The Nexus of Risk, Disruption, and Supply Chain Resilience: An Integrated Framework Moderated by Artificial Intelligence

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Abstract

In the era of globalization characterized by unpredictable volatility, the resilience and adaptability of supply chains are not merely defensive factors but also a foundation for building a sustainable competitive advantage. This paper delves into the multifaceted impacts of risks and disruptions on critical links within the supply chain – specifically procurement, transportation, and inventory management – and assesses the aggregate impact on the resilience of the overall supply chain resilience. Furthermore, given the increasing role of technology, this research also proposes to explore the moderating role of Artificial Intelligence (AI) adoption in the aforementioned relationships. Based on the literature reviews and preceding studies, an integrated conceptual model is proposed, promising both theoretical contributions and practical implications for building more resilient and intelligent supply chains. This underscores the imperative for businesses to proactively enhance risk management capabilities and construct a genuinely resilient supply chain to address challenges and seize opportunities in the new context.

Research purpose:
Synthesizing and systematizing the theoretical basis of risk, disruption, key supply chain activities (procurement, transportation, inventory management), and supply chain resilience as well as their relationships.

Research motivation:
Existing research often examines the impacts of risk and disruption in isolation, lacking a comprehensive framework that integrates multiple functional activities and their collective influence on resilience

Research design, approach, and method:
Systematic theoretical synthesis based on relevant literature..

Main findings:
Successfully establishes three principal supply chain activities, categorizes risks and disruptions by their primary origins, identifies six core elements of supply chain resilience, and develops an integrated conceptual research model.

Practical/managerial implications:
Providing highly practical scientific arguments that enable businesses to adapt to the current intensely competitive and digitalized landscape

Keywords: Supply Chain Disruption; Supply Chain Resilience; Artificial Intelligence (AI); Procurement; Transportation; Inventory Management.

1. INTRODUCTION

1.1. Practical Problem Statement

Modern supply chains, characterized by their complexity and global reach, are becoming increasingly sensitive to diverse types of risks and disruptions. Previous research has documented the severe consequences of these events, the contemporary business environment has witnessed an unprecedented escalation in supply chain disruptions, fundamentally challenging traditional approaches to supply chain management. Recent global events, including the COVID-19 pandemic, geopolitical tensions, natural disasters, and cyber-attacks, have exposed critical vulnerabilities in supply chains worldwide, resulting in billions of dollars in losses and highlighting the urgent need for enhanced resilience capabilities .

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The practical implications of these disruptions are profound. Companies across industries have experienced severe operational setbacks, including production shutdowns, inventory shortages, delivery delays, significant financial losses, and diminished customer responsiveness and brand reputation damage (Morales, 2025). For instance, the automotive industry faced semiconductor shortages that forced production halts globally, while the healthcare sector struggled with critical shortages of personal protective equipment during the pandemic . These events have demonstrated that traditional risk management approaches, which often treat risks in isolation, are insufficient for addressing the complex, interconnected nature of modern supply chain challenges.

Moreover, the increasing adoption of lean manufacturing and just-in-time practices, while beneficial for efficiency, has inadvertently increased supply chain vulnerability by reducing buffer stocks and creating single points of failure . This paradox between efficiency and resilience has become a critical strategic challenge for organizations seeking to maintain competitive advantage while building robustness against disruptions.

1.2. Research Streams and Literature Gaps

1.2.1 Supply Chain Risk Management Stream

The supply chain risk management literature has evolved significantly over the past two decades, with researchers developing various frameworks for risk identification, assessment, and mitigation . Studies have categorized risks based on their sources (internal vs. external), nature (operational vs. strategic), and impact levels (minor vs. catastrophic). However, this stream has primarily focused on individual risk types and their direct effects, often overlooking the systemic nature of risk propagation through supply chain networks.

1.2.2 Supply Chain Resilience Stream

The resilience literature has emerged as a response to the limitations of traditional risk management approaches, emphasizing the capacity to absorb, adapt, and recover from disruptions . Researchers have identified various dimensions of resilience, including anticipation, preparedness, response, and recovery capabilities, ex: (Ponomarov & Holcomb, 2009), (Christopher & Peck, 2004). Despite significant advances, this stream lacks consensus on the specific mechanisms through which resilience is built and maintained across different organizational contexts.

1.2.3 Supply Chain Performance Stream

Research on supply chain performance has traditionally focused on operational efficiency metrics such as cost, quality, delivery, and flexibility . Recent studies have expanded this view to include resilience-related performance indicators. However, the relationship between traditional operational performance and resilience outcomes remains underexplored, particularly regarding how specific operational activities contribute to overall supply chain resilience.

1.2.4 Artificial Intelligence in Supply Chain Stream

The AI in supply chain literature has grown exponentially, exploring applications in demand forecasting, inventory optimization, transportation planning, and risk prediction . While these studies demonstrate AI's potential to enhance operational efficiency, limited research has examined AI's role in moderating the relationships between risks, operational performance, and resilience outcomes.

1.3 Theoretical Issues in Extant Literature

Despite extensive research in these streams, several critical theoretical gaps remain:

First, the literature lacks an integrated theoretical framework that explains how supply chain risks and disruptions simultaneously affect multiple operational activities and ultimately influence overall resilience. Most studies examine bilinear relationships, ignoring the complex interdependencies and mediating mechanisms inherent in supply chain systems.

Second, there is insufficient theoretical clarity regarding the distinction between supply chain risk and supply chain disruption. While both concepts are widely used, they are often treated as synonymous or conflated, leading to conceptual confusion and limiting theoretical development.

