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Digital Transformation and Sustainability in Global Supply Chains: Insights from Recent Literature

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Abstract:
Global Supply Chains have withstood far-reaching transformations across the last few decades, driven by technological breakthroughs, sustainability needs, and global disruptions. The current research presents a structured literature review on the Sequential development of supply chains from Industry 3.0 and 4.0 to the new paradigms of Industry 5.0 and 6.0. With the help of adopting the PRISMA methodology, this study identified, screened, and examined 26 high-quality studies to trace the chronological and conceptual evolution of supply chain management.The outcomes suggest a clear progression in supply chain structures from conventional methods to a digitally connected, intelligent, and human-centric supply chain. Industry 3.0 laid the foundation with digital automation, and Industry 4.0 empowered organizations to make data-centric decisions by integrating IoT, big data, and advanced analytics. Industry 5.0 emphasises human–AI partnership, guided by ethical governance, and a strategic focus on sustainability, while Industry 6.0 pictures autonomous, adaptive, and circular supply chain ecosystems. Artificial Intelligence (AI) assumes a pivotal role in advancing agility, forecasting, and real-time optimization, underpinned by blockchain and cloud technologies for transparency. Despite these developments, research has exposed notable deficiencies in empirical validation, cross-sector adoption, and integrated governance of AI-driven supply chains. This study indicated a possible pathway for global supply chain management and offered perspectives for academicians and industries to navigate digital and sustainable SCM transformation in the Industry Revolution and beyond.
Keywords: *Supply Chain Management, Artificial Intelligence, Industry 3.0, 4.0, 5.0, 6.0, Blockchain, Artificial Intelligence (AI), Sustainability*

I. Introduction

In contemporary times, global supply chains have undergone substantial shifts stimulated by the convergence of emerging technology, changing geopolitical realities, and increasing demands for sustainability (Sun et al., 2025). The development of supply chains from conventional, linear systems to technology-enabled, agile, and resilient systems emphasises the pivotal role of organizations in responding rapidly to market volatility and global disruptions (Danach et al., 2024). Industrial transformation 4.0 took place from 2015 to 2025, and it led to the rapid adoption of technologies in industrial processes. Later in Industrial Revolution 5.0 and 6.0, along with technology, humanistic collaboration and autonomous sustainable operations have been adopted. This era marks a critical juncture where artificial intelligence (AI) is considered a fundamental element of supply chain management (SCM). Various supply chain management processes transformed from traditional operations to automation, such as resource allocation, demand forecast, inventory coordination, production scheduling, order processing, logistics, and transportation, etc (Elufioye et al., 2024). COVID-19 unearthed critical vulnerabilities in the global supply networks, magnifying the relevance of robust supply chain practices and risk management approaches (Siagian et al., 2021). Simultaneously, rising awareness about environmental and social sustainability has compelled firms to embrace green practices and circular economy principles in their supply operations (De Angelis et al., 2018).
Meanwhile, geopolitical tensions and trade disruptions have prompted organizations to rethink sourcing strategies, increasing emphasis on near-shoring, diversification, and digital compliance solutions (Ghobakhloo et al., 2022). Despite thorough analysis of discrete components such as AI applications, sustainability, and risk management, there is still insufficient knowledge of how these dynamic factors interact across global supply chains during this important period. The current research conducted a comprehensive systematic literature review (SLR) using the PRISMA framework. The comprehensive review of literature identified several aspects of global supply chain dynamics, such as significant themes and trends, the evolution of technologies, theoretical developments, and their practical implementations globally. Based on the available reviews and secondary information, the study aims to explore and analyze the chronological and thematic evolution of the global supply chain with a focus on assessing its historical and thematic advancement in the global supply chain system.

