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Rethinking Supply Chain Resilience Through Adaptive System-Level Approach

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Abstract

Supply chain disruptions have become increasingly prolonged, overlapping, and systemic, thus challenging supply chain resilience practices that are commonly grounded in recovery-based approaches. Despite the increasing discussion regarding adaptive responses, the supply chain resilience (SCRES) literature is dominated by capability-centric approaches, offering limited system-level guidance under continuous and cascading disruptions. This study develops a concise conceptual framework that reframes SCRES as an ongoing adaptive process instead of a one-time recovery. A triangulated literature-based approach was employed by integrating bibliometric mapping, systematic literature review, and integrative synthesis to develop the conceptual framework. The proposed SCRES – Adaptive System-Level (SCRES-ASL) framework distinguishes two fundamentals, namely enabling conditions and adaptive dimensions, which are iteratively connected through feedback loops. This alignment between structural conditions and adaptive processes, through the emphasis on feedback loops, supports co-evolution across supply chain tiers. This study contributes to the SCRES study by providing a system-level adaptive process framework that provides actionable clarity for understanding and managing resilience under constant turbulence.

Keywords: Adaptive Dimensions, Adaptive Pathway, Disruptions, Supply Chain Resilience, System Thinking

1. Introduction

Global supply chains are increasingly facing persistent and cascading disruptions, including natural hazards, geopolitical tensions, and sudden regulatory shifts. The disruptions often occur simultaneously and propagate across the supply network, causing system-level instability, rather than a mere operational failure. This phenomenon requires organizations to develop continuous adaptive mechanisms in coordinating and developing technology reconfigurations. Under cascading disruptive circumstances, the traditional understanding of resilience, which revolves around the state of ability to recover from a single disruption, becomes insufficient for managerial practice.

Supply chains play a vital role in economic growth and social welfare due to their role in supporting both the local and global economy, which in turn will improve the economic growth, as well as their role in ensuring the availability of needed products across the globe (Goel et al., 2021; Prayitno, 2024; Zhu, 2023). Its fundamental role drives the concern of maintaining its function amidst the presence of disruptions, which are commonly understood as supply chain resilience. Works in the area of supply chain resilience (SCRES) have been developed by various scholars. Arji et al. (2023), conducted a systematic literature review (SLR) to identify critical resilience strategies, focusing on the role of digital innovation in the supply chain. Guo et al. (2024) systematically review inventory management strategies in the context of SCRES to classify strategies in the supply-side and demand-side of the inventory. Rahman et al. (2022) utilizing a systematic review to classify SCRES strategies into the following categories: preparedness, response, and recovery. Chauhan et al. (2023) went beyond the strategic level by proposing pathways for SCRES through Industry 4.0 in strengthening SCN structures; digitalization, innovation, and entrepreneurship; capabilities and strategies; risk management; circular economy and sustainability.

These previous studies provide valuable insights into resilience strategies and potential enablers, especially related to cutting-edge technology. These studies also share a common understanding of managerial capabilities and operational mechanisms in the context of SCRES. However, these studies merely focus on identifying specific tools, strategies, or technological solutions at the organizational level. Within this view, resilience is understood as the ability of a supply chain to absorb disruptions and return to its pre-disruption state through predefined capabilities such as redundancy, buffering, flexibility, and contingency planning (Christopher & Peck, 2004; Suryawanshi & Dutta, 2022). While these contributions are important and advance the understanding of resilience practices, they offer a limited explanation of how resilience develops and emerges across the broader supply chain system. Responding to the real-world challenges faced by the supply chain, which are increasing in complexity and connectivity, to increase its relevance in today's situation, these limitations need to be improved. Resilience cannot be understood solely as recovery, but rather as a continuous adaptive process in which supply chain actors iteratively reconfigure structures, technologies, and coordination mechanisms in response to evolving disruptions (Chodakowska et al., 2024; Herold et al., 2021; İskendera et al., 2025; Kazancoglu et al., 2022). The improvement in the SCRES conceptualization needs to adopt a more adaptive and system-oriented conceptualization of supply chain resilience.

1.1. Dominant perspectives in supply chain resilience

The SCRES literature to date remains fragmented and dominated by operational capability perspectives, despite the growing recognition of continuous adaptations. Current studies in the SCRES field are dominated by a particular perspective and approach. From this perspective, SCRES is commonly framed using risk-based and recovery-oriented fundamentals, seeing SCRES as the ability to absorb shocks and restore operations to the original stable state. In the methodological layer, research in SCRES mostly uses optimization models, redundancy strategies, and risk management, without addressing how resilience emerges in a complete supply chain network (Alikhani et al., 2021; Christopher & Peck, 2004; Folke, 2016). Despite its value in countering predictable and short-duration disruptions, recent studies show that the actual challenges of supply chain organizations lie in prolonged, overlapping, and nonlinear unpredictable events. This condition requires firms to continuously adjust their structures, technologies, and coordination mechanisms (Chodakowska et al., 2024; Herold et al., 2021; İskendera et al., 2025). The over-reliance on recovery-oriented perspectives results in a lack of understanding regarding how system properties such as nonlinearity, feedback loops, co-evolution, and emergent behavior shape resilience in supply chain systems. These properties remain underexplored within SCRES discourse. This limitation indicates conceptual gaps between the available theoretical framework in understanding supply chain resilience and the complex reality of real-world supply chain disruptions.