Third, the mechanisms through which specific operational activities (procurement, transportation, inventory management) mediate the relationship between risks/disruptions and resilience outcomes lack theoretical grounding. The literature has not adequately explained why these activities serve as critical linkages in the risk-resilience relationship.

Fourth, the moderating role of AI adoption in supply chain relationships lacks comprehensive theoretical justification. While empirical studies show AI's benefits, the theoretical explanation of how and why AI moderates these relationships remains underdeveloped.

1.4 Research Questions and Objectives

Based on the identified gaps, this research addresses the following primary research question:
How do supply chain risks and disruptions affect supply chain resilience through the mediating mechanisms of key operational activities, and how does AI adoption moderate these relationships?

This primary question is decomposed into three specific research questions:

1. How do supply chain risks and disruptions differentially affect procurement, transportation, and inventory management performance?
2. How do these operational activities contribute to overall supply chain resilience?
3. How does AI adoption moderate both the risk-performance and performance-resilience relationships?

The research objectives are:

1. Theoretical Synthesis: Develop a comprehensive theoretical framework integrating supply chain risk, disruption, operational performance, and resilience constructs based on established management theories.
2. Conceptual Model Development: Propose an integrated conceptual model that explains the complex relationships among these constructs, including the moderating role of AI adoption.
3. Hypothesis Formulation: Derive testable hypotheses from the theoretical framework to enable future empirical validation.
4. Practical Implications: Provide actionable insights for managers seeking to build more resilient and intelligent supply chains

This research's contributions are expected to provide a robust foundation for further empirical analyses and offer significant implications for designing more resilient supply chains in the current disruptive environment.

2. THEORETICAL FOUNDATION AND LITERATURE REVIEW

To clarify the varying degrees of impact of risks and disruptions on different aspects of the supply chain, define a comprehensive framework outlining the constituent elements of supply chain resilience, and synthesize current research gaps and trends, 35 studies published in reputable international journals, ranked Q1 and Q2 by Scimago/Scopus, were selected.

2.1. Theoretical Foundations

This research is grounded in three complementary theoretical perspectives that collectively provide a robust foundation for understanding supply chain resilience dynamics.

2.1.1 Resource-Based View (RBV)

The Resource-Based View provides the foundational lens for understanding how supply chain capabilities contribute to competitive advantage and resilience . According to RBV, organizations achieve superior performance by leveraging valuable, rare, inimitable, and non-substitutable resources and capabilities. In the supply chain context, procurement capabilities, transportation networks, and inventory management systems represent strategic resources that, when properly integrated, create sustainable competitive advantages (Komakech et al., 2025).

RBV explains how supply chain activities serve as strategic resources that can be leveraged to build resilience. Effective procurement relationships with suppliers, efficient transportation networks, and optimized inventory management systems represent unique, difficult-to-replicate resources that yield sustainable competitive advantages when properly integrated . These capabilities become particularly valuable during disruptions when organizations with superior resource configurations can maintain operations while competitors struggle.

2.1.2 Dynamic Capabilities Theory (DCT)

Dynamic Capabilities Theory extends RBV by explaining how organizations develop, integrate, and reconfigure resources in response to changing environments . Dynamic capabilities are defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Pierce et al., 2008). In supply chain management, dynamic capabilities enable organizations to sense emerging risks, seize opportunities for improvement, and transform their operations to enhance resilience.

DCT is particularly relevant for understanding supply chain resilience because resilience inherently involves dynamic responses to disruptions. Organizations with strong dynamic capabilities can quickly reconfigure their supply chain activities, develop new supplier relationships, establish alternative transportation routes, and adjust inventory strategies in response to changing conditions .

2.1.3 Contingency Theory (CT)

Contingency Theory provides the theoretical foundation for understanding how AI adoption moderates supply chain relationships . CT posits that the effectiveness of organizational practices depends on the fit between these practices and contingent factors in the organization's environment. In the context of supply chains, the effectiveness of risk management and resilience-building efforts is contingent on various internal and external factors, including technological capabilities.

CT explains why AI adoption serves as a critical contingency factor that influences the strength and direction of relationships between risks, operational performance, and resilience outcomes. Organizations with advanced AI capabilities can better sense environmental changes, process complex information, and respond more effectively to disruptions .

2.2 Construct Definitions and Distinctions

2.2.1 Supply Chain Risk and Supply Chain Disruption

Building on recent theoretical developments, this research makes a clear distinction between supply chain risk and supply chain disruption:

- Supply Chain Risk is defined as the potential for adverse events that could negatively impact supply chain performance, characterized by uncertainty about future occurrences and their potential consequences. Risk is inherently forward-looking and probabilistic, representing threats that may or may not materialize.
- Supply Chain Disruption is defined as the actual occurrence of unexpected events that interrupt the normal flow of materials, information, or products within the supply chain, causing immediate operational impacts. Disruptions are realized events that have already occurred and are affecting current operations.

This distinction is crucial because risks and disruptions operate through different mechanisms and require different management approaches. Risks can be anticipated and mitigated through preventive measures, while disruptions require immediate response and recovery actions.

2.2.2 Supply Chain Risk and Disruption Categorization

Based on comprehensive literature analysis, (Jüttner et al., 2003) indicate that supply chain risks are categorized according to their primary origins:

- Environmental Risks: External risks arising from the broader business environment, including natural disasters, political instability, economic fluctuations, and regulatory changes.
- Network Risks: Risks inherent in the supply chain network structure, including supplier failures, transportation breakdowns, information system failures, and demand volatility.
- Organizational Risks: Internal risks arising from within the focal organization, including operational failures, resource constraints, strategic misalignments, and capability gaps.