Research questions are:

1. How the Global Supply Chain Evolved?
2. What are the integrating factors across 3.0 to 6.0?

II. Research Methodology:

A. PRISMA Methodology: This research adopted the PRISMA methodology, i.e., Preferred Reporting Items for Systematic Reviews and Meta-Analyses, to enable a systematic and transparent approach to literature analysis (Trifu et al., 2022). The PRISMA framework is designed, and the information is documented after following the sequential procedure, i.e., identification, screening, evaluation of eligibility, and inclusion of studies. The PRISMA flow diagram structured the literature review process:

- **Identification:** A wide-ranging volume of research was compiled from Scopus, Web of Science, Science Direct, and IEEE Xplore. Search filters were also applied during this stage. Year of studies from "2015 to 2025", "Only articles", and studies related to "global supply chain and AI integration" were the primary pre-requisites for study inclusion.
- **Screening:** Titles and abstracts were reviewed, duplicates were removed, and relevance was checked.
- **Eligibility:** Full texts assessed for inclusion and exclusion based on AI focus, SCM relevance, industrial context, language, and method.
- **Included:** Final selection comprised 26 high-quality, peer-reviewed articles for thematic and bibliometric analysis.

B. Search Strategy: The literature search was conducted, spanning several leading academic databases: Scopus, Web of Science, Science Direct, IEEE Xplore, etc., using Boolean operators. While using a holistic search strategy, it is ensured that several crucial components are involved so that a comprehensive literature review can be done. This was done by using and connecting relevant terms such as "supply chain management", "Industry 3.0, 4.0, 5.0, and 6.0", and "artificial intelligence". The search was limited to publications from 2015 to 2025, focusing on capturing literature relevant to the latest industry advancements. The data taken from these particular years safeguards the incorporation of up-to-date and relevant information, which is foremost for this study.
C. Inclusion and Exclusion Criteria: The process streamlined the selection of available literature. The process included high-quality, relevant articles in the study. Research was included if they (a) addressed artificial intelligence (AI) applications or effects on supply chain management (SCM), (b) examined trends and conceptual frameworks within Industry 3.0, 4.0, 5.0, or 6.0, (c) were included in peer-reviewed literature or conference proceedings, and (d) appeared between 2010 and 2023 to capture recent advances and major industrial evolutions. Studies were excluded if they (a) were editorials, book reviews, or opinion pieces, (b) did not focus on AI in industrial SCM, (c) were duplicates or inaccessible, or (d) did not provide sufficient methodological detail or rigorous evidence.
D. Data Extraction and Synthesis Method : Final information for this research was gathered from all the incorporated literature, which was recorded from bibliographic information. The research purposes, methods, AI technologies under discussion in studies, the advantages and disadvantages found by the studies, and their main outcomes.

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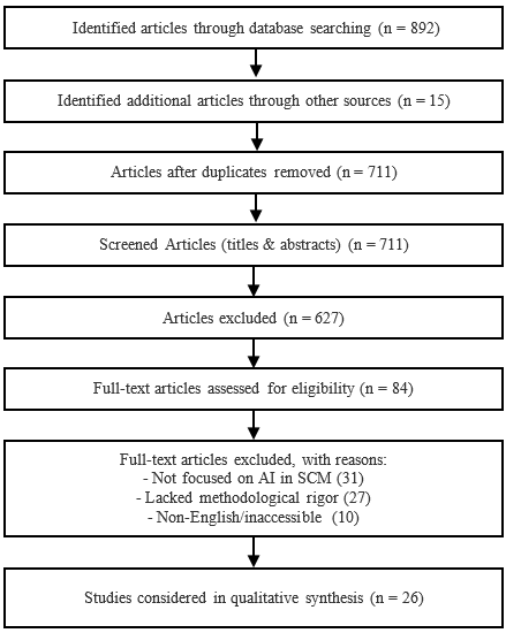
E. Quality Assessment of the Selected Studies: The established checklist assessed the quality, such as the Critical Appraisal Skills Programme (CASP), was used to evaluate methodological rigor, study design, data reliability, and clarity of reporting. Each study was rated based on quality using pre-determined criteria such as: research question focus, adequacy of search, comprehensiveness, methodological detail, bias risk, and relevance. Studies with significant methodological limitations or lacking credibility were excluded to maintain the review's validity and reliability.

