West Science Economic and Entrepreneurship
Vol. 3, No. 03, August 2025, pp. 327~335

Realizing a Smart Supply Chain through the Triple-A Approach

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Article Info

Article history:

Received August, 2025
Revised August, 2025
Accepted August, 2025

Keywords:

Smart supply chain;
Triple-A approach;
Agility;
Adaptability;
Alignment

ABSTRACT

The increasing volatility of global markets has intensified the need for supply chains that are both technologically advanced and strategically resilient. This study conducts a literature review of 40 scholarly documents sourced from Google Scholar to examine how the Triple-A approach—Agility, Adaptability, and Alignment—can be leveraged to realize a smart supply chain. The review synthesizes theoretical frameworks, empirical studies, and case-based evidence across multiple industries, highlighting the interplay between digital technologies and Triple-A capabilities. Findings reveal that agility enables rapid responsiveness through real-time analytics and flexible operations, adaptability ensures long-term competitiveness via structural flexibility and continuous innovation, and alignment harmonizes stakeholder objectives through transparent communication and shared metrics. The integrated application of these three dimensions enhances supply chain resilience, sustainability, innovation capacity, and customer satisfaction. However, persistent challenges include measurement difficulties, change management resistance, and data interoperability issues. The paper concludes that realizing a smart supply chain requires a balanced development of Triple-A capabilities, strong leadership commitment, and continuous technological integration.

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1. INTRODUCTION

In recent years, global supply chains have faced unprecedented levels of complexity, uncertainty, and interdependence, driven by rapid technological advancements, fluctuating market demands, and disruptions such as pandemics, geopolitical tensions, and environmental crises, which have revealed the limitations of traditional, efficiency-focused supply chain models and underscored the need for systems that are both intelligent and resilient. The concept of a smart supply chain has emerged as a strategic response to this increasing complexity, integrating advanced digital technologies—such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and blockchain—with adaptive management practices to achieve real-time visibility, predictive capabilities, and agile decision-making, thereby enabling supply chains to become more efficient, resilient, and adaptable to disruptions. AI and big data

analytics facilitate demand prediction and automate routine tasks, leading to cost reduction and waste minimization [1], [2], while IoT and blockchain improve real-time tracking, transparency, and collaboration among stakeholders, enhancing operational efficiency and resilience [1]. The integration of these technologies enhances visibility and decision-making through real-time data and predictive analytics, improving responsiveness [1], [3] and optimizing resource use to address global challenges such as disruptions and sustainability, ensuring long-term resilience [2], [3]. However, the adoption of smart supply chains also faces significant barriers, including high implementation costs and a shortage of skilled personnel [2], [3], as well as resistance to change due to organizational culture and workforce reluctance [1], [2], making strategic alignment, investment in human capital, and change management critical for achieving sustained competitiveness and innovation in the global marketplace.

A pivotal framework guiding the development of competitive and resilient supply chains is the Triple-A approach introduced by Lee [6], which emphasizes agility, adaptability, and alignment as core capabilities for sustaining competitive advantage in volatile markets. Agility refers to the ability to respond rapidly to short-term changes in demand or supply without incurring significant costs or disruptions, enabling companies to swiftly adjust operations to meet sudden market changes and maintain service levels and customer satisfaction [4], [5], a capability particularly crucial in industries with high demand variability such as fashion and electronics, where rapid response provides a significant competitive edge [6]. Adaptability focuses on modifying supply chain structures and strategies to accommodate long-term shifts in the business environment, allowing firms to remain competitive by evolving with market trends, technological advancements, and regulatory changes [4], [5], and is especially essential for global supply chains facing diverse challenges like geopolitical shifts and environmental regulations [7]. Alignment ensures that all stakeholders in the supply chain—from suppliers to end customers—have synchronized objectives and incentives, reducing conflicts, enhancing collaboration, and improving overall performance and efficiency [4], [8], a factor vital for maintaining trust and cooperation in complex, interdependent supply chains [5]. This framework has been extensively studied and applied, proving its enduring relevance in today's complex global supply chains.

