

DIGITAL TRANSFORMATION IN SUPPLY CHAIN MANAGEMENT: CONCEPTS, TECHNOLOGIES, BENEFITS, AND CHALLENGES

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Abstract

Supply chain management is changing as a result of digital transformation, which incorporates intelligent technologies that enhance decision-making, efficiency, visibility, and resilience. With an emphasis on important enabling technologies like artificial intelligence (AI), the Internet of Things (IoT), block chain, big data analytics, cloud computing, digital twins, and robotics, this paper explores the core ideas of digital transformation in supply chains. The study demonstrates how these technologies improve supply chain sustainability and transparency while streamlining logistics, inventory control, demand forecasting, procurement, and customer service. Major implementation hurdles are also covered, such as worker skill gaps, high investment prices, cybersecurity threats, data integration problems, and organizational reluctance to change. The report concludes by examining new developments and potential avenues for future research in the development of intelligent, resilient, and sustainable digital supply chains. For researchers, business professionals, and legislators looking to boost supply chain performance and expedite digital transformation in the era of Industry 4.0 and beyond, the review offers insightful information

1. INTRODUCTION

The way businesses handle their supply chains has completely changed due to the quick development of digital technologies. Traditional supply chain management (SCM), which primarily emphasized cost reduction and operational efficiency, is transforming into a digitally interconnected ecosystem defined by real-time data sharing, intelligent automation, and collaborative decision-making. In the current competitive and global business landscape, supply chains must exhibit agility, resilience, transparency, and the ability to

swiftly adapt to market swings, consumer demands, and unforeseen disruptions. Consequently, digital transformation has evolved into a strategic need rather than merely a technology choice. Supply chain management involves the planning, coordination, and oversight of activities related to obtaining raw materials, manufacturing products, warehousing, transportation, distribution, and customer support. The escalating intricacy of global supply chains, alongside heightened customer demands and recurrent disruptions from natural

catastrophes, geopolitical tensions, pandemics, and economic instability, has shown the inadequacies of traditional supply chain frameworks. Organizations increasingly necessitate intelligent systems that deliver comprehensive visibility, predictive insights, and swift response capabilities to guarantee business continuity and operational excellence.

Digital transformation denotes the incorporation of sophisticated digital technologies into corporate operations, organizational strategies, and decision-making processes to enhance value for stakeholders. In supply chain management, digital transformation allows firms to substitute disjointed and manual processes with integrated, data-driven, and automated technologies. These systems enable ongoing information exchange among suppliers, manufacturers, logistics providers, distributors, retailers, and customers, thus boosting coordination, minimizing inefficiencies, and augmenting overall supply chain performance.

Industry 4.0 has expedited the digitalization of supply chains via the integration of intelligent technologies, including Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), Big Data Analytics, Blockchain, Cloud Computing, Digital Twins, Robotics, Autonomous Vehicles, and advanced communication networks. These technologies produce real-time operational data, facilitate predictive analytics, automate repetitive processes, refine demand forecasts, optimize inventory management, enhance transportation efficiency, and enable proactive risk management. Consequently, firms may expedite and enhance the precision of their decision-making while augmenting flexibility and client happiness. A primary benefit of digital transformation is the capacity to achieve comprehensive supply chain visibility. Interconnected sensors, intelligent gadgets, and cohesive information systems enable firms to oversee products, cars, warehouses, and manufacturing facilities in real time. This visibility enhances inventory precision, decreases delays, reduces operational expenses, and fortifies collaboration among supply chain partners.

Moreover, sophisticated analytics and AI-driven decision-support systems empower firms to foresee disruptions, enhance resource allocation, and refine forecasting precision, thus augmenting overall supply chain resilience. The COVID-19 pandemic underscored the significance of digital supply chains by revealing weaknesses in conventional logistics and manufacturing systems. Lockdowns, transit limitations, workforce shortages, and global trade disruptions highlighted the necessity for intelligent, adaptable, and digitally integrated supply chain networks that can swiftly respond to unexpected occurrences. As a result, enterprises in manufacturing, healthcare, retail, agriculture, automotive, and e-commerce have expedited investments in digital technologies to enhance operational continuity and mitigate future risks.

Although it offers significant benefits, digital transformation poses various implementation obstacles. Organizations frequently face substantial initial investment costs, cybersecurity threats, data privacy issues, interoperability challenges among diverse systems, a scarcity of digitally skilled professionals, and resistance to organizational change, and complications in integrating legacy infrastructure with contemporary digital platforms. Small and medium-sized firms (SMEs) encounter supplementary financial and technological obstacles that may impede digital adoption. Confronting these problems necessitates strategic planning, robust leadership, workforce development, standardized digital architectures, and efficient governance. Besides operational enhancements, digital transformation plays a crucial role in promoting environmental sustainability and social responsibility. Intelligent transportation systems, energy-efficient warehouses, improved routing algorithms, predictive maintenance, and digital monitoring diminish fuel usage, carbon emissions, and material waste. These capabilities facilitate green logistics, circular economy efforts, and sustainable supply chain practices, while assisting firms in adhering to progressively rigorous environmental rules and stakeholder expectations. This review

article offers a thorough examination of digital transformation in supply chain management, focusing on its ideas, enabling technologies, significant benefits, implementation obstacles, and prospective research avenues. It consolidates recent scholarly literature and industrial advancements to provide a comprehensive knowledge of how digital technologies are transforming contemporary supply chains. The article intends to be a significant resource for scholars, practitioners, policymakers, and industry leaders aiming to create intelligent, resilient,

sustainable, and competitive supply chain systems in the digital age.