Figure 1: PRISMA Model



Source: Compiled by Author

III. Literature Review

A. AI-Driven Transformation of Supply Chain Management: Contemporary studies illustrate the paradigm-shifting, significant contribution of Artificial Intelligence (AI) aimed at strengthening operational performance, adaptability, and robustness across various supply chain activities. The application of AI across demand forecasting, inventory management, routing optimization, and supplier choice has optimized strategic planning and adoption to market dynamics (Shen et al., 2024). The incorporation of AI Supports companies in countering challenges stemming from the pandemic and simultaneously advancing sustainability through optimized resource usage and supply chain transparency (Siagian et al., 2021). Nonetheless, challenges remain in terms of workforce skills, cybersecurity, and ethical considerations in AI adoption.

B. Artificial Intelligence Evolution Along the Industry 3.0–6.0 Timeline

The industrial paradigm evolution and transformation provide the backbone for understanding AI's integration into supply chains:

- **Industry 3.0**, often considered the "Digital Revolution", introduced computers, programmable logic controllers (PLCs), and early automation to manufacturing and logistics. This era witnessed the foundational integration of digital technologies that facilitated process automation and precision but largely within isolated systems (Ghobakhloo et al., 2022). AI existed in a formative phase, with applications predominantly related to automating discrete tasks and decision support at local levels.
- **Industry 4.** develops further through harnessing Internet of Things (IoT), cyber-physical frameworks, data analytics, computing infrastructure, and smart sensors to deliver integrated digital connectivity and real-time visibility for networked supply chains**.** Machine learning and advanced analytics have established themselves as core to forecasting, predictive maintenance, and process optimization (Borchardt et al., 2022). Industry 4.0 enabled the transition toward digitally connected and data-informed supply chains.
- **Industry 5.0** is a revolution from manual manufacturing to automation, emphasizing the interplay between humans and intelligent machines, such as cobots, interactive robots, augmented reality interfaces, and rather than replacing humans/manual processes, AI systems are engineered to work alongside. This era is characterised by a focus on worker well-being, customized products, and embedding sustainability within operational processes (Villar et al., 2023).
- **Industry 6.0**, the new framework, projects a complete autonomy in supply chains powered by AI, quantum computing, and pervasive digital twins. It gives precedence to hyper-connectivity, self-optimizing operations, and stringent sustainability and ethical governance, enabling intelligent ecosystems that dynamically balance social, economic, and environmental goals (Boison et al., 2025).

C. Benefits and Complications of AI Integration in Supply Chains: The AI innovation offers notable benefits, including advanced demand forecasting accuracy, improved logistics operations, inventory optimization, and amplified supply chain resilience (Boison et al., 2025; Belhadi et al., 2024). This fusion of AI with human operators in Industry 5.0 enhances creativity, problem-solving, and service personalization (Olorunyomi et al., 2024). However, hindrances like cybersecurity vulnerabilities, high implementation costs, transparency, workforce up-skilling, and ethical use of AI require strategic management (Danach et al., 2024)

D. Systematic Synthesis of Global Supply Chain Literature

Table I. Systematic Synthesis of Global Supply Chain Literature

S. No.	Research Agenda	Authors (Year)	Key Findings
1	Sustainable supply chain finance	Sun et al. (2025)	Discussed SMEs' path to sustainable supply chains via finance and risk management tools.
2	AI for supplier collaboration	Boison et al. (2025)	Demonstrated AI's contribution to strengthening supplier collaboration and enhancing performance
3	Blockchain & Collaboration in SCM	Boison et al. (2025)	Highlighted the AI and blockchain role in collaboration and performance.
4	AI for supply chain resilience	Belhadi et al. (2024)	AI-driven innovation strengthens supply chain resilience and operational performance under changing conditions.
5	AI in agricultural supply chains	Elufioye et al. (2024)	Examined the efficacy and limitations of AI in agricultural demand forecasting and optimization.
6	AI for supply chain optimization	Olorunyomi et al. (2024)	Summarized current practices and future opportunities of AI in supply chain optimization.
7	AI for efficient SCM	Danach et al. (2024)	Reviewed AI's transformative role for efficiency and sustainability in SCM.
8	Explainable AI in SCM	Kosasih et al. (2024)	Reviewed neuro-symbolic techniques for implementing explainable AI in supply chains.
9	Drug supply chain with AI+VMI	Shen et al. (2024)	Case study on AI and vendor-managed inventory for pharmaceutical supply chains in China.
10	Supply chain 5.0	Villar et al. (2023)	Recommended flexible, sustainable, and people-oriented supply chains in the post-pandemic era
11	Value cocreation in digital supply chains	Lin (2023)	Investigated challenges in digital-era value co-creation among supply chain partners.

