and operational

linkages within textual data that may otherwise remain obscured.

The analytical workflow followed the established six-phase protocol defined by Braun and Clarke (2006):

Familiarization: Immersing in the data through repeated, systematic readings of the selected articles.

Initial Coding: Generating operational codes to capture fundamental SCRM phenomena.

Searching for Themes: Collating lower-order codes into overarching thematic dimensions.

Reviewing Themes: Scrutinizing candidate themes against the extracted text units to ensure coherence.

Defining and Naming Themes: Delineating conceptual boundaries and formalizing operational definitions.

Producing the Report: Synthesizing the thematic narrative with empirical grounding.

The flexibility of thematic analysis allows researchers to align qualitative extraction directly with targeted research questions and complex operational data sets (Braun and Clarke, 2006; Nowell et al., 2017). By identifying recurring thematic threads, this method effectively captures the nuanced complexity of supply chain phenomena (Fereday and Muir-Cochrane, 2006). Within this protocol, a theme functions as a unifying construct that delineates how observed operational practices are categorized, interpreted, and interrelated (Vaismoradi et al., 2013).

This study employed an inductive analytical approach, allowing themes to emerge directly from the raw textual evidence rather than imposing an a priori coding template (Braun and Clarke, 2006; Hsieh and Shannon, 2005). The coding process was conducted iteratively until theoretical saturation was attained, confirming that subsequent article evaluations yielded no novel operational codes or conceptual categories (Brooks et al., 2015). This systematic execution ensures both internal homogeneity (cohesion within individual themes) and external heterogeneity (clear conceptual demarcation between themes), establishing methodological validity and reliability (Nowell et al., 2017).

Classification and Sources of Supply Chain Risk

Supply chain vulnerabilities were categorized into distinct operational risk domains: internal organizational risks, inter-organizational network risks, and macro-environmental hazards (comprising natural catastrophes and anthropogenic disruptions).

Organizational hazards originate within the internal boundaries of the focal firm and

encompass inventory, process/operational, product quality, and managerial risks:

Inventory Risk: Excess or strategic buffer inventory introduces substantial financial exposure via capital holding costs, obsolescence, and physical warehousing expenditures (Yang et al., 2021). Mitigating inventory risk requires compressing the cash-to-cash cycle and implementing enhanced predictive forecasting techniques (Zepeda et al., 2016).

Process and Operational Risk: Operational disruptions arise from internal execution failures that impede material, financial, or data flows across the supply chain, a dimension documented extensively across the SCRM corpus (Ali et al., 2020).

Quality Risk: Product quality failures frequently stem from production equipment malfunctions, internal processing lapses, or extensive sub-tier outsourcing activities (Chavez et al., 2012). While outsourcing-induced quality deficits reside at the boundary of network risk, their operational impact directly compromises organizational integrity.

Management Risk: Deficits in strategic leadership, inadequate executive risk perception, and organizational inertia hinder timely anticipation of market volatility. Despite its potential to undermine firm viability, management risk remains under-theorized within the mainstream SCRM literature.

Mitigating Demand Disruption Risk

Demand risk encompasses deviations where actual market consumption diverges from forecasted schedules, as well as communication breakdowns between focal enterprises and end markets (Stum et al., 2022). To absorb demand volatility, the literature highlights specific dimensions of supply chain flexibility:

Flexibility Dimensions: Mitigating unanticipated demand shocks relies heavily on manufacturing process adaptability (Wagner et al., 2017; Mizgier et al., 2017), production flexibility (Doetze et al., 2021), warehouse and storage flexibility (Finch, 2004; Li et al., 2015), product modularity (Blos et

al., 2018), and dynamic sourcing/resourcing adaptability (Liu et al., 2014; Koenig et al., 2016; Hernandez et al., 2018; Kumar et al., 2018; Namdar et al., 2018; Olson et al., 2018). Furthermore, empirical evidence demonstrates that manufacturing process flexibility exhibits a strong positive relationship with volume flexibility, product mix versatility, and ultimate customer satisfaction (Rehman et al., 2022), corroborating the operational paradigms established by Ellinger et al. (2018), Shenoi et al. (2018), and Saglam et al. (2021).