1.2. The need for adaptive system-level resilience under cascading disruptions

To address the limitations of recovery-oriented resilience, this research adopts a complexity-oriented perspective to understand and explain supply chain dynamics by adopting the *complex adaptive system* (CAS) as an

ontological foundation. CAS highlights the nature of the supply chain as a system that comprises heterogeneous agents that interact with each other based on their bounded rationality, and generate system-level behavior such as emergence, self-organization, non-linear dynamics, and co-evolution, which determine the system-level phenomenon such as recovery trajectories (Carter et al., 2015; Nooteboom, 2022; Walker & Salt, 2006). Therefore, in a complex system perspective, supply chain resilience (SCRES) cannot be understood solely through the development of predefined capabilities; it is a continuous adaptive process emerging from interactions within the supply chain network.

Complementing this view, *resilience thinking* is also utilized at the strategic level to understand how the system should maintain its functionality through reorganization and evolution rather than bouncing back to a single state of equilibrium (Folke et al., 2016; Holling & Gunderson, 2002a). Within this perspective, realizing resilience means focusing on the development of the system's capabilities to adapt, reorganize, and evolve while maintaining its functional thresholds. Therefore, resilience is associated with adaptability and transformability that allow systems to persist and evolve amidst continuous disturbances. The key concept of this perspective lies in shifting attention from recovery toward continuous adaptation and learning within dynamic environments (Folke et al., 2010; Holling & Gunderson, 2002a).

To operationalize these conceptual approaches in sequential strategic responses, the *adaptive pathways* concept was adopted. Adaptive pathways explain how organizations adjust their responses in a sequential manner in enabling flexible transitions between alternative strategic options (Kivimaa et al., 2021; Sparkes et al., 2023). Adopting *adaptive pathways* allows the proposed conceptual framework to explain how continuous adjustment should be taken into action by various actors in the supply chains through structural arrangements in response to disturbances.

Through the adoption of CAS as an ontological foundation, *resilience thinking* as a strategic lens, and *adaptive pathways* as an operational approach, this study provides a comprehensive conceptual foundation for supply chain resilience. In this reconceptualization, resilience is seen as a system-level adaptive process in facing continuous disruptions rather than organizational or individual-level strategies in facing a single disruption and achieving a one-time recovery outcome.

1.3. Theoretical Foundation: Complex Adaptive System, Resilience Thinking, and Adaptive Pathways

The growing body of literature in supply chain displays the characteristics of complex adaptive systems (CAS) embedded in supply chain networks, represented by heterogeneous actors whose behaviours are shaped by local rules, bounded rationality, and nonlinear interactions (Choi et al., 2001; Holland, 1992). Placing CAS as the ontological foundation, supply chain architecture is seen as a system embedded with system-level phenomena such as disruption propagation, ripple effects, and recovery trajectories that emerge from non-linear interactions, evolving network structures, and feedback loops, instead of isolated decisions (Ahmad et al., 2024; Surana et al., 2005). The CAS literature commonly highlights four recurring structural dimensions as elements of a system, namely: agents and interactions, network connectivity and architecture, system dynamics and adaptations, and emergent properties, in which each element carries distinct implications for resilience. Agent heterogeneity creates diverse response options; network topology affects buffering and shock diffusion; and the feedback-learning process shapes long-term adaptation character (Carmichael & Hadžikadić, 2019; Yaroson et al., 2021).

Serving as the ontological foundation, the CAS-based understanding aligns closely with resilience thinking as a strategic lens, which shifts attention from restoring a prior equilibrium towards maintaining the system's functionality through reorganization and evolution (Folke, 2016). In situations where prolonged and cascaded disruptions occur, organizations iteratively adjust their structures, reconfigure resources, and refine coordination networks and mechanisms. These observed resilience practices align with the concept of adaptive cycle ($r-K-\Omega-\alpha$), where system are considered to move through phase of growth (r), conservation (K), collapse or release (Ω), and reorganization (α), emphasizing that resilience is a developmental process through iterative feedbacks, restructuring, and renewal rather than returning to a single equilibrium state (Carpenter et al., 2001; Holling & Gunderson, 2002b). Furthermore, path-dependent learning highlights the role of past decisions and historical

practices that determine the future adaptive options. Through learning paths, organizations develop sensitivity towards both known and unknown disruptions. These dynamics reflect structural adjustments performed in recent supply chain systems in managing uncertainties (İskendera et al., 2025; Ivanov, 2024; Massari & Giannoccaro, 2023).

Temporal logic is needed to operationalize this perspective. Hence, adaptive pathways are utilized to provide this temporal logic. By framing resilience not as a fixed capability, but instead as a sequence of short-, medium-, and long-term decisions adjusted to the evolving conditions (Kivimaa et al., 2021; Sparkes et al., 2023). Four recurring mechanisms were commonly discussed in SCRES literature to illustrate how adaptive pathways operate in practice; these mechanisms include:

- 1 Decentralized adaptation, reflecting options owned by agents, distributed decision rights, and coordination pivots shaped by local information (Adobor, 2020; Wieland & Durach, 2021).
- 2 Network reconfiguration, comprising structural adjustments such as modularization, redundancy, alternative routing, and prevention of long-term lock-in (Alikhani et al., 2023; Hart Nibbrig et al., 2025; Rajesh, 2020b).
- 3 System dynamics and learning, emphasizing feedback learning, identification of adaptation tipping points, and periodic revision of strategies (Carpenter et al., 2001; Holling & Gunderson, 2002b; Ivanov et al., 2010).
- 4 Scenario branching and system renewal, allowing alternative trajectories and transformational adjustments, when disruptions altered baseline assumptions (Kivimaa et al., 2021; Öberg, 2023).

