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AI Meets Supply Chain Management: A Conceptual Framework for Intelligent and Adaptive Supply Chains

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Abstract

Artificial intelligence (AI) is increasingly recognized as a transformative force in supply chain management (SCM). However, existing studies often treat AI as a supporting tool rather than a core element of supply chain intelligence. This paper adopts a conceptual perspective to explore how the integration of AI fundamentally reshapes SCM. We propose a conceptual framework in which AI is embedded as the central intelligence enabling perception, learning, reasoning, and adaptation across supply chain processes. The framework illustrates the interaction between data ecosystems, AI-driven decision-making, and supply chain operations, highlighting continuous learning as a defining characteristic of intelligent supply chains. The framework conceptualizes AI as a learning and reasoning core that continuously transforms data into adaptive decisions across planning, coordination, and execution. By focusing on adaptability rather than technological implementation, this study advances a systems-level understanding of how AI redefines supply chain management and supports resilience in complex environments. The framework provides a theoretical basis for understanding how AI-enabled SCM can support long-term sustainable supply chain development. By reconceptualizing SCM as an adaptive and cognitive system, this study provides a theoretical foundation for future empirical and analytical research on AI-enabled supply chains.

Keywords: Artificial Intelligence, Cognitive Supply Chains, Intelligent Systems, Supply Chain Management, Conceptual Framework

1. Introduction

Supply Chain Management (SCM) plays a critical role in coordinating material, information, and financial flows across interconnected organizations. Classical SCM literature emphasizes efficiency, cost reduction, and synchronization across sourcing, production, and distribution activities, often relying on static planning cycles and rule-based decision-making (An *et al*., 2026) [1]. While these approaches have proven effective in relatively stable environments, recent global disruptions, market volatility, and increasing sustainability pressures have exposed fundamental limitations of traditional SCM practices.

In response to these challenges, artificial intelligence (AI) has received growing attention in both academic research and industrial applications within supply chain contexts. Prior studies indicate that AI can improve demand forecasting accuracy, optimize logistics operations, and enhance decision-making under uncertainty (Singh *et al*., 2026) [2]. However, the majority of existing research conceptualizes AI as a supporting technology applied to isolated supply chain functions, rather than as an integrated intelligence that reshapes supply chain management as a whole. Consequently, the systemic role of AI within SCM remains insufficiently theorized.

Recent contributions in management and information systems research argue that AI should be understood not merely as a technological tool, but as a form of embedded intelligence capable of learning, reasoning, and adaptation within organizational systems (Ghahri *et al*., 2026) [3]. From this perspective, AI has the potential to transform how supply chains perceive environmental changes, coordinate decisions, and respond to disruptions. Nevertheless, SCM theory has yet to fully incorporate this intelligence-centered view into coherent conceptual models.

Furthermore, adaptability and resilience have emerged as critical dimensions of contemporary supply chain performance. Studies on supply chain resilience emphasize the importance of continuous adjustment and learning in the face of uncertainty

(Jayasinghe *et al*., 2005) [4]. Despite this growing focus, the conceptual linkage between AI-enabled intelligence and adaptive supply chain capabilities remains fragmented, with limited frameworks explaining how learning-oriented decision-making is embedded within SCM.

To address this gap, this paper adopts a purely conceptual approach to examine the convergence of artificial intelligence and supply chain management. Drawing on systems-based perspectives and principles of theoretical contribution (Etxeberria *et al*., 2026) [5], we propose a conceptual framework that positions AI as the core intelligence embedded within SCM. The proposed framework reconceptualizes supply chains as intelligent and adaptive systems capable of continuous learning and evolution, thereby providing a theoretical foundation for future empirical and analytical research on AI-enabled supply chains.