2.2.3 Key Supply Chain Activities

This research focuses on three core supply chain activities that serve as critical mediating mechanisms between risks/disruptions and resilience outcomes. These activities are selected based on their comprehensiveness, essentiality, integrative potential, and holistic coverage of supply chain operations :

Procurement: encompassing purchasing and broader functions like supplier management and contract negotiation, is critical for firms. It plays a key role in cost control through strategic negotiations and long-term contracts. Procurement also mitigates risk and ensures supply continuity by diversifying suppliers and implementing contingency plans (Elock Son, 2018). Effective procurement enhances overall supply chain performance by adhering to strategic principles, directly impacting profitability and value.

*Transportation***:** involves the movement of goods throughout the supply chain, from initial supplier to final customer (Chopra & Meindl, 2016). It is a vital and often costly component, especially in global supply chains, creating spatial and temporal utility by delivering goods to the right place at the right (de Jong et al., 2006). Transportation acts as a crucial link, connecting all supply chain stages and ensuring seamless material flow, thereby improving service speed and quality. Its efficiency, influenced by both vertical and horizontal business relationships, significantly contributes to overall supply chain performance.

Inventory Management: is a crucial supply chain function balancing customer demand with storage costs, while fostering flexibility and responsiveness (Becerra et al., 2022). Inventory exists as raw materials, work-in-progress, and finished goods. Effective inventory management optimizes cost efficiency and enhances competitive advantage. It improves supply chain performance by reducing demand information distortion and limiting upstream stockouts. Optimal inventory levels also mitigate risks like stockouts during lead time extensions or demand surges, and help protect against price volatility, thereby enhancing customer satisfaction and supply chain adaptability (Lee et al., 2004).

According to the SCOR (Supply Chain Operations Reference) model developed by APICS – *Association for Supply Chain Management*, the 6 primary supply chain processes include: Plan, Source, Make, Deliver, Return, and Enable. While the latest version – SCOR Digital Standard – has introduced many changes, processes like Source and Fulfill remain core, emphasizing the role of Procurement, Transportation, and Inventory Management activities.

The drivers of supply chain performance include: (1) Facilities, (2) Inventory, (3) Transportation, (4) Information, (5) Sourcing, (6) Pricing (Chopra & Meindl, 2016). These cross-functional drivers are increasingly becoming crucial in enhancing supply chain surplus in recent years. In addition, these drivers do not operate in isolation but interact closely, with supply chain management increasingly focusing on *three key cross-functional drivers*: Sourcing, Transportation, and Inventory Management (Sumarsono & Muflihah, 2021).

Drawing on the *Resource-Based View (RBV*) in supply chain management, core supply chain structures, including logistics capabilities (transportation), inventory management, and supplier relationships (procurement), represent unique, difficult-to-replicate resources that yield sustainable competitive advantages when properly integrated (Komakech et al., 2025).

Several studies highlight the benefits of *integrating these three core activities*: transportation, procurement, and inventory management. For instance, (SAMITA et al., 2020) demonstrated that integrating these operations improves supply chain reliability during demand fluctuations and transportation disruptions, as supply and inventory adjustments can be rapidly synchronized with demand changes. Similarly, (Kantari et al., 2022) proposed an integrated model that mitigates disruption risks through flexible inventory rotation and adaptable transportation sourcing (spot vs. long-term contracts). From a cost optimization perspective (Gupta et al., 2022) showed that a multi-objective model simultaneously optimizing procurement, inventory, and transportation costs reduced total supply chain costs by up to 15% compared to optimizing each function individually. Furthermore, a System Dynamics simulation by (Wilson, 2007) revealed that integrating inventory, procurement, and transportation management yields 30% greater stability in inventory and delivery fluctuations under disruptive conditions.

Collectively, academic evidence and practical applications consistently demonstrate that Procurement, Inventory Management, and Transportation are indeed the three principal supply chain operations due to their:

1. **Comprehensiveness:** They encompass the core SCOR processes (Source, Plan, Deliver).
2. **Essentiality:** They are identified as indispensable functional areas in every supply chain.
3. **Integrative Potential:** Research shows that simultaneous optimization of these three activities delivers superior overall effectiveness.
4. **Holistic Coverage:** These activities ensure a continuous flow from supply sources to the end customer, aligning with the fundamental objectives of supply chain management.

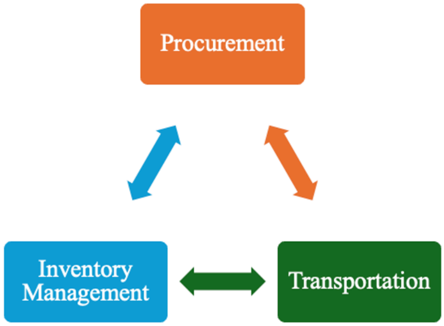

Fig 1. Three main supply chain operations

2.2.4 Supply Chain Resilience Elements

In this section, to concisely present the constituent elements of supply chain resilience, this study focuses on reviewing Systematic Literature Review researches on the Capabilities and Performance Metrics of supply chain resilience that have been validated and ranked Q1 and Q2 by Scimago/Scopus (**Appendix A**). With a sample of 62 research papers identified and cited from a total of 6 literature reviews (**Appendix A**), the analysis results are as follows:

Table 1. Summary of the occurrence rates of the supply chain resilience elements

Element	Occurrence	Occurrence Rate (Estimated)
Diversification/Redundancy	53	85%
Collaboration	48	78%
Recovery	43	70%
Adaptability	43	70%
Visibility	35	57%
Anticipation	32	52%
Other elements (Security, Leadership, Innovation…)	15 (Max)	24%