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12	Cloud-based supply chain platforms and services	Ivanov et al. (2022)	Discussion on Industry 4.0 and digital platforms to develop a digitally equipped Supply Chain approach.
13	Industry 5.0 in operations	Borchardt et al. (2022)	Examined Industry 5.0's influence beyond technology, focusing on business and operations management perspectives.
14	Sustainability in the Era of Industry 5.0	Ghobakhloo et al. (2022)	Formulated a roadmap highlighting the implementation of Industry 5.0 in advancing development with sustainability.
15	Cybersecurity in supply chains	Kumar & Mallipeddi (2022)	Reviewed cybersecurity trends and implications for operations and SCM.
16	Blockchain in supply chain	Ahmad et al. (2021)	Suggested blockchain applications for the COVID-19 supply chain and waste management.
17	Blockchain for product recall	Patro et al. (2021)	Developed a blockchain-driven approach for managing automotive supply chain product recalls.
18	Supply chain resilience & COVID-19	Siagian et al. (2021)	Demonstrated collaboration to improve adaptability, agility, and innovation, which ultimately contributes to enhancing business performance.
19	Supply chain digitisation	Schniederjans et al. (2020)	Linked digitization of the supply chain operations with intellectual capital management for performance enhancement.
20	Supply chain management systems	Yin (2020)	Studied SCM information systems in foreign trade enterprises for digital transformation.
21	Resource-efficient supply chain	De Angelis et al. (2018)	Proposed integration of SCM with circular economy principles for sustainability.
22	IoT-enabled SCM	Dweekat & Al-Aomar (2018)	Design and implementation of IoT-enabled platforms for dynamic management of supply chain operations.
23	Analytics-driven supply chains	Chavez et al. (2017)	Linked industrial capabilities and customer satisfaction with data-driven supply chains.
24	Systematic literature reviews in SCM	Durach et al. (2017)	Suggested a novel framework for performing supply chain management systematic literature reviews.
25	Big data in SCM	Gunasekaran et al. (2016)	Evaluated the application of big data and predictive analytics for optimizing the supply chain operations.
26	Supply chain resilience theory	Tukamuhabwa et al. (2015)	Defined and reviewed the theoretical foundations of supply chain resilience.

Source: Compiled by Author

IV. Results

A. Detailed Discussion of Findings:Throughout the last decade, studies concerning supply chain management have witnessed a noteworthy progression, advancing from conventional resilience frameworks to digitally driven, intelligent, and sustainable supply chain models. Initial scholarly efforts (2015-17) analyzed the principle-driven foundations of supply chain agility and the **potential of big data and predictive analytics.** These investigations were largely conceptual, establishing the groundwork for grasping how supply chains could respond to disruptions but offering limited practical, technology-driven solutions. Across 2018-2020, attention progressively transitioned towards **digitalization and sustainability**. Researchers began exploring **IoT-enabled frameworks, circular supply chains, and supply chain digitisation trends**, signalling the early application of Industry automation principles. However, AI adoption throughout this period was relatively minimal. The post-2021 period signalled a pivotal shift, influenced largely by COVID-19 and the global emphasis on sustainability and supply chain resilience. Studies pointed to the escalating incorporation of use of **AI, blockchain, and cloud-based solutions** for enhancing traceability, efficiency, and collaboration. Notably, **blockchain applications for waste management and product recalls, AI-driven optimization in agricultural and industrial supply chains,** and **risk-focused frameworks for sustainable supply chains** emerged as the dominant themes. The most recent literature (2024–2025) denotes the incubation of Industry 5.0, underlining human-centred, intelligent, and sustainable supply chain frameworks. Scholars are now examining **explainable AI, supplier collaboration through digital platforms, and the integration of advanced analytics with cybersecurity** to construct supply chains that are enduring and aligned with social and environmental obligations. In summary, the literature reveals a **clear evolution from conceptual frameworks to AI- and blockchain-enabled, human-centric supply chains.** Nonetheless, critical limitations are evident in the **empirical validation, cross-industry implementation, and the holistic integration of AI, blockchain, and cybersecurity.** Addressing these gaps warrants further research aimed at developing and accessing integrated, intelligent, and sustainable supply chain models for the Industry 5.0 era.