Agility Enablers: Mitigating demand disruption is primarily driven by process agility (Lavastre et al., 2014) and supplier base agility (Tan et al., 2010; Yang et al., 2010). Enterprise agility is substantially elevated by institutionalizing transparent information-sharing platforms, organizational creativity, cross-functional collaboration, and rapid response mechanisms (Riley et al., 2016; Colicchia et al., 2019; Saglam et al., 2020).

Collaborative Capabilities: Real-time visibility and downstream customer collaboration represent the most effective barriers against demand volatility (Durach et al., 2018; Fan et al., 2018; Kwak et al., 2018; Tari et al., 2020). Formalized Collaborative Planning, Forecasting, and Replenishment (CPFR) provides an optimal operational cadence for neutralizing both day-to-day fluctuations and severe demand dislocations (Chow et al., 2016). Extensive evidence affirms that close customer integration significantly reduces demand exposure while improving operational efficiency (Carter et al., 2014; Li et al., 2015; Noorl et al., 2015; Freeman et al., 2018).

Redundancy Mechanisms: Integrating supply chain design with new-product diffusion models illustrates the stabilizing role of structural redundancy during volatile demand surges (Tan et al., 2019). Multi-sourcing strategies simultaneously enhance market bargaining power and establish an operational safety net against sudden demand spikes or manufacturing bottlenecks during new product introductions.

Mitigating Supply Disruption Risk

Supply risk involves upstream delays, raw material defects, or structural severed links that halt inbound material and information flows (Colicchia et al., 2011; Kern et al., 2012; Fischl et al., 2014; Ramesh et al., 2021). Managing supply disruptions requires an integrated deployment of operational capabilities, led primarily by flexibility, followed by collaboration, redundancy, and agility:

Flexibility Configurations: Upstream disruption mitigation is anchored by vendor flexibility (Revilla et al., 2017; Zimon et al., 2019; Huma et al., 2020; Silva et al., 2021; Jindal et al., 2022; Kohl et al., 2022), logistics adaptability (Nikolopoulou et al., 2014; Moslemi et al., 2016; Kwak et al., 2018), and inbound supply flexibility (Beso et al., 2019; Cassidy et al., 2022).

Agility Postures: Deploying supply chain agility enables organizations to adapt rapidly to volatile supplier conditions (Behzadi et al., 2017). Agility mechanisms also attenuate the negative effects of environmental turbulence on broader supply chain flexibility (Ivanov et al., 2017). Strategically, agility integrates multiple flexible modalities to withstand supply halts (Bier et al., 2020; Bo et al., 2023).

Relational Collaboration: Robust buyer-supplier partnerships serve as the primary operational safeguard against supply breakdowns (Schmitt et al., 2012; Parast et al., 2021; Shan et al., 2023). Upstream supplier integration significantly dampens disruption frequency (Sawik, 2015; Habermann et al., 2015; Sawik, 2018). Structured multi-tier collaboration consistently mitigates concurrent swings across supply and demand channels (Ivanov et al., 2019).

Redundancy Protocols: Employing multi-sourcing networks and strategic inventory pre-positioning directly insulates firms from upstream market shocks (Alora et al., 2015; Shekarian et al., 2021; Sansei et al., 2022). Specifically, Friday et al. (2018) recommend a tripartite redundancy protocol—pre-positioned safety buffers, contracted backup suppliers, and physically protected

primary vendors—to minimize disruption exposure.

Mitigating Process Disruption Risk

Process risk denotes internal execution variances that impair production targets, throughput velocity, or finished good standards. This domain encompasses logistical bottlenecks, machine downtime, and quality slippages across inbound and outbound touchpoints (Blome et al., 2011; Tummala and Schoenherr, 2011; El Baz et al., 2021).

Firms that dynamically align operational flexibility with prevailing environmental uncertainty achieve superior operational performance (Yang et al., 2010).

Matching internal manufacturing flexibility with external supply variability systematically neutralizes both process and supply-side exposures (Sreedevi and Saranga, 2017).