The occurrence rates are estimated; however, despite being derived from a large sample, they do not encompass all existing studies. The details of the elements that constitute supply chain resilience from the perspective of the studies are presented in **Appendix B. Appendix B** summarizes the statistical results of elements constituting supply chain resilience, citing authors from 6 literature reviews studies in **Appendix A.**

These 6 highest occurrence rate constituent elements of supply chain resilience do not exist in isolation but are intricately linked and mutually supportive. The six aforementioned factors encompass all three phases of Supply Chain Resilience (SCR): Pre-disruption (Readiness), During-disruption (Response), and Post-disruption (Recovery). This ensures the comprehensiveness and holistic nature of the supply chain resilience measurement scale. Therefore, this research proposes 6 main constituent elements of supply chain resilience, including: *Diversification/Redundancy, Collaboration, Recovery, Adaptability, Visibility, Anticipation.*

2.2.5 Artificial Intelligence Adoption

AI adoption in supply chains refers to the implementation and utilization of artificial intelligence technologies, including machine learning, predictive analytics, natural language processing, and autonomous systems, to enhance supply chain decision-making, optimization, and performance.

From a contingency theory perspective, AI adoption represents a critical technological capability that influences how organizations sense, interpret, and respond to supply chain risks and disruptions. AI enables more sophisticated risk prediction, real-time monitoring, automated decision-making, and adaptive responses to changing conditions.

2.3 Theoretical Model Development

The integrated theoretical model draws upon the three theoretical foundations to explain the complex relationships among constructs:

RBV Foundation: Supply chain activities (procurement, transportation, inventory management) represent strategic resources that contribute to competitive advantage and resilience. Organizations with superior capabilities in these areas are better positioned to withstand and recover from disruptions.

DCT Foundation: The relationships between risks/disruptions and operational performance, and between operational performance and resilience, are dynamic and context-dependent. Organizations must continuously adapt and reconfigure their capabilities in response to changing conditions.

Contingency Theory Foundation: AI adoption serves as a critical contingency factor that moderates the strength and effectiveness of supply chain relationships. Organizations with advanced AI capabilities can better leverage their operational resources and respond more effectively to risks and disruptions.

2.4. Overview of relevant studies and research gaps

Based on the selected research, the next step is analyzing the impacts of categorized risks and disruptions on aspects of the three main activities.

Procurement is directly vulnerable to risks and disruptions, with supply risk significantly impacting performance. Supply shortages, lead time increases, and diminished supplier reliability stemming from events like natural disasters, geopolitical conflicts, or supplier failures necessitate constant adaptation. Macroeconomic factors also increase supplier risk (Louis & Pagell, 2019). Consequently, procurement faces price volatility and increased costs from sourcing alternatives or expedited shipping , alongside higher operating expenses from managing these crises.

Transportation experiences substantial impacts on routes, capacity, and costs. Disruptions due to natural disasters, geopolitical conflicts, or port congestion severely impact schedules and increase transit times. These events also constrain transport capacity (e.g., equipment or labor shortages) and limit infrastructure capabilities. Cost increases are inevitable, driven by fluctuating fuel prices, higher freight rates due to capacity shortfalls, and incidental expenses like demurrage and insurance. Furthermore, prolonged transit or re-routing increases the risk of goods damage, loss, or theft (Gordon, 2023).

Inventory Management is challenged by both excess and insufficient stock. Disruptions in supply or transportation can lead to stockouts if safety stock is inadequate, while sudden demand drops or forecasting errors cause excess inventory. Proactive "just-in-case" stockpiling can also result in surplus (Kilpatrick et al., 2025). These issues translate into higher holding costs due to increased storage needs, tied-up capital, and higher insurance. Forecasting and planning become more complex and less reliable amidst high volatility.

Fig 2 illustrates the impact of risks and disruptions on individual supply chain resilience elements. The specific effects are presented in detail in the **Table 2**.

Table 2. Detail Impacts of Risks and Disruptions on 6 Supply Chain Resilience Elements

Element	Impact
Diversification/ Redundancy	*Ripple effect*: Geopolitical tensions and abrupt trade policy shifts in developing sourcing hubs create cascading disruptions that propagate through supply networks. These ripple effects counteract diversification benefits by simultaneously impacting multiple alternative sourcing locations, particularly when regional clusters share similar risk exposures (Ivanov, 2020).
Collaboration	*Ripple effect:* Disruptions propagate through tightly linked supply chain nodes, from raw material suppliers to manufacturers, distributors, and retailers. A disruption in one part of the chain can trigger ripple effects throughout the entire network, thereby diminish the firm's coordinated capability (Christopher & Peck, 2004).
Recovery	– *Reduced Operational Continuity:* When disruptions such as natural disasters, pandemics, or industrial disputes, terrorism…the flow of materials and products becomes constrained, leading to delivery delays and production process interruptions. This forces businesses to activate contingency plans, incurring costs and prolonging recovery times (Christopher & Peck, 2004).