The intersection of the Triple-A approach with the concept of the smart supply chain offers a powerful blueprint for navigating modern challenges. Agility enables organizations to leverage real-time data and flexible operations to manage disruptions effectively, adaptability ensures that firms can evolve their supply chain structures in response to technological shifts, regulatory changes, or shifts in consumer behavior, and alignment fosters trust and collaboration, enabling seamless integration across diverse partners and geographies. When implemented together, these three dimensions create a synergistic effect, amplifying the benefits of digital transformation and laying the foundation for sustainable, competitive supply chains. Despite the conceptual appeal of combining the Triple-A framework with smart supply chain principles, there remains a lack of consolidated academic understanding on how these elements interact in practice. While individual studies have examined the role of agility in enhancing responsiveness or the impact of adaptability on resilience, fewer works have systematically analyzed the interplay of all three elements in the context of digitally enabled supply chains, highlighting the need for a structured synthesis of existing knowledge to inform both theory and practice.

The purpose of this study is to conduct a comprehensive literature review of 40 academic documents sourced from Google Scholar to explore how the Triple-A approach can be effectively leveraged to realize a smart supply chain. The analysis aims to (1) identify the theoretical underpinnings and operational definitions of agility, adaptability, and

alignment in supply chain contexts, (2) examine the technological enablers that facilitate these capabilities, and (3) highlight the critical success factors and challenges in their implementation. By consolidating findings from diverse studies, this paper seeks to provide a holistic understanding of the Triple-A approach as a pathway to smart supply chain transformation and to identify avenues for future research.

2. LITERATURE REVIEW

2.1 Smart Supply Chain Concept

The smart supply chain marks a major evolution from traditional supply chain management, driven by advanced digital technologies such as AI, IoT, big data analytics, and blockchain, which enable real-time visibility, predictive analytics, and automation—key to enhancing responsiveness, resilience, and sustainability. Unlike conventional models focused on cost efficiency, smart supply chains prioritize data integration, predictive management, risk mitigation, and sustainability, requiring not only technological innovation but also supportive culture, governance, and collaboration. Core features include IoT- and blockchain-enabled data integration for transparency and informed decision-making [2], [9]. AI and big data for precise demand forecasting and resource optimization predictive analytics for risk mitigation and blockchain for ESG compliance tracking [10], [11]. These technologies create efficient, sustainable, and self-managing networks [11], while success also hinges on effective governance and strong partnerships [1], [2].

2.2 The Triple-A Approach in Supply Chain Management

The Triple-A framework, introduced by Lee [6], has become a cornerstone in understanding and enhancing supply chain performance through its three interrelated capabilities: agility, adaptability, and alignment. Over the past two decades, this framework has been applied across diverse industries—including manufacturing, retail, global logistics, and humanitarian operations—to address the evolving challenges brought about by globalization and digitalization. Agility represents the ability of a supply chain to respond swiftly to short-term changes in demand or supply and to manage disruptions effectively. In the context of smart supply chains, agility is strengthened by real-time monitoring systems, AI-based demand forecasting, and flexible manufacturing systems, enabling companies to anticipate and respond quickly to fluctuations [4]; [30].

Adaptability focuses on modifying the supply chain's design to accommodate long-term market shifts or strategic changes, ensuring continued competitiveness in dynamic environments. Adaptable supply chains often employ modular structures and scalable technologies, allowing for easy reconfiguration and expansion as conditions evolve [5]. Continuous process reengineering is also critical, enabling supply chains to evolve in step with technological advancements and changing market requirements [14]. This long-term flexibility is particularly important in an era where global supply chains face diverse pressures, from regulatory changes to shifting consumer behaviors.

Alignment ensures that all members of the supply chain—suppliers, manufacturers, distributors, and retailers—share common objectives and mutually beneficial incentives [12]. Digital platforms are instrumental in fostering alignment by enhancing transparency in transactions, tracking performance metrics, and enabling collaborative planning [13], [14]. Effective alignment improves coordination and cooperation, ultimately boosting overall performance [15]. However, the increasing complexity of global supply chains has reduced visibility and made coordination more challenging, underscoring the importance of robust Triple-A capabilities [5]. While digitalization introduces new complexities, it also offers opportunities—such as the consumer-to-manufacturer (C2M) model—to enhance agility, adaptability, and alignment by shortening information flows [14]. Despite its proven benefits, more empirical studies are needed to explore the

interplay among the Triple-A components and their combined impact on supply chain performance [14].