B. Comparative Insights

Table II: Comparative Dimensions of Industry Revolution 3.0, 4.0, 5.0, and 6.0

Category	Industry Revolution 3.0	Industry Revolution 4.0	Industry Revolution 5.0	Industry Revolution 6.0
Focus	Digital automation & isolated control	Intelligent Cyber-Physical Networks & IoT connectivity	Partnership & customization of Human-AI	Fully autonomous & intelligent sustainable systems
Human Role	Limited interaction; computerized control	Limited to supervisory & monitoring roles	Enhanced collaboration & wellbeing emphasis	Symbiotic AI-human systems with ethical governance
Key Technologies	PLCs, computers	IoT, AI, big data, cloud computing	Cobots, augmented reality, and AI-human interface	AI, quantum computing, digital twins
AI Contribution	Basic automation and data processing	Advanced analytics, predictive & prescriptive AI	Augmentation of human capabilities and creativity	Autonomous decision-making and system self-optimization
Sustainability Integration	Minimal to none	Early adoption, focus on resource efficiency	Embedded in design, operations & worker wellbeing	Full lifecycle sustainability & circular economy
Challenges	Manual oversight, limited connectivity	Data integration, cybersecurity	Balancing automation & human factors, ethics	Infrastructure complexity, governance, and ethics
Implications for SCM	Improved automation, reliability	Real-time visibility & connectivity	Personalized, flexible, sustainable supply chains	Dynamic, self-optimizing & fully resilient supply chains

Source: Compiled by Author

Table III: AI-Driven Supply Chain Integration: Insights Across Industry Revolution 3.0–6.0

Factor	Industry Revolution 3.0	Industry Revolution 4.0	Industry Revolution 5.0	Industry Revolution 6.0
Technology-Enabled Integration	Computer/PLC Automation	IoT, Data Analytics, Cloud Platforms	Collaborative AI, Cobots	Progressive Artificial Intelligence, Quantum, Digital Twins
Human–Machine Integration	Manual/Isolated	Traditional Automation	Synergistic, Personalized	Seamless, Autonomous Ecosystems
Data Management	Local/Batch Processing	Real-time, Predictive Analytics	Real-time, secure, human-in-the-loop	Fully automated, advanced analytics
Operational Efficiency	Error Reduction/Speed	Process Optimization, Visibility	Customization, Flexibility	Adaptive, Self-optimizing Systems
Sustainability	Minimal	Resource Efficiency Starts	Circular Economy/Green Integration	Closed-loop, Full Sustainability
Cybersecurity	Basic/IT Focus	Data Privacy, Risk Detection	Advanced, Privacy-focused	Autonomous Security Protocols
Skills	Technical/IT	Digital/Analytics	Collaborative, Human-AI Training	AI/Sustainability Leadership
Regulation	Compliance	Evolving, Tech-driven	Human/AI Co-governance	Robust, Integrated Governance
Innovation	Incremental	Digital Process Innovation	Disruptive, Worker-Driven	Continuous, AI-facilitated

Source: Compiled by Author

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Table IV: Systematic Assessment of Industry Revolution 3.0, 4.0, 5.0, and 6.0 with Reference to AI in Supply Chains

Category	Industry Revolution 3.0	Industry Revolution 4.0	Industry Revolution 5.0	Industry Revolution 6.0
Focus	Digital Automation	Smart, Connected Manufacturing	Human-AI Customization & Collaboration	Autonomous, Hyper-adaptive Ecosystems
Key Technologies	PLCs, Basic IT	IoT, Big Data, Robotics, AI	Cobots, Advanced AI, Human Interfaces	AI, Quantum Computing, Digital Twins
Human–AI Interaction	Low, Computer-Assisted	Medium, Data-driven Decisions	High, Creativity & Ethics Emphasized	Symbiotic, Self-learning Systems
Sustainability	Limited	Initiated, Resource Efficient	Embedded, Social/Environmental Goals	Fully Closed-loop, Net-zero
SCM Implications	Efficiency, Error Mitigation	Visibility, Early Resilience/Agility	Flexibility, Personalized Resilience	Autonomous, Sustainable & Resilient
AI Contribution	Automation, Rule-based	Analytics, Forecasting, Optimization	Human Augmentation, Decision Support	Direct Control, Full Automation
Challenges	Siloed Processes, Skills	Data Security, Integration	Ethics, Transparency, Human Adaptation	Complexity, Societal/Ethical Governance
Benefits of AI Integration	Reliability, Speed	Real-time Optimization, Flexibility	Customization, Workforce Well-being	Sustainability, Antifragility