	– *Increased recovery costs:* Supply chain disruptions are typically accompanied by high recovery expenses, including buffer inventory costs, transportation mode modifications, production capacity restoration, and partner compensation. Research by (Hendricks & Singhal, 2005) demonstrates that disruption events can reduce a firm's expected profits and cause prolonged stock losses of 33%–40%. – *Increased management and insurance costs*: To mitigate risks, enterprises must invest in insurance premiums and safety stock buffers., elevating fixed costs and reducing resources allocated for post-disruption recovery activities (McKINNON, 2014). – *Disruption tails:* the backlog of orders and delayed deliveries that persist after the main disruption has ended, can continue to destabilize supply chains and significantly prolong the recovery period. This effect leads to excessive inventory accumulation and resource misallocation, impeding a quick return to normal operations (Ivanov & Rozhkov, 2019)
Adaptability	– *Limitation of flexibility and adaptability:* Structural risks, such as dependence on a single supplier or facilities, can reduce flexibility in switching to alternative sources and prolong recovery time after a disruption (Ivanov & Dolgui, 2021). – *Increased internal vulnerability:* When risks such as material price volatility or market fluctuations occur, the sensitivity of production and distribution processes intensifies, diminishing the firm's endurance capacity (Pettit et al., 2019).
Visibility	– *Reduce real-time visibility capabilities:* Natural disasters, labor-related, or technical failures can delay shipment status updates. This latency cascades into delayed alert systems and compromised response agility (Mubarik et al., 2021). – *Critical IT infrastructure failures:* IT infrastructure compromised by power outages or network failures interrupts data flow between partners, diminishing inter-organizational information integration capabilities (Mubarik et al., 2021). – *Failures in automatic identification and data capture (AIDC) components:* Malfunctioning sensors or AIDC devices degrade automated collection processes, necessitating a reversion to less efficient manual methods (Mubarik et al., 2021).
Anticipation	*Reduced forecasting and preparation effectiveness:* High-uncertainty risks diminish visibility in the supply chain, thereby impairing early detection capabilities and corresponding planning efforts (Aigbogun et al., 2022).

In summary, supply chain risks and disruptions create a network of negative impacts, not only directly affecting resilience factors but also through ripple effects, increasing costs and reducing the overall responsiveness of the supply chain.

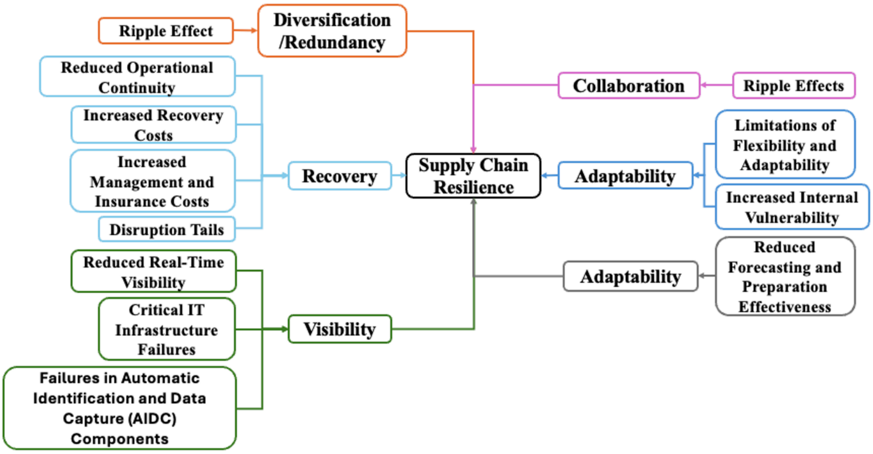

Fig 2. Impact of Risks and Disruptions on 6 Supply Chain Resilience Elements

It is evident that many studies have explored the impact of risk on supply and elements of resilient supply chains. However, several limitations are noted:

(1) **Lack of Integration:** Most studies examine isolated relationships (e.g., supply risk to procurement performance, to suppliers, inventory operations...) instead of a holistic model combining various operations (procurement, transportation, inventory management) and supply chain resilience.
(2) **Unclear Mediating Role:** The mechanism through which risk impacts resilience via the performance of specific operations has not been fully elucidated within a single framework.
(3) **Lack of Integrated Theoretical Models on the Moderating Role of AI:** The role of Artificial Intelligence (AI) in altering (enhancing or diminishing) the intensity of relationships within the supply chain has not yet been integrally assessed.

This research aims to address these gaps by proposing a multivariate structural model, focusing on the mediating role of procurement, transportation, and inventory management performance, as well as the moderating role of AI in mitigating the impact of risk and enhancing resilience through the aforementioned activities performance.

3. HYPOTHESIS DEVELOPMENT AND PROPOSED RESEARCH FRAMEWORK

3.1. Direct Effects of Risks and Disruption's Impact on three main operations

3.1.1 Theoretical Foundation

The relationship between supply chain risks/disruptions and operational performance is grounded in Resource-Based View and Dynamic Capabilities Theory. From an RBV perspective, risks and disruptions threaten the value-creating potential of supply chain resources by introducing uncertainty, constraining resource availability, and forcing suboptimal resource allocation . DCT explains how these threats challenge organizations' dynamic capabilities, requiring rapid sensing, seizing, and transforming responses that may temporarily reduce operational efficiency.

3.1.2 Risk/Disruption Effects on Procurement Performance

Supply chain risks and disruptions significantly impact procurement performance through multiple mechanisms. Environmental risks such as natural disasters and geopolitical tensions can simultaneously affect multiple suppliers, reducing supply base diversity and forcing procurement teams to seek alternative sources at higher costs . Network risks including supplier failures and quality issues directly compromise procurement effectiveness by disrupting established relationships and forcing emergency sourcing decisions.

From a dynamic capabilities perspective, procurement teams must rapidly reconfigure their supplier networks, develop new relationships, and establish alternative sourcing strategies in response to risks and disruptions. This reconfiguration process, while necessary for long-term resilience, typically involves higher transaction costs, longer lead times, and reduced operational efficiency in the short term.

H1: Supply chain risks and disruptions negatively impact procurement performance.