2. Background

Supply Chain Management (SCM) has long been recognized as a critical managerial discipline concerned with the coordination of material, information, and financial flows across organizational boundaries. Early SCM research emphasizes integration, efficiency, and coordination among supply chain partners (Kulkarni, 2023) [6]. Traditional SCM frameworks are largely built on deterministic planning, linear optimization, and periodic decision cycles, aiming to minimize cost and improve service levels. While effective in stable environments, these approaches face significant challenges when supply chains operate under high uncertainty and complexity. Despite its managerial importance, traditional SCM has been criticized for its limited ability to cope with uncertainty and disruptions. Conventional planning-based approaches often rely on historical data and predefined rules, making them reactive rather than adaptive. Such limitations have become increasingly evident in the face of global disruptions, where supply chains require rapid sensing, learning, and response capabilities beyond the scope of traditional SCM models. The digital transformation of supply chains has introduced new data sources, platforms, and analytical capabilities. Technologies such as IoT, cloud computing, and big data analytics have enhanced visibility and connectivity across supply chain networks. However, digitalization alone does not guarantee intelligent decision-making. Without embedded intelligence, digital supply chains remain data-rich but insight-poor, highlighting the need for more advanced decision-support mechanisms. Artificial intelligence has emerged as a promising technology for addressing complex decision-making problems in SCM. Early studies demonstrate the potential of AI techniques in areas such as demand forecasting, scheduling, and logistics optimization. More recent research further emphasizes the role of AI and analytics in enhancing supply chain performance (Hove-Sibanda, P., & Pooe, 2018) [7]. Nevertheless, much of this literature focuses on functional applications rather than the conceptual integration of AI within SCM as a holistic system. Beyond its technical applications, AI is increasingly conceptualized as embedded intelligence within organizational systems. Management scholars argue that AI enables systems to learn, reason, and adapt, fundamentally altering decision-making processes. This perspective suggests that AI should not be viewed merely as a tool, but as a cognitive capability integrated into organizational structures. However, SCM theory has yet to fully embrace this intelligence-centric view. The concept of cognitive or intelligent supply chains has gained traction in recent years. These supply chains are characterized by their ability to sense environmental changes, interpret data, and autonomously adjust decisions. While this notion aligns closely with advances in AI, existing studies often lack a clear conceptual framework explaining how intelligence is embedded across supply chain layers, from data acquisition to operational execution. Adaptability and resilience have become central themes in contemporary SCM research. Resilient supply chains are designed not only to withstand disruptions but also to recover and adapt through learning mechanisms. Scholars emphasize that adaptability requires dynamic decision-making and continuous feedback, capabilities that traditional SCM approaches struggle to support. SCM is increasingly viewed through the lens of systems thinking, recognizing supply chains as complex socio-technical systems involving people, processes, and technologies. From this perspective, isolated optimization of individual components is insufficient. Instead, intelligence must be embedded across the system to enable coordination, learning, and adaptation. This view provides a theoretical foundation for integrating AI into SCM at a conceptual level. Conceptual frameworks play a crucial role in advancing theory by organizing key constructs and clarifying their relationships. In management research, conceptual contributions are valued for their ability to offer new perspectives and guide future empirical inquiry. In the context of AI and SCM, the lack of integrative conceptual frameworks limits theoretical progress and hinders the systematic understanding of AI-enabled supply chains. Although prior studies acknowledge the potential of AI to enhance supply chain performance, the literature remains fragmented and application-driven. Existing research rarely addresses how AI reshapes SCM as a system of decision-making, coordination, and adaptation (Shahzadi *et al*., 2024) [8]. Consequently, there is a clear need for a conceptual framework that explains the convergence of AI and SCM and articulates the foundations of intelligent and adaptive supply chains.

3. Literature Review

Early studies on supply chain management focus on integration and coordination across organizational boundaries. SCM is commonly defined as the management of material, information, and financial flows among firms to enhance overall performance Traditional SCM theory emphasizes efficiency, cost minimization, and synchronization through deterministic planning and control mechanisms. While these foundations remain influential, they provide limited insight into how supply chains adapt under dynamic and uncertain conditions. Several scholars highlight structural limitations in traditional SCM approaches. Rule-based planning and reliance on historical data constrain responsiveness and adaptability in volatile environments (Zhou *et al*., 2025) [9]. These limitations become particularly evident during large-scale disruptions, where predefined plans fail to accommodate unexpected events. As a result, researchers increasingly call for more adaptive and learning-oriented supply chain models. The digital transformation of supply chains has introduced new levels of connectivity and visibility. Digital supply chain research emphasizes the role of technologies such as IoT,