Source: Compiled by Author

The comparative tables and thematic synthesis reveal how AI's contribution to supply chain management has evolved in tandem with broader industrial transitions. In Industry 3.0, AI systems were primitive and fragmented, constrained by weak connectivity and a narrow range. Industry 4.0 opened the door to large-scale, data-driven integration, allowing for process optimization and foundational sustainability initiatives, but it continued to be impeded by data storage and cybersecurity (Kumar & Mallipeddi, 2022).

Industry 5.0 fostered collaboration between humans and AI, supporting adaptability, creativity, and tailored solutions, alongside a commitment to sustainability and worker satisfaction. Challenges included maintaining transparency and ethical governance. Industry 6.0, still evolving, is expected to deliver fully autonomous, closed-loop supply chains, with AI enabling self-healing, dynamic, and sustainable ecosystems, while at the same time prompting renewed debates on governance, standardization, and advanced skills requirements (Ghobakhloo et al., 2022). Publication trends and theme analysis confirm a distinct academic shift toward human-centric, ethical, and sustainable supply chain models. The literature demonstrates surging interest in Industry 5.0 and 6.0's integration of AI with social and ecological priorities, documented by the steady rise in relevant, high-impact studies. Resultantly, the findings emphasize the critical need for organizations to pair technological innovation with sustained workforce training, strong cybersecurity protocols, and rigorous ethical standards to thrive in the future supply chain management arena.

V. Conclusion and Future Scope of Study

The systematic review reveals that global supply chain dynamics between 2015 and 2025 have been redefined under the impact of swift technological advancements, unprecedented global disruptions, and evolving sustainability imperatives. The transformation across Industry 3.0–6.0 illustrates a linear to cyclical evolution—from siloed automation to fully integrated, autonomous, and human-centric supply networks. Through a PRISMA-based selection of 26 high-quality studies, the analysis demonstrates the expanding relevance of artificial intelligence (AI) as a major driver of supply chain transformation. This includes autonomous decision-making, predictive analytics, and digitally governed ecosystems. While Industry 4.0 introduced data-centric agility, the emergent paradigms of Industry 5.0 and 6.0 emphasize human–AI collaboration, ethical governance, and sustainability, making supply chains characterized not only by speed and efficiency, but also by social responsibility and adaptability to evolving human and environmental demands. Furthermore, this review demonstrates that the managerial role is evolving from operational oversight to strategic arrangement, requiring new competencies in digital literacy, ethical leadership, and sustainability management. Industry-level insights, supported by comparative frameworks, corroborate the trend toward hyper-personalized, resilient, and decentralized supply chain systems. However, organizations must still overcome challenges related to skills shortages, data integration, ethical transparency, and cybersecurity. The application of PRISMA offered a strong basis for conducting comprehensive and replicable research, yielding a trustworthy evidence base for both academic researchers and industry stakeholders.

Prospective research should concentrate on emerging topics, with particular attention to the integration of quantum computing into supply networks, cross-cultural impacts of AI on global supplier relationships, and governance models for Industry 6.0. More in-depth studies are warranted to examine human-related dimensions of technological change, particularly change management, workforce reskilling, and AI ethics in decision-making. Interdisciplinary research combining management science, behavioural economics, and artificial intelligence will be essential to develop comprehensive models that are adaptable to volatile and diverse global contexts. With supply chains transforming into intelligent, interconnected ecosystems, forward-looking managerial leadership and inclusive innovation are essential for fostering resilient and equitable global trade.

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