3.1.3 Risk/Disruption Effects on Transportation Performance

Transportation systems are particularly vulnerable to supply chain risks and disruptions due to their dependence on infrastructure, regulatory environments, and interconnected networks . Environmental risks such as natural disasters can simultaneously affect multiple transportation routes, ports, and distribution centers, forcing carriers to use longer, more expensive alternatives.

The transportation network's complexity creates cascading effects where disruptions in one area propagate throughout the system. From a systems perspective, transportation performance degrades as the network attempts to maintain service levels while operating with reduced capacity and increased uncertainty. Dynamic capabilities theory explains how transportation providers must rapidly sense disruptions, seize alternative routing opportunities, and transform their operations to maintain service levels, often at reduced efficiency.

H2: Supply chain risks and disruptions negatively impact transportation performance.

3.1.4 Risk/Disruption Effects on Inventory Management Performance

Inventory management performance suffers during risks and disruptions due to increased demand uncertainty, supply variability, and the need for higher safety stock levels . Environmental risks create uncertainty about future supply availability, forcing inventory managers to increase stock levels as insurance against potential shortages. Network risks disrupt established replenishment patterns, requiring more frequent expediting and emergency orders.

From a resource-based perspective, inventory represents a critical resource that must be strategically positioned to maintain service levels while minimizing costs. Risks and disruptions force suboptimal inventory allocation decisions, typically resulting in either excess inventory (increasing holding costs) or stockouts (reducing service levels). Dynamic capabilities theory explains how inventory managers must continuously adjust their strategies in response to changing risk profiles, often at the expense of short-term efficiency.

H3: Supply chain risks and disruptions negatively impact inventory management performance.

3.2. Three main Operations Performance's Impact on Supply Chain Resilience

3.2.1 Theoretical Foundation

The relationship between operational performance and supply chain resilience is grounded in both Resource-Based View and Dynamic Capabilities Theory. RBV explains how superior operational capabilities serve as valuable resources that can be leveraged to build resilience . DCT explains how effective operational performance provides the foundation for developing higher-order resilience capabilities.

3.2.2 Procurement Performance and Resilience

Effective procurement performance contributes to supply chain resilience through multiple pathways. Superior procurement capabilities enable organizations to develop diversified supplier bases, establish strong collaborative relationships, and maintain visibility into supplier operations – all critical elements of supply chain resilience.

From a dynamic capabilities perspective, effective procurement provides the sensing capabilities needed for early risk detection through supplier monitoring and market intelligence. Strong supplier relationships enable collaborative problem-solving during disruptions, while diversified supplier bases provide the redundancy needed for rapid recovery . These procurement capabilities directly support the resilience elements of diversification, collaboration, visibility, and anticipation.

H4: Procurement performance positively impacts supply chain resilience.

3.2.3 Transportation Performance and Resilience

Transportation performance contributes to supply chain resilience by providing the connectivity and flexibility needed to maintain operations during disruptions. Effective transportation capabilities enable organizations to rapidly reroute shipments, access alternative suppliers, and redistribute inventory in response to disruptions.

From a network perspective, transportation performance provides the adaptive capacity needed to reconfigure supply chain flows when primary routes are disrupted. Superior transportation capabilities support resilience elements including adaptability (through flexible routing), recovery (through rapid restoration of flows), and collaboration (through coordinated logistics planning with partners).

H5: Transportation performance positively impacts supply chain resilience.

3.2.4 Inventory Management Performance and Resilience

Inventory management performance contributes to resilience by providing buffers against uncertainty and enabling rapid response to demand changes . Effective inventory management creates strategic stockpiles that can be deployed during disruptions, while advanced forecasting capabilities enable proactive adjustment to changing conditions.

From a dynamic capabilities perspective, inventory management provides the absorptive capacity needed to buffer against disruptions while maintaining service levels. Strategic inventory positioning enables rapid recovery by ensuring product availability during supply disruptions, while demand forecasting capabilities support the anticipation element of resilience.

H6: Inventory management performance positively impacts supply chain resilience.

3.3. Direct Effects of Risks and Disruptions on Supply Chain Resilience

3.3.1 Theoretical Foundation

While operational activities mediate much of the relationship between risks/disruptions and resilience, direct effects also exist. From a systems perspective, severe disruptions can overwhelm organizational adaptive capacity regardless of operational performance levels. Dynamic capabilities theory explains how extreme disruptions can exceed organizations' sensing, seizing, and transforming capabilities, directly undermining resilience.

3.3.2 Direct Resilience Impact

Supply chain risks and disruptions can directly impact resilience through several mechanisms that bypass operational performance. Catastrophic disruptions may simultaneously affect multiple operational activities, creating system-wide failures that overwhelm adaptive capacity. Cascading failures can propagate through interconnected networks faster than organizations can respond, directly undermining resilience elements such as recovery and adaptability.

H7: Supply chain risks and disruptions negatively impact supply chain resilience.

3.4. AI's Moderating Role

3.4.1 Theoretical Foundation

The moderating role of AI adoption is grounded in Contingency Theory, which explains how technological capabilities influence the effectiveness of organizational practices . AI adoption represents a critical contingency factor that enhances organizations' ability to sense environmental changes, process complex information, and respond adaptively to disruptions.

3.4.2 AI Moderation of Risk-Operations Relationships

AI adoption moderates the negative impact of risks and disruptions on operational performance through enhanced sensing, prediction, and response capabilities. AI-powered systems can process vast amounts of data to identify early warning signals, predict potential disruptions, and recommend proactive mitigation strategies.