Together, the CAS ontology, resilience thinking, and adaptive pathways reframe resilience as a continuous and systemic process, instead of a bounce-back ability to the predefined state. Those foundations provide guidance for resilience navigation by improving sensitivity towards changes, decentralized response coordination, feedback navigation, and continuous adjustment.

1.4. Research Question and Study Objectives

Building on these perspectives and filling in the current gaps between SCRES conceptualization and real-world challenges, this study proposed a conceptual framework that reconceptualizes supply chain as an ongoing adaptive process, operating at the system level. That answers the following research question: What are the enabling conditions and core adaptive components required to develop a supply chain resilience framework under continuous and cascading disruptions? To answer this question, three objectives were formulated:

- 1 To identify conceptual and methodological fragmentation in the current SCRES conceptualization by examining the dominant perspective in SCRES literature.
- 2 Examine how the dynamic and systemic characteristics of temporary disruptions are captured in existing studies.
- 3 Develop a conceptual framework that reconceptualizes SCRES as a system-level adaptive process by providing enabling conditions and adaptive dimensions derived from literature synthesis.

The integration insight derived from Complex Adaptive System (CAS) as ontological foundations, resilience thinking as a strategic lens, and adaptive pathway as operational approaches provided a structured conceptual architecture for understanding resilience in the supply chain system under continuous disturbances

2. Method

This study integrates bibliometric mapping, systematic literature review (SLR), and an integrative synthesis in a triangulated methodological design to develop the proposed framework of SCRES. The breadth and depth analysis was expected to be a thorough, complementary analysis. The literature corpus was assembled through a structured search of peer-reviewed journal articles across Scopus, Web of Science, and ScienceDirect databases,

using key terms related to “supply chain”, “resilience”, and “model” or “design”, following the established protocol by Tranfield, Denyer and Smart (2003) and Kitchenham (2007). Inclusion criteria were applied by limiting to English-language journal publications from the recent five-year period. After the screening of relevance and quality, the literature corpus resulted in 87 relevant articles, forming the literature base for the analysis. The relevant articles were then processed through the triangulated review method. Bibliometric maps informed the thematic cluster based on their emergence in the breadth of the SCRES literature. SLR was carried out to envelop the pattern of conceptualization regarding SCRES literature. Informed by the results of these two synthesis methods, integrative analysis was conducted by expanding the understanding through a deep review of the literature on resilience thinking, complex system concept, and adaptive pathways. These comprehensive syntheses result in the proposal of a conceptual framework titled Supply Chain Resilience – Adaptive System-Level (SCRES-ASL). This triangulation review method ensures both breadth and depth analysis of existing literature in the field of SCRES. Figure 1 summarizes the research design comprising methodological activities, their analytical purposes, and the nature of the outcome at each stage, while Figure 2 shows data collection following the PRISMA protocol.