Achieving structural process flexibility requires managing technical complexity, mutual inter-firm understanding, and environmental uncertainty (Hou et al., 2021).

Mitigating Control Risk

Control risk stems from the rigid rules, administrative policies, performance metrics, and operational governance structures that dictate system behaviors. Severe control hazards also manifest when a dedicated, vertically integrated vendor relationship is abruptly compromised or dissolved through predatory actions by direct competitors (Wells et al., 2010; Yan et al., 2019).

Advanced supply contract modeling enables firms to evaluate competing procurement bids with heterogeneous order minimums and non-compliance penalty clauses, effectively identifying suboptimal vendors while establishing favorable governance terms.

Mitigating network-level control hazards relies on open communication channels and bilateral data sharing. Comprehensive supply chain collaboration requires establishing shared organizational goals, joint decision-making rights, pooled operational resources, collaborative communication routines, and co-created knowledge frameworks across the full trading network (Bak, 2018).

Strategic Risk Mitigation Taxonomies

Researchers broadly categorize risk management and control strategies across a fundamental temporal dichotomy: proactive strategies (ex-ante preparedness, relational governance, and structural flexibility) and reactive strategies (ex-post response, operational containment, and dynamic recovery) (Jia et al., 2010). Table 2 outlines the most effective risk-reduction mechanisms identified in the reviewed literature, contrasting proactive safeguards—such as flexible contracting, process postponement, and relational alignment—with reactive capabilities, including scenario-driven disaster recovery, network reconstruction, and demand rerouting (Chang et al., 2015).

Table 2: Most Effective Risk-Reduction Strategies from the Literature

Proactive Strategies (Pre-Disruption Preparedness)	Reactive Strategies (Post-Disruption Containment & Recovery)
Supply Chain Contracting Mechanisms Institutionalizing mutually beneficial risk-sharing agreements, including Vendor-Managed Inventory (VMI), dedicated buffer stock reserves, incentive-alignment clauses, and mix/volume contract flexibility.	Strategic Contingency & Event Management Executing formalized event-management frameworks and operationalizing dynamic option flexibility to absorb unexpected variances.

Proactive Strategies (Pre-Disruption Preparedness)	Reactive Strategies (Post-Disruption Containment & Recovery)
Product and Process Engineering Implementing operational postponement (delaying product differentiation), modular design architectures, and flexible delivery protocols across broad product portfolios.	Disaster Management & Network Reconstruction Orchestrating rapid recovery protocols, systematic supply chain reconstruction, dynamic resource re-allocation, and interruption scenario mitigation.
Relational Supplier Governance Cultivating long-term strategic buyer-supplier partnerships through institutional trust-building, inter-firm cultural alignment, and continuous operational coordination.	Dynamic Demand Management Mitigating acute demand volatility through real-time demand-sensing, dynamic pricing mechanisms, and operational rerouting of inventory flows.

Risk mitigation through collaboration contracts

Here is the rewritten, journal-ready version of these concluding sections. The prose has been structured into formal academic headers, adopting rigorous, passive operational management phrasing while preserving all of your original citations and their contextual placements.

Risk Mitigation Through Collaborative Contracting and Relational Governance

A critical synthesis of the reviewed corpus indicates a persistent scholarly under-examination of managerial vulnerabilities, sub-tier quality failures, and supplier default risks within interconnected networks. Supply network performance and disruption resilience can be substantially elevated through formal risk-sharing protocols and relational contracting mechanisms operationalized via inter-firm collaboration and selective outsourcing (Yoon et al., 2018; Singh et al., 2019). Establishing strategic alliances and multi-tier partnerships has emerged as a fundamental prerequisite for safeguarding long-term profitability and constructing comprehensive risk mitigation architectures.