For procurement, AI enhances supplier risk assessment, enables predictive supplier performance modeling, and automates contingency planning (Bhonsle & Sawhney, 2025). For transportation, AI optimizes routing in real-time, predicts capacity constraints, and enables dynamic adjustment to changing conditions (K., 2024). For inventory management, AI improves demand forecasting accuracy, optimizes safety stock levels, and enables dynamic replenishment strategies (Cohen & Tang, 2024).

From a contingency theory perspective, organizations with advanced AI capabilities are better equipped to maintain operational performance during risks and disruptions because AI enhances their adaptive capacity and decision-making speed.

H8: AI adoption moderates (reduces) the negative impact of supply chain risks and disruptions on procurement performance.
H9: AI adoption moderates (reduces) the negative impact of supply chain risks and disruptions on transportation performance.
H10: AI adoption moderates (reduces) the negative impact of supply chain risks and disruptions on inventory management performance.

3.4.3 AI Moderation of Operations-Resilience Relationships

AI adoption also moderates the positive relationship between operational performance and supply chain resilience by amplifying the resilience-building effects of superior operational capabilities. AI enables organizations to more effectively leverage their operational strengths to build resilience.

AI enhances the translation of operational performance into resilience outcomes through improved coordination, information sharing, and adaptive capacity. AI-powered systems enable real-time visibility across supply chain networks, facilitate collaborative planning and response, and support rapid reconfiguration of operations during disruptions.

From a dynamic capabilities perspective, AI enhances organizations' ability to sense disruption signals, seize opportunities for improvement, and transform their operations to build resilience. Organizations with both superior operational performance and advanced AI capabilities can more effectively build and maintain resilience.

H11: AI adoption moderates (enhances) the positive impact of procurement performance on supply chain resilience.
H12: AI adoption moderates (enhances) the positive impact of transportation performance on supply chain resilience.
H13: AI adoption moderates (enhances) the positive impact of inventory management performance on supply chain resilience.

4. INTEGRATED CONCEPTUAL MODEL

Fig 3 presents the proposed integrated conceptual model. Within this framework, supply chain disruptions and risks are measured based on a classification of three origins of risk and disruption including *Environmental risks, Network risks, and Organizational risks.* Meanwhile supply chain resilience is measured based on six main constituent elements of supply chain resilience, including *Diversification/Redundancy, Collaboration, Recovery, Adaptability, Visibility, and Anticipation* both directly and through the mediating mechanisms of procurement, transportation, and inventory management performance, with AI adoption serving as a critical moderating factor.

While risk and disruption are conceptually distinct, they are causally intertwined. Given that their downstream impacts on the variables of interest are congruent within this study's framework, the authors have operationalized risk and disruption as a unified research variable. This approach suggests that the findings hold true for instances of either supply chain risk or disruption.

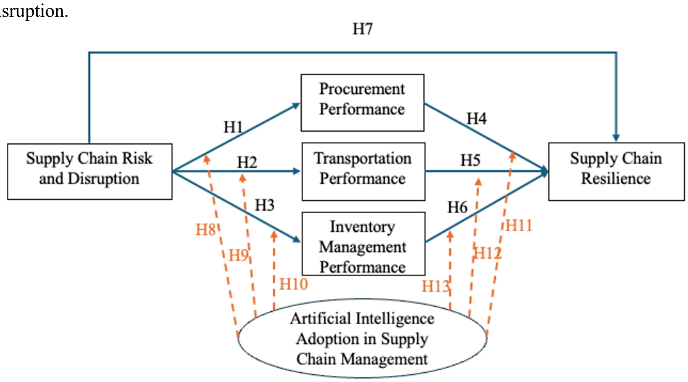

Fig 3. Proposed integrated conceptual model

The model advances existing theory by:

1. Providing theoretical clarity between supply chain risk and disruption as distinct but related constructs
2. Explaining mediating mechanisms through which risks/disruptions affect resilience via operational performance
3. Establishing the moderating role of AI adoption in both risk-performance and performance-resilience relationships
4. Integrating multiple theoretical perspectives (RBV, DCT, CT) into a coherent framework
5. Offering testable propositions for future empirical validation

5. CONCLUSION AND IMPLICATIONS

5.1 Theoretical Contributions

This research makes several significant theoretical contributions to the supply chain management literature. First, it provides much-needed conceptual clarity by distinguishing between supply chain risk and supply chain disruption as related but distinct constructs, addressing a long-standing source of confusion in the literature.

Second, the research advances understanding of the mechanisms through which risks and disruptions affect supply chain resilience by identifying procurement, transportation, and inventory management as critical mediating activities. This contribution moves beyond approaches that characterize much of the existing literature.

Third, the research provides comprehensive theoretical justification for AI's moderating role in supply chain relationships, grounded in established management theories rather than purely technological perspectives.

5.2 Practical Implications

The theoretical framework provides several actionable insights for practitioners. Managers should recognize that building supply chain resilience requires simultaneous attention to multiple operational activities, not just isolated risk management efforts. The framework suggests that organizations should invest in AI capabilities as a means of enhancing both risk mitigation and resilience building efforts.

The distinction between risk and disruption has practical implications for management approaches, with risks requiring proactive prevention strategies and disruptions requiring reactive response capabilities. Organizations should develop differentiated capabilities for managing both scenarios.

5.3 Future Research Directions

This theoretical foundation establishes the groundwork for extensive empirical research. Future studies should test the proposed relationships across different industries and contexts, examine boundary conditions for the theorized effects, and explore additional moderating factors that may influence these relationships.

The framework also opens opportunities for investigating the dynamic aspects of resilience building, examining how organizations develop and maintain resilience capabilities over time, and exploring the role of learning and adaptation in resilience development.