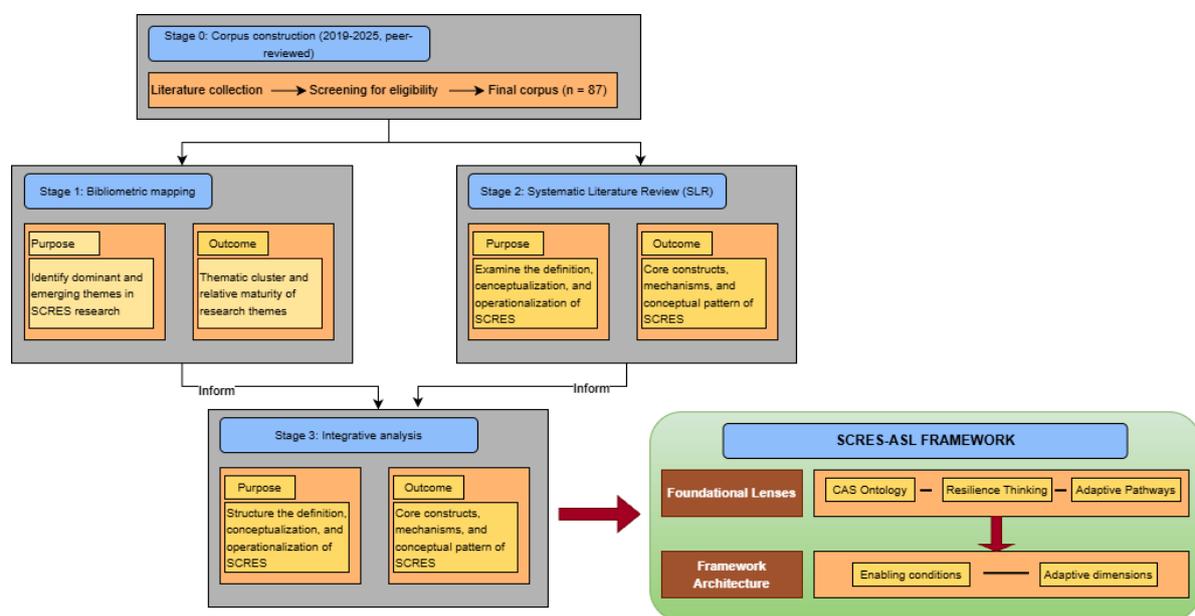


Figure 1: Research design

Source: Author

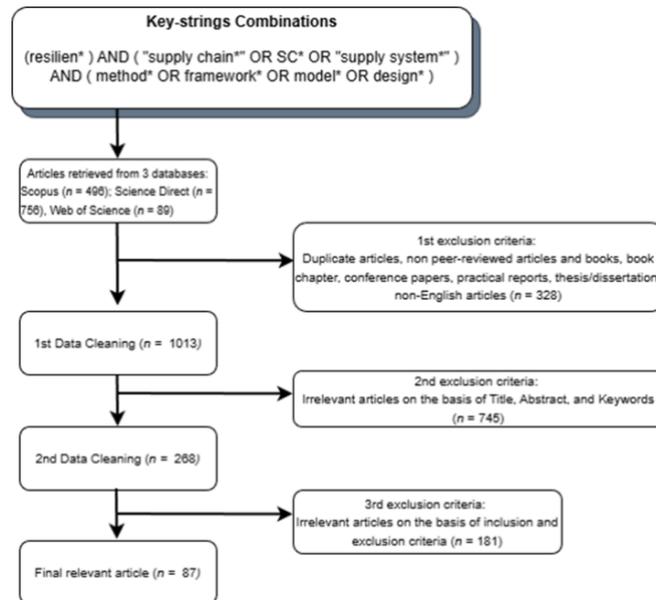


Figure 2: Systematic search and articles selection strategy on the Supply Chain Resilience (SCRES) model and design

Source: Author

2.1 Bibliometric mappings

Bibliometrics serves as a means to map the published articles and gather knowledge regarding the evolution of the themes and interconnectedness between different themes in the SCRES research domain (Amlan et al., 2023; Candeias Fernandes & Franco, 2022). As a methodology, bibliometrics focuses on quantitative analytics of academic outputs through network analysis and trend mapping on the author, content, and institutions. In this study, bibliometric analysis was conducted to obtain a macro-level overview of SCRES literature. The identification of dominant themes, conceptual clusters, and topic evolution patterns was executed to enable a structural visualization of the field's conceptual landscape and to show the organization of the topic. Conducting this analysis allows researchers to gain a macro-level view of the specified research topic.

2.2 Systematic Literature Review (SLR)

SLR is useful in synthesizing broad research in a particular research area (Snyder, 2019). Complementing the thematic analysis, a systematic literature review (SLR) was conducted to examine how SCRES has been conceptually defined, operationalized, and theoretically grounded across studies in recent years (2019 – 2025). SLR provides a structured approach, utilized to examine the definition, conceptualizations, and operationalization of SCRES across peer-reviewed publications. SLR was conducted in three stages: planning, implementation, and reporting, following Kitchenham's SLR protocol (Kitchenham et al., 2009). The review protocol is using PICOC (Population, Intervention, Comparison, Result, Context). The collected literature was screened for relevance and quality check, resulting in the identification of established assumptions, resilience mechanisms, and analytical point of view. Following this protocol, the population consists of peer-reviewed literature on supply chain resilience, strategies, mechanisms, and conceptual approaches revolving around SCRES perspectives. This process contributes to the in-depth analysis of literature in SCRES. This process aims to identify conceptual limitations and fragmentations across the research corpus, reflecting the state-of-the-art of SCRES research.

2.3 Integrative Synthesis

The integrative analysis developed by combining insights gathered from the bibliometric mapping and SLR, complemented with deep narrative review on foundational theory related to resilience, ranging from complexity theory, resilience thinking, and adaptive pathways. This review on foundational works such as CAS by Holland,

adaptive cycle by Holling, and resilience thinking by Folke allows the grounded conceptual understanding needed to develop a coherent system-level framework. This approach follows established practices in theory development, where insights generated from literature review analysis are interpreted and synthesized through broader cross-disciplinary fundamentals to reconcile fragmented constructs to develop an integrated conceptual architecture, as seen in Holling & Gunderson (2002a), Tranfield et al. (2003), and Massari & Giannoccaro (2023). Fundamental works in CAS concept and resilience thinking provide ontological and strategic scaffolding needed to consolidate contemporary SCRES phenomena into a coherent system-level framework, in which the adaptive pathway concept complements these concepts with operationalization tools. Through this comprehensive synthesis, dispersed insights were reorganized into a hierarchical conceptual structure that informed the development of the SCRES-ASL (Supply Chain Resilience – Adaptive System-Level) framework, which integrates the enabling conditions and adaptive dimensions of adaptive supply chain resilience. These integrated analytical layers inform the development of a hierarchical architecture that distinguishes (i) the enabling condition required for adaptive functioning and (ii) the core adaptive dimensions of SCRES.

3. Results

The outputs of the synthesis are presented in this section, beginning with the thematic map visualization and proceeding to the development of a consolidated, foundational architecture for the resilience framework.

3.1 Insights from Literature Synthesis

The literature synthesis offers complementary insights that informed the proposed framework. The bibliometric maps in Figure 3 show topic clustering within the SCRES corpus, with the motor theme cluster dominated by Supply Chain Resilience, indicating its central position in the corpus and its integrative function. More operational themes such as risk management, disruption, digitalization, and collaboration exhibit high centrality but lower internal density, indicating their widespread use in literature. Conceptual themes such as supply chain visibility, viability, and systematic review appear in the niche theme quadrant, suggesting the fragmentation of discussion in this topic in the SCRES discourse. The domain-specific and methodological themes, such as food supply chain and fuzzy modelling, fell into the emerging/declining quadrant, indicating their context-bound applications that need further reinforcement.