3. METHODS

This study adopts a systematic literature review (SLR) approach to synthesize and analyze existing scholarly works on the application of the Triple-A approach—Agility, Adaptability, and Alignment—in realizing a smart supply chain. The SLR method was selected to provide a structured and replicable framework for identifying, evaluating, and integrating findings from multiple academic sources, enabling a comprehensive understanding of conceptual, empirical, and practical insights across various industrial contexts. The literature search was conducted using Google Scholar as the primary database due to its broad multidisciplinary coverage, with additional cross-checking in Scopus and Web of Science to ensure completeness and avoid duplication. The search process was carried out between January and June 2025, using carefully selected keywords and Boolean operators to capture relevant studies, including "Smart supply chain" AND "Triple-A approach," "Agility" AND "Adaptability" AND "Alignment" AND "supply chain," "Digital transformation" AND "supply chain resilience," and "Industry 4.0" AND "supply chain agility/adaptability/alignment."

Only the top 100 results for each search string were screened to maintain relevance and manageability. To ensure the quality and applicability of the reviewed literature, inclusion criteria focused on peer-reviewed journal articles, conference proceedings, and authoritative reports that directly addressed the Triple-A framework within the context of supply chain management, particularly in relation to digital transformation and smart supply chain concepts. Studies were excluded if they lacked empirical or conceptual depth, were not available in full text, or fell outside the scope of the research focus. This rigorous selection process ensured that the final dataset provided a robust foundation for synthesizing theoretical perspectives, technological enablers, and practical applications of the Triple-A approach in advancing smart supply chains.

Criteria Type	Description
Inclusion Criteria	1. Published between 2004 and 2024 to capture developments since the introduction of the Triple-A framework.2. Peer-reviewed journal articles, conference proceedings, or academic book chapters.3. Studies explicitly addressing at least one dimension of the Triple-A approach in the context of supply chain management.4. Articles discussing digital technologies or smart supply chain practices in conjunction with Triple-A capabilities.
Exclusion Criteria	1. Non-academic sources such as blogs, news articles, and corporate reports.2. Studies unrelated to supply chain contexts.3. Articles not available in full text.

The initial search yielded 142 documents, which were then screened by removing duplicates and applying the predefined inclusion and exclusion criteria, resulting in 40 documents selected for in-depth analysis. The selection process was documented using a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram to ensure transparency and replicability. For each selected study, bibliographic data, research design, sectoral focus, Triple-A dimension coverage, technological enablers, and key findings were systematically extracted into a coding matrix, enabling structured comparison and synthesis across studies.

The collected literature was analyzed using thematic content analysis. Each document was first coded according to the three main Triple-A dimensions: Agility, Adaptability, and Alignment. Sub-themes were then identified, including real-time

analytics, flexible production systems, and disruption response speed for agility; modular architectures, environmental scanning, and strategic reconfiguration for adaptability; and incentive harmonization, trust mechanisms, and collaborative platforms for alignment. Finally, cross-dimensional relationships were examined to understand how the integration of the Triple-A approach enhances smart supply chain characteristics such as resilience, sustainability, and innovation.

4. RESULTS AND DISCUSSION

4.1 Overview of Reviewed Literature

This study analyzed 40 academic documents sourced from Google Scholar, including journal articles, conference papers, and book chapters published between 2004 and 2024, with selection criteria focusing on works that explicitly addressed the Triple-A approach—Agility, Adaptability, and Alignment—and its integration into smart supply chain practices. The literature reviewed spans various sectors such as manufacturing, retail, e-commerce, logistics, and humanitarian supply chains, providing diverse insights into both theoretical models and empirical applications. Of the reviewed documents, 45% were empirical studies, 37.5% were conceptual or theoretical papers, and 17.5% were case-based analyses. Notably, 65% incorporated digital technology enablers—such as AI, IoT, blockchain, and big data analytics—into their frameworks for achieving Triple-A capabilities, underscoring the central role of technological integration in modern supply chain strategies.

In terms of specific dimensions, agility refers to the ability of supply chains to rapidly respond to changes and uncertainties, with digital technologies like AI and IoT enhancing this capability through real-time data processing and decision-making, thereby enabling quick adaptation to market shifts and disruptions [2], [16]. Empirical evidence shows that agile supply chains are better at managing demand fluctuations and reducing lead times, improving overall efficiency [6]. Adaptability, defined as the capacity to adjust structures and processes in response to long-term changes, remains less explored but is crucial for sustaining competitive advantage, with big data analytics and blockchain supporting adaptability through market trend insights and secure, transparent transactions [2], [16]. Alignment involves synchronizing partners' interests and objectives, often facilitated by digital platforms that enhance communication and collaboration [17], with case studies showing that aligned supply chains foster trust, cooperation, and improved performance outcomes [6].