5.4 Limitations

As a theoretical contribution, this research has inherent limitations. The proposed model requires empirical validation to establish the strength and significance of the theorized relationships. The focus on three operational activities, while theoretically justified, may not capture the full complexity of supply chain operations. The moderating role of AI may be more nuanced than the linear relationships proposed in the model.

Despite these limitations, this research provides a solid theoretical foundation for advancing understanding of supply chain resilience in the digital age and offers a roadmap for future empirical research that can validate and refine these theoretical propositions.

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Appendix A. Systematic Literature Reviews on Supply Chain Resilience

Tiltle	**Publication**	**Total citations**	**Authors**	**Number of research works**
Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation	International Journal of Physical Distribution & Logistics Management	696	(Hohenstein et al., 2015)	67
A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research	International Journal of Production Economics	772	(Kamalahmadi & Parast, 2016)	100
Supply chain resilience: a systematic literature review and typological framework	International Journal of Physical Distribution & Logistics Management	304	(Kochan & Nowicki, 2018)	383
A Systematic Literature Review of the Capabilities and Performance	International Journal of Production Research	208	(Han et al., 2020)	153
Supply chain resilience and key performance indicators: a systematic literature review	Production	105	(Karl et al., 2018)	57
Systematic Literature Reviews in Supply chain resilience: A Systematic Literature Review	Annual International Conference on Industrial Engineering and Operations Management	9	(Simbizi et al., 2021)	17 systematic literature reviews

Appendix B. The constituent elements of Supply Chain Resilience

Supply chain resilience element	**Diversification /Redundancy**	**Collaboration**	**Adaptability**	**Recovery**	**Visibility**	**Anticipation**	Security	Leadership	Innovation	Supply chain structure	Complexity
Number of articles	53	48	43	43	35	32	15	4	4	2	1
Rice and Caniato (2003)	x	x	x	x	x	x	x				
Christopher and Peck (2004)	x	x	x	x	x	x	x				
Sheffi and Rice (2005)	x	x	x	x	x	x					
Ponomarov and Holcomb (2009)	x	x	x	x	x	x					
Pereira (2009)	x	x	x		x						
Williams et al. (2009)	x			x		x	x				
Oke and Gopalakrishnan (2009)	x		x			x					
Zsidisin and Wagner (2010)	x	x	x			x					
Dowty and Wallace (2010)		x									
Blackhurst et al. (2011)	x	x	x	x	x						

Stavros T. Ponis et Epaminondas Koronis (2012)	x	x	x	x	x	x				x	
Zhu and Ruth (2013)		x	x								
Talluri et al. (2013)	x		x		x						
Funo et al. (2013)		x		x	x						
Pettit et al. (2013)	x	x	x	x	x	x					
Boone et al. (2013)	x			x							
Wu et al. (2013)	x	x		x		x					
Christopher and Silva (2014)	x	x	x	x	x	x					
Urciuoli et al. (2014)	x	x		x	x		x				
Scholten et al. (2014)	x	x	x	x		x	x				
Peng et al. (2014)	x	x	x								
Soni et al. (2014)		x	x	x	x						
Roberta Pereira et al. (2014)	x	x	x	x	x	x					
Brandon-Jones et al. (2014)		x			x						
Cedillo-Campos et al. (2014)			x				x				
Scholten and Schilder (2015)	x	x	x		x	x					
Scavarda et al. (2015)	x	x	x		x						
Hohenstein et al. (2015)	x	x	x	x	x	x					
Ambulkar et al. (2015)	x	x		x							
Tukamuhabwa et al. (2015)	x	x	x	x	x	x	x		x		
Boyes (2015)							x				
Rajesh and Ravi (2015)	x	x	x	x	x	x	x				
Manning and Soon (2016)	x		x	x							
Kamalahmadi et Parast (2016)	x	x	x	x	x	x		x	x		
Wang et al. (2016)	x		x			x	x				
Ivanov et al. (2016)	x				x						
Rajesh (2016)		x			x						
Eltantawy (2016)	x	x		x		x					
Lam and Bai (2016)	x		x		x		x				
Tukamuhabwa, Stevenson and Busby (2017)	x	x	x	x	x	x					
Birkie, Trucco and Campos (2017)	x	x		x		x					
A. Ali et al. (2017)	x	x	x	x	x	x	x				
Datta (2017)	x	x	x			x				x	x
Trucco and Campos (2017)	x	x		x		x					
Cheng and Lu (2017)		x		x							
Kamalahmadi and Parast (2017)	x	x	x	x	x						
Sahu et al. (2017)	x	x	x	x	x	x					
Brusset and Teller (2017)	x		x	x							
Linnenluecke (2017)	x	x									
Stone and Rahimifard (2018)	x	x	x	x	x	x	x	x			
Adobor and McMullen (2018)	x	x	x	x				x			
Kochan et Nowicki (2018)	x	x	x	x	x		x				
Pires Ribeiro et Barbosa-Povoa (2018)	x			x		x					
Tan, Cai and Zhang (2019)	x			x							
Abeysekara, Wang and Kuruppuarachchi (2019)	x	x	x	x							
Vlajic, Vorst and Dragan (2019)	x	x		x							
Costa et al. (2019)	x	x	x	x	x				x		
Shin et Park (2019)	x	x	x	x	x	x	x				
I. Ali et Ismail (2019)	x	x	x		x	x			x		
Gligor, Gligor, et al. (2019)	x		x	x							
Hosseini et al. (2019)	x	x	x	x	x	x					
Han et al. (2020)	x	x	x	x	x	x	x	x			