Figure 3 also shows visible patterns of connection between different themes that represent keyword co-occurrence relationships. These connections reveal the different themes that are frequently discussed together in SCRES research. Themes such as visibility, viability, and systematic review are connected to the SCRES theme through supply chain management, and risk management, indicating the connection between those themes as a unified discussion, not isolated streams.

Overall, the thematic maps show the central role of Supply Chain Resilience, which also serves as the most developed focus. SCRES are developed around operational enablers and conceptual developments. Importantly, the co-occurrence connections between topics show the topics that are frequently discussed together, indicating intellectual linkages between those topics. However, these connections do not show a structure that explains the relation of these topics in the system level. Therefore, highlighting the need for an integrative analysis that provides organization and structure for these dispersed yet related themes.

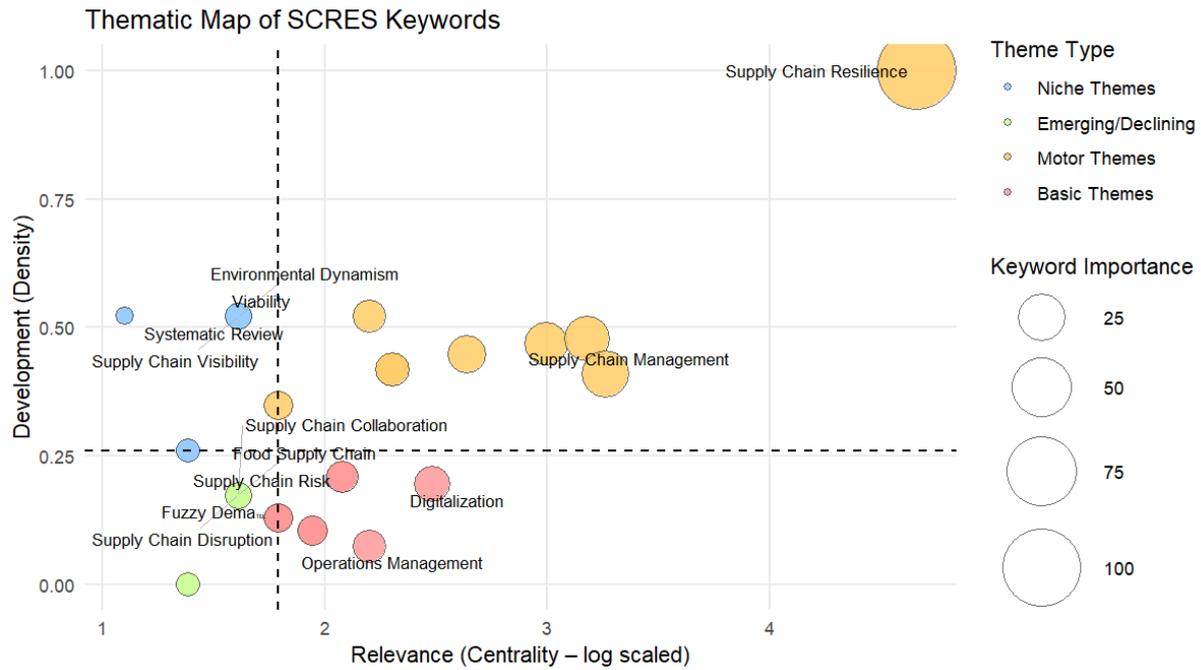


Figure 3: Thematic maps of academic works in supply chain resilience (SCRES)

Source: Author

3.2. Insights from SLR

The SLR process resulted in the dominant perspectives revolving around SCRES conceptual approaches, showing the state-of-the-art research in SCRES. Four key insights were derived from this process. First, the SLR shows dominance of capability-based resilience, where SCRES conceptualizes operational capabilities such as redundancy, flexibility, buffering, and contingency planning. This perspective resulted in a particular framing that see resilience as a set of predefined capabilities, rather than an evolving system property. The second stream of literature focuses on the technology-oriented resilience, in particular related to digital technologies and Industry 4.0 technology that improve SC visibility, coordination and analytical efficiency. Technology, however, only seen as a tool rather than a part of a system-level adaptive mechanism that influences emergence behavior. Another major body of work focuses on SCRES as part of risk management frameworks that emphasize risk identification, mitigation strategies, and preparedness-response-recovery cycles. These streams see resilience as the embodiment of risk mitigation and disruption management. The details of the literature explaining these key takeaways is described in Table 1.

Table 1: Key takeaways of state-of-the-art research in SCRES

Literature streams	Detail	Author
Capability – based resilience conceptualization	Redundancy, flexibility, buffering, adaptive routing, adaptive capability development	(Alikhani et al., 2023; Bag, Sabbir, et al., 2023; Y. Bai et al., 2025; Bowen & Siegler, 2024; Centobelli et al., 2023; Dura et al., 2025a; Furstenau et al., 2022a; Gavalas, 2025; Gruchmann et al., 2024; Ivanov, 2025; Khalilpoor et al., 2025; Liu et al., 2023; Machfudiyanto et al., 2025; Mahmud et al., 2023; Manafi & Sayan, 2025; Modgil et al., 2022; Olfati & Paydar, 2023; Oliveira Silva et al., 2024; Pang et al., 2025; Pu et al., 2025; Rajesh, 2020a; Riccardo et al., 2021; Sawik, 2022; Song et al., 2022; F. R. Taghikhah et al., 2025; Tiwari et al., 2024; Wube et al., 2025;