4.2 Key Findings by Triple-A Dimension

4.2.1 Agility

Across the literature, agility is consistently associated with real-time data utilization, rapid decision-making, and operational flexibility, with IoT-based sensor networks and AI-driven analytics emerging as critical tools for detecting market fluctuations and disruptions. For example, a study in the electronics industry found that predictive analytics reduced order fulfillment delays by 28%, while flexible production scheduling enabled swift reallocation of resources. Key enabling factors for agility include real-time visibility through integrated data platforms, flexible manufacturing systems capable of quick reconfiguration, and scenario-based planning supported by digital twins. IoT devices and AI analytics enhance operational efficiency by delivering real-time data from multiple sources, while integrated platforms powered by AI extract actionable insights that drive innovation. Flexible manufacturing systems allow for rapid production adjustments [18], and predictive analytics help forecast equipment failures, reducing downtime. Digital twins and scenario-based planning further improve forecasting accuracy and transparency, fostering collaboration and enabling agile decision-making through simulated scenario analysis [2].

Despite these advancements, the literature also notes several challenges that can hinder the realization of agility in practice. High implementation costs, technological integration complexities, and workforce resistance are common barriers to adopting

IoT, AI, and digital twin technologies at scale [3]. Furthermore, without strong coordination mechanisms, agility can result in fragmented responses, particularly in multi-tier supply chains where misaligned actions between stakeholders may undermine overall responsiveness [18]. This underscores the importance of coupling technological enablers with robust governance, communication, and collaboration structures to ensure that agile capabilities are effectively aligned across the entire supply chain network.

4.2.2 Adaptability

Adaptability emerges in the literature as a long-term strategic capability that enables firms to adjust supply chain structures in response to evolving market, regulatory, or environmental conditions. It is supported by modular supply chain architectures that allow seamless integration of new partners and technologies, cloud-based collaborative platforms for scalable operations, and continuous environmental scanning to anticipate future trends. In the apparel industry, for instance, adopting a modular supplier network reduced the time needed to integrate new suppliers by 40%, significantly improving market responsiveness [19]. Cloud-based platforms facilitate real-time data sharing and agile procurement, enabling organizations to swiftly adjust strategies in line with market fluctuations and customer demands, thereby enhancing satisfaction and loyalty [20]. Continuous environmental scanning further allows firms to anticipate disruptions and adapt proactively—an essential capability in turbulent markets where flexibility is vital for survival [21], [22].

However, the successful implementation of adaptability requires more than technological upgrades; it demands substantial investment in change management and workforce upskilling. The literature highlights that many organizations underestimate the cultural, leadership, and training requirements needed to fully realize adaptable supply chains [4], [20]. Without leadership commitment and strategic alignment, the integration of modular architectures, cloud-based platforms, and environmental scanning tools may fall short of delivering the intended benefits. As such, adaptability should be approached not merely as a set of tools or technologies, but as an organizational capability that blends flexible structural design with a proactive and skilled workforce.

4.2.3 Alignment

Alignment in the smart supply chain context centers on harmonizing incentives, strategies, and information flows among all stakeholders, with key mechanisms including blockchain technology for transparent and tamper-proof transactions, joint performance metrics that balance cost efficiency with responsiveness and sustainability, and collaborative planning across supply chain tiers. Blockchain provides a secure and immutable ledger that enhances transparency, trust, and real-time monitoring, reducing fraud and counterfeiting risks while also lowering operational costs [23], [24], [25]. Joint performance metrics, such as shared KPIs, have been shown to improve on-time delivery rates by 22% and reduce shipment disputes, ensuring that stakeholders' short-term efficiency objectives are balanced with long-term sustainability goals [26]. Collaborative planning fosters joint decision-making, encourages information and resource sharing, and minimizes misalignment, which is often caused by conflicting priorities. A logistics sector study further demonstrated that alignment achieved through shared KPIs and cloud-based tracking systems significantly improved delivery performance and reduced operational disputes, highlighting its critical role in enhancing efficiency, transparency, and sustainability in modern supply chains.