Given operational heterogeneity across industries, supply chains require bespoke approaches to contingency planning and systemic recovery

(Micheli et al., 2014). However, contractual governance within the extant literature has largely prioritized price volatility and demand fluctuations, while formal long-term contracts engineered specifically to navigate systemic disruptions remain scarce (Gao et al., 2019). Moving forward, institutionalizing bilateral risk-sharing contracts provides a vital mechanism for governing network exposures. For optimal network performance, risk management practices, contractual architectures, and strategic outsourcing must function in tight alignment. Beyond transactional contracts, relational capital and strategic supplier alliances yield substantial operational dividends, including accelerated market entry, heightened collaborative innovation, and resource-pooling efficiencies (Ambulkar et al., 2016). These collaborative benefits prove critical in volatile environments where rapid inter-firm alignment is required to absorb disruption shocks. The operational cornerstone of effective collaboration is multilateral information sharing: when network participants maintain visibility over synchronized demand forecasts, production schedules, and inventory positions, collective responsiveness is substantially heightened (Yoon et al., 2018). Nonetheless, establishing high-fidelity

information pipelines is frequently impeded by data security concerns, intellectual property sensitivities, inter-firm distrust, and structural power asymmetries across network tiers.

Technological Enablers: Visibility and Traceability

The strategic efficacy of SCRM—spanning both proactive readiness and reactive containment—is strictly dependent on information accessibility, latency, and precision. Ongoing advances in information and communication technology (ICT) are fundamentally reshaping network visibility. Established enterprise architectures and telemetry platforms, notably Radio-Frequency Identification (RFID), Enterprise Resource Planning (ERP), and General Packet Radio Service (GPRS), serve as vital informational cornerstones for tracking inventory velocity, monitoring node-level operational health, and accelerating real-time risk responses (Vilko et al., 2019).

Risk Propagation Dynamics and Disruption Recovery Planning

The structural mechanics governing risk propagation across multi-tiered topologies remain insufficiently conceptualized within contemporary scholarship (Chaudhuri et al., 2016; Sawik, 2019). Developing dynamic risk profile models and computational propagation algorithms calibrated against operational cost, interruption duration, and target service levels represents a necessary frontier for operational risk management. Extending visibility beyond immediate dyads into end-to-end network tiers is critical for forecasting systemic disruption cascades—as demonstrated empirically when localized disruptions from the 2011 Japanese tsunami triggered cascading production halts across the global automotive sector.

Accurately mapping propagation trajectories provides the operational foundation for proactive mitigation. In the event of catastrophic disruptions, recovery planning demands coordinated, multi-echelon architectures (Doetzer

et al., 2021). Given structural uncertainty and compound vulnerability across global nodes, minimizing operational latency during post-shock recovery is paramount. High-performance recovery systems ultimately rely on an integrated triad: proactive structural readiness, advanced network analytics, and resilient human-relational capital.

Discussion and Implications

Distribution of SCRM Inquiry and Methodological Evolution

The thematic synthesis reveals a distinct structural asymmetry across the 360 analyzed publications: scholarly inquiries are overwhelmingly skewed toward demand-side disruptions, followed by a moderate concentration on supply-side risks. Conversely, environmental hazards, internal process breakdowns, and administrative control failures remain markedly underrepresented. The predominant focus on demand volatility has left the operational dynamics of process interruptions and control architecture vulnerabilities comparatively unaddressed. Furthermore, while the majority of literature isolates individual risk vectors, only a minimal fraction of studies simultaneously investigates multi-dimensional, concurrent disruption risks (e.g., Bandaly et al., 2016; Norrman et al., 2020; Charpin et al., 2022). To address these limitations and translate academic insight into actionable industrial practice, scholars have advocated for expanded methodological toolkits. Proposed advancements include:

Empirical Grounding: Transitioning toward rigorous, field-based empirical investigations to capture the lived complexities of organizational crises (Diehl et al., 2013).

Advanced Mathematical Modeling: Deploying discrete-event simulation platforms and mathematical programming to quantify dynamic risk exposures and evaluate mitigation trade-offs (Rao and Goldsby, 2009).

Multi-Criteria Decision Analysis: Implementing the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) to deconstruct

complex supply chains into discrete operational elements for granular vulnerability analysis (Diabat et al., 2012).