Technology-oriented resilience	Digital supply chain, Industry 4.0, data visibility, sensing and monitoring, SC data analytics, digital platforms, digitalization	Ye et al., 2025; Zheng et al., 2025) (Aslam et al., 2025; Bag, Dhamija, Singh, et al., 2023; X. Bai et al., 2025; Boone et al., 2025; Bowen & Siegler, 2024; Centobelli et al., 2023; Dong et al., 2025; Dura et al., 2025b; Furstenau et al., 2022b; Ivanov, 2025; Jafarian et al., 2025; Lv, 2025; Modgil et al., 2022; Peron et al., 2025; D. Singh et al., 2025; G. Singh et al., 2023; F. R. Taghikhah et al., 2025; Wang et al., 2025; Zhao et al., 2025)
Risk management and disruption mitigation perspective	Risk identification, mitigation strategies, preparedness-response-recovery cycles	(Bag, Dhamija, Luthra, et al., 2023; X. Bai et al., 2025; Bowen & Siegler, 2024; Broekaert et al., 2025; Centobelli et al., 2023; Chen et al., 2025b; Dura et al., 2025b; Furstenau et al., 2022b; Gruchmann et al., 2024; Ivanov, 2025; Jain et al., 2024; Khalilpoor et al., 2025; C. R. Lin et al., 2025; López et al., 2025; Lv, 2025; Mahmud et al., 2023; Modgil et al., 2022; Ozdemir et al., 2022; Pan et al., 2025; G. Singh et al., 2024; S. Singh et al., 2025; F. Taghikhah et al., 2021; Tiwari et al., 2024; Wang et al., 2025; Zhao et al., 2025)

Source: Author

Literature streams mostly focused on firm-level capabilities and strategies, without further explanation on how resilience emerged in system-level across multi-tier supply networks. Consequently, the conceptualization of SCRES remains fragmented and lack of understanding regarding persistent and cascading disruptions in complex supply networks. This limitation, therefore, highlights the need for an alternative that frames SCRES from system-level conceptualization that able to explain adaptive process within complex supply networks.

3.3. Insights from Integrative Analysis: Categories and factors of SCRES-ASL

The systematic literature review (SLR) that was complemented and refined through integrative analysis conducted in this study resulted in the formulation of the SCRES-ASL architecture, which consists of two conceptual clusters. The first cluster contains enabling conditions that need to be in place to realize adaptive behavior. If these enabling conditions are met, then the supply chain system can go through an adaptive process, which is the second cluster. The enabling conditions comprise governance, visibility, collaboration, learning system, and digitalization, while the adaptive process is characterized by decentralized responses, network reconfiguration, feedback-driven learning, and scenario branching. These constructions are then organized into a two-level categorization and labelled as follows:

1. Label A1-A5 are the Enabling Conditions; and
2. Label B1-B4 are the Adaptive Dimensions

These categories provide a coherent hierarchical structure that comprises the prerequisite conditions followed by adaptive processes.

Table 2: Enabling conditions for SCRES-ASL

Enabling Condition	Definition	Author
A1. Governance & Decision Rights	Establishes clear cross-tier responsibilities, flexible escalation paths, and adaptive decision mandates. Enables network-level governance to empower adaptive decision-making under uncertainties.	(J. Lin & Fan, 2024; Tsolakis et al., 2023; Wu et al., 2023)

A2. Data & Visibility Infrastructure	Provides interoperable data systems, shared indicators, and early warning tools to enhance transparency and timeliness. Strengthening sensing capabilities is vital for rapid detection and informed response.	(Bag, Dhamija, Singh, et al., 2023; Bowen & Siegler, 2023; Chen et al., 2025a; Tiwari et al., 2024)
A3. Collaboration & Incentive Alignment	Enhance cross-firm action by developing relational mechanisms, trust, and coordinated routines, while ensuring aligned incentives through benefit and risk sharing, and risk mitigation arrangements.	(Mwesiumo et al., 2021; Orji & U-Dominic, 2024; Peron et al., 2025; Ul Akram et al., 2024)
A4. Learning & Knowledge Systems	Creates routines for post-event learning, capturing feedback, and reflecting on performance. Enables the learning loop across tiers while retaining organizational knowledge	(Gao et al., 2021; Herold et al., 2021; Schoenherr et al., 2023; Zighan et al., 2024)
A5. Digital Enablement	Enhances the sensing, coordination, and scenario evaluation through the integration of AI, data analytics, digital twins, and simulation tools, supporting faster and better adaptive response	(Iftikhar et al., 2025; Ivanov & Gusikhin, 2026; Jafarian et al., 2025; Modgil et al., 2022)

Source: Author

Table 3: Core Adaptive Dimensions of SCRES-ASL

Adaptive Dimension	Operational Factors	Author
B1. Decentralized Adaptation (Agents & Interactions)	<ul style="list-style-type: none"> • Define agent-level response options, reflecting heterogeneity and bounded rationality. • Establish coordination pivots that align distributed decisions as disruptions evolve. 	(Adobor, 2020; Wieland & Durach, 2021; Yaroson et al., 2021)
B2. Network Reconfiguration (Connectivity & Architecture)	<ul style="list-style-type: none"> • Implement modular, flexible network structures that allows re-routing and multi-sourcing. • Maintain redundancy and alternate pathways while preventing structural lock-in. • Flexibility on coupling/decoupling to manage propagation risks. 	(Alikhani et al., 2023; Hart Nibbrig et al., 2025; Rajesh, 2020a; Sawik, 2022)
B3. System Dynamics & Learning Loops	<ul style="list-style-type: none"> • Define monitoring indicators responding to feedback loops and system delays. • Identify adaptation tipping points (ATPs) that trigger transitions across adaptive phases. • Revision of pathways based on learning and evolving system states 	(Carpenter et al., 2001; Holling & Gunderson, 2002a; Ivanov, 2024; Massari & Giannoccaro, 2023)

- B4. Scenario Branching & System Renewal (Emergent Properties)
- Create alternative pathways for diverging future conditions. (Kivimaa et al., 2021; Öberg, 2023; Sparkes et al., 2023)
 - Identify convergence points stabilizing trajectories.
 - Design transformational options in case of unreliable prior configurations.