4.3 Integrated Insights on Triple-A and Smart Supply Chains

The cross-analysis of the 40 studies shows that the Triple-A dimensions—agility, adaptability, and alignment—are highly interdependent, and their integration produces amplified benefits for smart supply chains. When these three capabilities are achieved simultaneously, supply chains demonstrate superior performance in resilience, sustainability, innovation, and

customer satisfaction. Resilience is strengthened through the ability to absorb and recover from disruptions, supported by technologies like AI and IoT that provide real-time data and improve forecasting accuracy [3]. Sustainability is enhanced through alignment, which integrates environmental and social goals with operational practices, while blockchain ensures transparency and traceability to support sustainable operations [5]. Innovation benefits from agility and adaptability, as these dimensions accelerate the adoption of emerging technologies and new business models, with AI-powered analytics enabling predictive trend analysis that fosters innovative practices [3]. Customer satisfaction is improved through higher service levels and personalization capabilities, supported by digital technologies that deliver deeper customer insights and tailored solutions [27], [28].

Digital technologies act as a unifying enabler, bridging gaps between the Triple-A capabilities and amplifying their collective impact. AI enhances agility by enabling rapid and informed decision-making, while also supporting adaptability through predictive analysis of future trends. Blockchain strengthens alignment by facilitating transparent information sharing and trust across the supply chain, while IoT supports all three dimensions by integrating real-time operational data into decision-making. processes. This synergy creates a robust framework for supply chain management, enabling organizations not only to respond effectively to disruptions but also to proactively shape more sustainable, innovative, and customer-focused operations.

4.4 Challenges and Research Gaps

Despite the clear benefits of integrating the Triple-A framework into smart supply chains, several challenges remain. Measurement difficulties persist, as few studies provide robust metrics to quantify the impact of Triple-A capabilities, making it difficult to benchmark and prioritize them effectively [13]. The lack of comprehensive quantitative models linking digital maturity with Triple-A performance outcomes further limits strategic decision-making. Change management resistance is another barrier, as organizational culture often lags behind technological adoption, weakening adaptability and alignment initiatives [29]. Overcoming this requires effective change management practices, including clear communication, leadership commitment, and workforce training to foster a culture of innovation. Data silos and interoperability issues also hinder agility and alignment, as fragmented systems impede seamless data sharing. While digital tools such as the consumer-to-manufacturer (C2M) model at JD.com offer promising solutions by shortening information flows [30], widespread implementation remains challenging.

The literature also identifies important research gaps that should guide future studies. Longitudinal research is needed to evaluate the sustainability of Triple-A benefits over time, as most current studies focus only on short-term impacts [13]. Cross-industry comparisons could yield valuable insights into sector-specific best practices, enhancing the transferability of successful strategies across contexts [31]. Additionally, developing robust quantitative models that integrate digital maturity metrics with Triple-A performance outcomes could provide a stronger empirical foundation for both academic inquiry and practical implementation. Addressing these gaps will be crucial for advancing the theoretical understanding and real-world application of the Triple-A approach in building agile, adaptable, and well-aligned smart supply chains.

5. CONCLUSION

This study consolidates evidence from 40 scholarly works to examine the role of the Triple-A approach in realizing smart supply chains, confirming that Agility, Adaptability, and Alignment are not isolated competencies but mutually reinforcing pillars. When integrated with advanced digital technologies, these capabilities form a synergistic framework for supply chain excellence. Agility, driven by real-time

visibility and flexible operations, allows organizations to respond swiftly to disruptions. Adaptability, supported by modular architectures and continuous environmental scanning, ensures strategic longevity and the capacity to embrace emerging technologies. Alignment, facilitated by transparent information flows and shared performance metrics, fosters trust and collaboration across the supply chain network. Collectively, these dimensions underpin resilience, sustainability, and competitive advantage in dynamic market environments.

Despite these benefits, the literature highlights persistent challenges, including the difficulty of quantifying Triple-A performance, organizational resistance to change, and technical complexities in achieving seamless data interoperability. Overcoming these barriers requires leadership commitment, cultural transformation, and strategic investment in interoperable digital infrastructure. Ultimately, the path to a smart supply chain is not merely a technological upgrade but a holistic transformation of processes, structures, and relationships. Future research should prioritize the development of standardized performance metrics, conduct longitudinal studies to assess long-term impacts, and explore sector-specific models for effectively integrating Triple-A capabilities into digitally enabled supply chains.

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