cloud computing, and big data analytics in improving information sharing and operational transparency. However, digitalization alone does not guarantee intelligent decision-making, as many digital supply chains remain dependent on human judgment and static decision rules. Artificial intelligence has been widely applied to specific supply chain functions. Prior studies demonstrate AI's effectiveness in demand forecasting, inventory optimization, and logistics planning. More recent reviews confirm that AI and advanced analytics can significantly improve supply chain efficiency and responsiveness (Maulana *et al*., 2026) [10]. Nevertheless, these studies primarily adopt an application-oriented perspective, offering limited conceptual integration across SCM processes. Beyond functional applications, AI is increasingly viewed as a form of organizational intelligence. Management research conceptualizes AI as an embedded capability that enhances learning, reasoning, and decision-making within organizations. Similarly, scholars argue that AI reshapes managerial processes by augmenting human cognition and enabling data-driven adaptation. This intelligence-centered view provides a valuable theoretical lens for rethinking SCM. The notion of cognitive or intelligent supply chains has gained attention in recent years. These supply chains are characterized by their ability to sense changes, analyze information, and autonomously adjust decisions. While this concept aligns closely with advances in AI, existing research often lacks a unified framework explaining how intelligence is embedded across different supply chain layers. Adaptability and resilience are increasingly recognized as essential performance dimensions in SCM. Resilient supply chains emphasize learning, flexibility, and rapid response to disruptions. Studies on resilience argue that adaptive decision-making is crucial for maintaining supply chain continuity under uncertainty. However, the mechanisms through which AI supports adaptability remain conceptually underexplored. Systems thinking has emerged as an important perspective in SCM research, recognizing supply chains as complex socio-technical systems. This view highlights the interdependence of actors, processes, and technologies, suggesting that isolated optimization is insufficient. Embedding intelligence at the system level is therefore critical for achieving coordinated and adaptive supply chain behavior. Conceptual frameworks play a central role in advancing theory by clarifying constructs and their relationships. In management research, conceptual contributions are valued for their ability to organize fragmented knowledge and guide future empirical inquiry. In the context of AI and SCM, the absence of integrative conceptual frameworks limits theoretical progress and hinders a holistic understanding of intelligent supply chains. Despite extensive research on AI applications in SCM, the literature remains fragmented across functional and technological silos. Existing studies rarely address how AI reshapes SCM as an integrated system of decision-making, coordination, and adaptation. Consequently, there is a clear gap in conceptual research that explains the convergence of AI and SCM and articulates the foundations of intelligent and adaptive supply chains.