Source: Author

The two sets of categories above operate as interdependent elements, in which resilience emerges as a system-level process. The enabling conditions act as structural foundations covering institutional, informational, relational, learning-related, and technological aspects as enablers of adaptive behavior in practice. Governance and decision rights (A1) define the authority and coordination mechanisms needed for distributed responses. Data and visibility infrastructures (A2) strengthen sensing and early warning across tiers, allowing early recognition of propagation risks. Collaboration and incentive alignment (A3) supports coordination and burden sharing when adaptation requires cross-firm trade-offs. Learning and knowledge systems (A4) allow feedback and revision of routines, while digital enablement (A5) provides analytics and simulation needed for sensing, coordination, and scenario evaluation. Together, these enabling conditions provide the structural basis to inform the development and refinement of adaptive dimensions as conditions evolve.

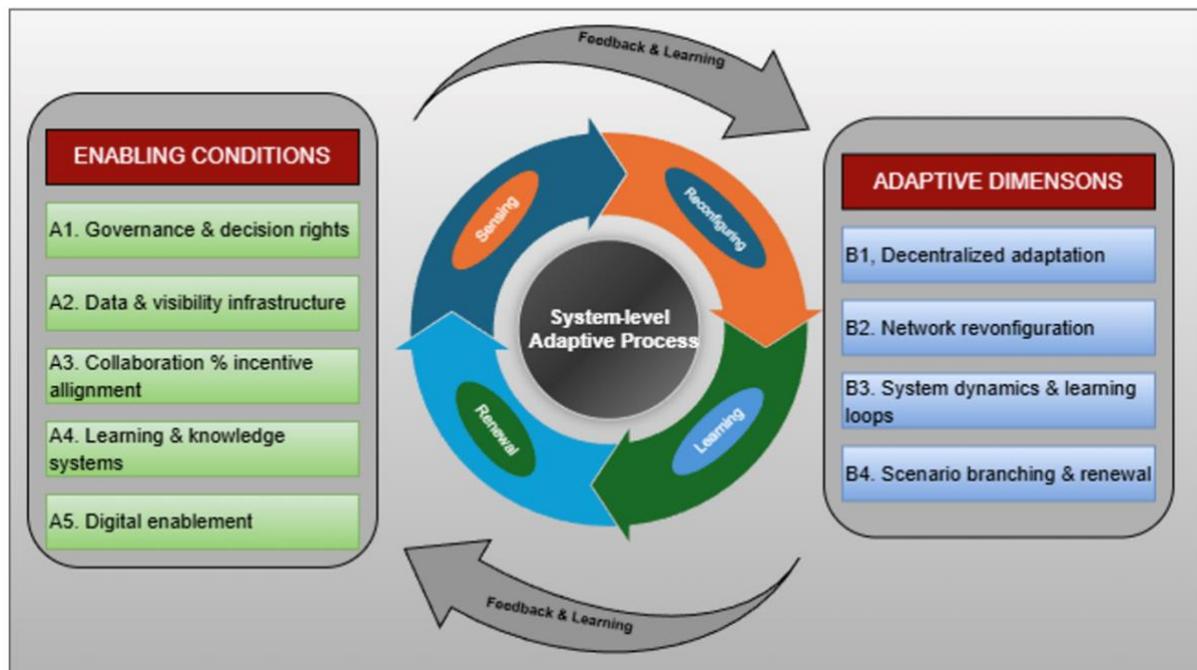


Figure 4: SCRES – ASL Integrated Conceptual Framework

Source: Author

The SCRES-ASL architecture framework, as depicted in Figure 4, has a two-level hierarchical structure that describes how the supply chain resilience should unfold in a continuously turbulent situation through a system-level adaptation. The enabling conditions labelled A1-A5 act as prerequisite conditions needed to sense changes, coordinate decisions, and mobilize responses across tiers. These conditions are the baseline of the adaptive dimension labelled as B1-B4. This dimension explains how resilience in the supply chain should be regarded as an ongoing process of continuous adjustment, instead of a one-time recovery attempt. The adaptation process goes iteratively between Enabling Conditions and Adaptive Dimensions, emphasizing the co-evolution situation, where the adaptive actions reshape the governance arrangements, the information structure needed, the collaboration routines, the learning process, and the technology adaptation, which in turn becomes the

foundation of the next adaptation cycle. This process goes iteratively, thus showing the feedback loops situation that connects the enabling situations and adaptive mechanisms to ensure the evolution process.

SCRES-ASL contributes to practical domain by informing supply chain managers a diagnostic design through the following sequence: (1) assess gaps in current situation across supply chain tiers; (2) identify the adaptive dimensions that are currently lacking in the gaps; (3) prioritize the enabling conditions that allows adaptive movements; and (4) revisit the assessment following the evolution of disruptions. For example, when a disturbance emerges that limits visibility, sensing lags and early signals of propagation are missed, thus hindering the network reconfiguration process, because rerouting and multisource decisions are late. This situation hampers feedback-driven learning because indicators are incomplete or delayed. In this case, data and visibility infrastructure need to be strengthened to support the decentralized response, followed by reconfiguration that reduces the escalation of the disturbance and lock-in effects.