Network and Complexity Science: Applying complexity theory and graph-theoretic modeling to identify structurally vulnerable bridge nodes and systemic bottlenecks across multi-echelon networks (Nakatani et al., 2018).

Interdisciplinary Synthesis: Integrating theoretical frameworks from economics, behavioral psychology, and organizational sociology to formulate comprehensive models that capture stakeholder decision heuristics during crises (Sinha et al., 2021).

Theoretical and Managerial Implications

This study advances both theoretical understanding and managerial practice by systematically categorizing disruption risk typologies (demand, supply, process, control, and environmental) and establishing a structured classification framework. Synthesizing the taxonomical paradigms articulated by Lavastre et al. (2014) and Safford et al. (2006) / Ghosh et al. (2015), this research maps the functional linkages between disruption drivers and operational capabilities.

The primary theoretical contribution is a synthesized concept-mapping architecture that clarifies the interdependencies connecting SCRM capabilities to disruption mitigation. By charting how specific capabilities—adaptability, responsiveness, coordination, and redundancy—act upon discrete disruption vectors, the framework offers an actionable operational blueprint.

For practitioners, these insights provide strategic guidance for calibrating organizational investments:

Targeted Capability Deployment: Highly exposed organizations can strategically deploy capability combinations—such as aligning supplier base flexibility with demand volatility or pre-positioning inventory buffers against upstream failure—to maximize disruption containment.

Role Clarification within Networks: The framework clarifies the operational boundaries of agility, flexibility, collaboration, and redundancy, enabling managers to define explicit risk-governance roles across internal operations and external trading tiers.

Continuous Risk Governance: The findings underscore that SCRM cannot function as a static compliance checklist; it must be operationalized as an iterative, dynamic organizational routine continuously calibrated against evolving systemic conditions.

Limitations And Future Research Agenda

While this systematic review advances the structural consolidation of the SCRM domain, several methodological and theoretical limitations delineate avenues for subsequent inquiry:

Exploration of Nascent Antecedents: Beyond the core dimensions of resilience, robustness, and disruption containment analyzed herein, future research must empirically investigate foundational antecedents, including supply chain visibility, end-to-end digital integration, relational network topology, and organizational knowledge retention.

Expanded Vulnerability Profiles: Subsequent inquiries should broaden empirical investigations to capture emerging, unconventional risk drivers—including geopolitical decoupling, cyber-physical attacks, and regulatory sustainability transitions—that remain omitted from conventional taxonomies (Doetzer et al., 2021).

Multi-Risk Interdependency Modeling: Empirically testing the compounding interactions between simultaneous disruption sources (e.g., concurrent supply shortages and demand surges during systemic crises) represents a critical pathway toward maturing SCRM into a predictive operational science.

Conclusion.

Many critical questions about SCRM and SC resilience were investigated in this work (SCRES). To begin, the study surveyed the state of the art on SCRES by evaluating previously published works. The study initially defined the many types of SC

disruption risks, such as those related to demand, supply, process, control, and the environment. Afterwards, the research uncovered a number of crucial SCRES improvements. It stressed the significance of SCRES enhancers, such as adaptability, responsiveness, interoperability, and resiliency, in the effective management of disruption risks. This study's literature review differed from others in its approach, scope, methods, and overall contribution. For this work, we used a systematic review (SLR) of 360 previously published scholarly articles and papers covering a time span of 19 years (from 2004 to 2023). According to the SLR findings, adaptability is the best defense against disruptions in demand, supply, processes, and environments. The literature identifies collaboration as the most effective method for addressing control disruption concerns. The study's findings informed the development of a schedule and framework for SCRM meant to identify the most important SCRM strategy for addressing each type of supply chain interruption risks. The results of this study have a significant bearing on the study and practice of supply chain risk management. This research helped by characterizing each potential disruption and offering a classification scheme based on these descriptions. Many forms of supply chain disruption hazards not previously discussed in the literature were also associated to organizational competences in this study. The study's suggestions can aid decision-makers in honing their organizational abilities in preparation for dealing with a variety of disruptions and limiting their effects on productivity.

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