4. Analysis and Discussion

The proposed framework reframes supply chain management from a flow-oriented coordination mechanism into an intelligent system capable of perception, learning, and adaptation. Classical SCM emphasizes integration and efficiency through planning and control (Ahmed *et al*., 2025) [11]. By embedding AI as a core intelligence, SCM is conceptually transformed into a system that continuously interprets environmental signals and adjusts decisions, aligning with emerging views of cognitive and intelligent supply chains. A key analytical distinction emerging from this study is between AI as a tool and AI as embedded intelligence. Prior research largely focuses on AI applications in isolated SCM functions. In contrast, the proposed framework conceptualizes AI as structurally embedded within SCM, shaping decision-making processes across strategic, tactical, and operational levels. This shift has significant theoretical implications, as it positions AI as an integral component of SCM rather than an external support mechanism. Decision-making represents the central mechanism through which AI reshapes supply chain management. Traditional SCM decisions are typically periodic and deterministic, relying on historical data and predefined rules. The framework suggests that AI enables a transition toward continuous, learning-based decision-making, where plans are dynamically updated in response to real-time data. This aligns with organizational intelligence perspectives emphasizing adaptive and data-driven managerial processes. Continuous learning emerges as a defining characteristic of intelligent and adaptive supply chains. Resilience research highlights learning as a critical capability for responding to disruptions. The proposed framework extends this view by positioning AI as the mechanism through which learning is institutionalized within SCM. Rather than relying on post-event adjustments, intelligent supply chains continuously refine decisions through feedback and adaptation. From a systems thinking perspective, SCM involves complex interactions among multiple actors, processes, and technologies. The framework highlights that embedding AI at the system level enhances coordination across supply chain functions. Intelligence is not confined to individual nodes but distributed across the network, enabling synchronized and coherent decision-making. This systems-level integration represents a significant departure from fragmented optimization approaches. Adaptability is increasingly recognized as a core performance dimension in SCM. Traditional models struggle to cope with uncertainty due to their reliance on static planning assumptions. The conceptual framework suggests that AI-enhanced learning and reasoning capabilities provide the foundation for adaptive behavior. By continuously interpreting changes in demand, supply, and environmental conditions, AI-embedded SCM enables proactive rather than reactive adaptation. The framework offers important insights into supply chain resilience. Resilience literature emphasizes the ability to withstand, recover, and adapt to disruptions. By embedding AI-driven learning and decision-making within SCM, the proposed framework conceptualizes resilience as an emergent property of intelligent supply chains. This perspective shifts resilience from a reactive capability to a continuously cultivated system attribute. From a theoretical standpoint, this study contributes by extending SCM theory toward an intelligence-centered paradigm. While prior research acknowledges the potential of AI in SCM, it often lacks integrative conceptualization (Firos & Khanum, 2026) [12]. By organizing key constructs and their relationships, the framework advances theory development in line with

criteria for strong conceptual contributions. As a purely conceptual study, the proposed framework abstracts away from specific technologies, industries, and organizational contexts. While this abstraction enhances generalizability, it also introduces boundary conditions. The effectiveness of AI-embedded SCM depends on data availability, organizational readiness, and governance structures, factors highlighted in digital supply chain research. These considerations suggest important directions for contextualized future research. The framework provides a foundation for multiple future research streams. Scholars may empirically examine the relationships between AI capabilities and supply chain performance, explore case-based implementations, or develop analytical models grounded in the proposed conceptual structure. By clarifying the role of AI as embedded intelligence, this study supports cumulative theory building in intelligent and adaptive supply chain management.

5. Conclusion and Future Works

This study set out to examine the convergence of artificial intelligence and supply chain management from a purely conceptual perspective. By positioning AI as embedded intelligence within SCM, the proposed framework advances existing theory beyond tool-based applications toward intelligent and adaptive supply chains. Consistent with prior SCM foundations the framework provides a coherent structure that supports future empirical and analytical investigations. The primary contribution of this study lies in its conceptual reframing of SCM as an intelligent system. While prior research highlights AI's operational benefits, this paper extends the literature by clarifying AI's systemic role in learning and adaptation. Future research may validate this framework through empirical studies across diverse supply chain contexts. This paper concludes that AI should be understood as embedded intelligence rather than an auxiliary technology in SCM. This perspective aligns with organizational intelligence research emphasizing learning and reasoning capabilities. Future work may explore how different levels of AI maturity influence supply chain adaptability and performance. The proposed framework conceptualizes intelligent supply chains as systems capable of continuous adaptation. This view complements resilience research highlighting learning as a key capability. Future studies may examine how AI-enabled learning mechanisms contribute to long-term supply chain resilience. By emphasizing AI-driven decision-making, this study highlights a shift from static planning to dynamic coordination in SCM. Traditional decision frameworks are extended through learning-based intelligence. Future research may investigate decision autonomy and governance in AI-enabled supply chains. In conclusion, this study provides a conceptual foundation for understanding how AI reshapes supply chain management into an intelligent and adaptive system. By embedding AI as core intelligence, the proposed framework advances SCM theory and offers a platform for future research exploring empirical validation, practical implementation, and theoretical refinement. Supply chains operate across diverse cultural and institutional contexts. Future research may explore how contextual factors influence the effectiveness of AI-embedded SCM frameworks.

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