4. Discussion

This study proposed a reconceptualization of SCRES through a triangulated methodology involving bibliometrics analysis, SLR, and integrative analysis. Bibliometrics and SLR show several persistent limitations in the existing SCRES literature. A capability-centric perspective dominated the literature, framing SCRES primarily as the development of discrete operational capabilities such as redundancy, flexibility, and buffering. Further, these studies emphasized recovery from a single disruptive event, rather than continuous adaptation in a prolonged disruption, a situation that is more relevant in today's world. The elaboration of resilience is fragmented across different bodies of literature regarding structural conditions and organizational-level resilience strategies. Thus, offering limited guidance for a system-level perspective on how resilience evolves through nonlinear interactions among supply-chain actors. These limitations highlight the need for a coherent perspective that bridges structural enabling conditions with adaptive operational processes across the supply chain system.

SCRES-ASL framework proposed in this study enriches the current understanding of supply chain resilience by offering a system-level view that integrates enabling conditions with the adaptive process needed to unfold resilience over time. The existing SCRES literature is dominated by the perspective that sees SCRES as a situation achieved through predefined, recovery-oriented capabilities such as redundancy, buffering, and risk-based optimization. This dominant perspective frames resilience as capabilities that need to be developed to achieve a predefined outcome, thereby neglecting the dynamic adjustments within the system. Through the SCRES-ASL framework, the perspective was shifted by reconceptualizing supply chain resilience as a continuous system-level process that emerges through cycles of sensing, reconfiguration, learning, and renewal. From this perspective, SCRES is conceptualized as a learning and evolutionary process. The proposed SCRES-ASL framework aligns with current empirical observations that underscore the importance of dynamic adjustment and feedback-driven coordination in mitigating prolonged disruptions. Therefore, this perspective points out the key role of interaction within supply chain tiers in supporting the evolving nature of resilience, rather than by defining engineered attributes.

Furthermore, by integrating structural elements with adaptive mechanisms, SCRES-ASL provides an evolutionary process driven through continuous sensing, decentralized coordination, reconfiguration, and system renewal. Hence, this framework complements the dynamic capability perspective by extending the analytical lens from firm-level adjustment to network-level co-adaptation. The system-level integration allows SCRES-ASL framework to capture the evolving nature of resilience development that frames SCRES as an emergent, continuous adaptive process, shaped by the structural and relational foundations of the supply chain system. This conceptualization thus goes beyond the static engineering conceptual approach.

SCRES-ASL framework provides valuable insights for managers and policymakers by providing practical direction for resilience design under contemporary continuous disruptions. The Enabling Conditions can be used to measure structural or relational problems, such as a low level of visibility, unclear decision mandates, a weak learning process, and more problems that potentially hinder the adaptation process. The Adaptive Dimensions further provide process-oriented guidance that manages the sequence of actions. These dimensions provide

understanding of the conditions when decentralized adjustments are appropriate, when the network reconfiguration needs to take place, when the existing feedback loops require realignment, and when there is a need to reform the emerging trajectories. Further, to fully realize the resilience of the supply chain, this framework helps policymakers to strengthen the institutional arrangements and data infrastructure required in enabling coordination and cross-organizational adaptation. Overall, by treating supply chain as an adaptive economic system, SCRES-ASL provides the structure of system-level architecture that synthesizes dispersed perspectives in the SCRES literature and provides practical pathways to navigate the supply chain system under persistent disruptions.

5. Conclusion

This study proposes a framework titled as SCRES – Adaptive System-Level (SCRES-ASL) that advances the conceptualization of supply chain resilience (SCRES) through the integrated synthesis of bibliometric mapping, systematic literature review, and theory-informed deep synthesis. This study achieved three key objectives. It identified structural patterns and major limitations in the contemporary literature corpus comprising SCRES conceptualization. This study also synthesized insights from CAS, and *resilience thinking* as theoretical grounding, and *adaptive pathways* as operational approach to construct SCRES-ASL frameworks. This study further provide theoretical guidance for SCRES under continuous disruptions by articulated enabling conditions and adaptive dimensions. Through the establishment of Enabling Conditions and Adaptive Dimensions the framework moves beyond the static resilience thinking emphasizing recovery-centric approaches toward a dynamic understanding of resilience development process through continuous sensing, reconfiguration, learning, and renewal. In this hierarchical architecture, the framework provides clarity on how the foundational structures comprise governance, visibility, collaboration, learning systems, and digitalization operationalizes through adaptive mechanisms at multiple system levels, offering managers and policymakers an actionable guidance for designing and evaluating SCRES under continuous and cascading disruptions.

As a conceptual proposition, the proposed SCRES-ASL framework calls for further empirical examination to operationalize and realize the adaptive factors through structural assessment, applying simulation or a system-dynamic modelling to explore the various pathways under different disruption contexts. Longitudinal case studies are also valuable in tracing adaptive processes and interacting across supply-chain tiers. The exploration on how digital technologies, data-sharing policies, and institutional arrangements should be developed under the framework on diverse industries also needed. Such investigations not only deepen the understanding of resilience under this framework but also provide more practical and empirical evidence across different contexts.

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