Digital transformation in supply chain management denotes a shift at both organizational and network levels, wherein companies leverage technologies such as big data analytics, cloud computing, IoT, and 3D printing to redefine value creation, enhance interactions with suppliers, partners, and customers, and refine competitive strategies in the marketplace (Agrawal et al., 2018)(Alkan et al., 2022).



Figure 1: Evolution of Supply chain Management

A digital supply chain transcends a mere digitization of the traditional supply chain; it is a novel business model founded on digital technologies to enhance value and improve efficiency in accordance with supply chain strategy (Nowicka, 2020). The concept extends beyond the automation of discrete tasks. The integration of digital tools spans planning, procurement, production, and logistics, systematically transforming supply chain processes, management approaches, business models, strategies, as well as inter-firm relationships and operational networks (Chen et al., 2024)(Liu et al., 2021)(Perano et al., 2023)(Eller et al., 2020). A significant topic in the literature is that this transition is not merely a technical implementation endeavor; it constitutes a fundamental socio-technical revolution that alters products, processes, organizational

frameworks, and management paradigms along the entire supply chain (Salvini et al., 2020). Consequently, supply chain digital transformation is sometimes characterized as a transition towards a more integrated, linked, dynamic, and predictive supply chain, wherein real-time visibility enables enterprises to identify difficulties earlier and adapt according to current conditions rather than predetermined workflows (Fu et al., 2023). Recent research indicates that the notion of the digital supply chain has arisen from the proficient application of digital technologies in supply chain management; nonetheless, companies continue to grapple with the fundamental issue of selecting a pragmatic and economical approach at the onset of transformation (Zhang et al., 2024).

2. Core digital technologies and architectures

Digital supply chains are constructed from a limited array of recurring technologies: IoT and sensors for data acquisition, cloud and ERP platforms for integration, analytics and AI for decision-making, and tools such as blockchain, digital twins, robotics, and 3D printing for execution and traceability. An essential architectural transition is from separated systems to interconnected platforms, such as digital ERP and control towers, which offer comprehensive, real-time visibility.

The data layer comprises IoT, sensors, RFID, and cyber-physical systems. These instruments acquire real-time data on products, assets, inventory, location, and operational conditions, enhancing the visibility and coordination of the supply chain. Literature consistently recognizes IoT, RFID, and CPS as fundamental components of digital supply chains due to their ability to link physical flows with digital information flows. (Oubrahim et al., 2023; Aarasse et al., 2023; Rodchenko et al., 2023; Singh, 2024; He et al., 2024)

Cloud computing offers a communal infrastructure. Cloud platforms enable companies to store, exchange, and process supply chain data across locations and partners, rather than confining it within local systems. This facilitates integrated and automated operations and is frequently categorized along IoT, AI, and analytics as a fundamental facilitator of digital transformation in supply chain management. Oubrahim et al. (2023), Aarasse et al. (2023), Singh (2024), He et al. (2024)

Big data analytics, machine learning, predictive analytics, and artificial intelligence constitute the intelligence layer. These systems convert supply chain data into forecasts, alerts, and decision assistance for planning, inventory management, logistics, and demand-supply alignment. The prevailing theme is that digital transformation encompasses not merely data collection, but also the application of analytics and AI to enhance

prediction and coordination. (Chidozie et al., 2023)(Oubrahim et al., 2023)(Rodchenko et al., 2023)(Singh, 2024)(He et al., 2024)(Syed, 2025)

ERP continues to serve as a fundamental backbone, however it is undergoing a revamp. One article emphasizes that digitalized ERP is a fundamental supply chain system that must evolve from inflexible record-keeping to more adaptable, intelligence-enhanced assistance. This indicates that, in practice, numerous organizations do not completely replace ERP systems; instead, they modernize them and integrate them with contemporary digital tools. (Li et al., 2023)

The digital supply chain control tower represents a significant evolving framework. A control tower serves as a central command hub for comprehensive visibility, decision-making, and actions informed by real-time data across several supply chains. This is architecturally significant as it demonstrates the transition from distinct functional systems to a coordinating layer capable of overseeing the entire network. Li et al. (2023)

Blockchain facilitates traceability, fosters trust, and ensures secure information sharing. It is frequently depicted as a means to enhance transparency and security in logistics and supply chains, particularly when numerous companies want a common and trustworthy record of transactions or product movement. (Chidozie et al., n.d.)(Rodchenko et al., 2023)(Singh, 2024)(Al-Ababneh et al., 2025)

Digital twins are employed to replicate and evaluate supply chain activities. Literature recognizes digital twin technology as a component of the contemporary digital toolset for optimization, enabling organizations to mimic conditions, monitor performance, and facilitate improved decision-making. (Chidozie et al., n.d.) Automation technologies facilitate the implementation of digital transformation. Intelligent automation, robots, and human-machine collaboration enable companies to transition from digital insights to digital actions in

warehousing, production, and logistics operations. This indicates that digital transformation encompasses both information technologies and operational technologies. (Chidozie et al., n.d.)(Al-Ababneh et al., 2025)

3D printing functions as a specialized manufacturing and supply framework. Although not always applicable, it is referenced as a component of the digital supply chain toolset due to its potential to transform sourcing, inventory, and fulfillment by relocating certain operations nearer to demand. (Aarasse et al., 2023)

B2B networks :B2B networks and partner connectivity constitute integral components of the design rather than mere supplementary elements. Digital transformation in supply chain management relies on systems that interlink enterprises across organizational boundaries, rather than solely on technologies within a single company. B2B networks are categorized alongside IoT, cloud computing, and analytics as fundamental technologies. (Oubrahim et al., 2023)

Cybersecurity and data privacy have become fundamental design imperatives. As supply chains increasingly integrate and rely on data, secure architectures are essential for dependable data exchange and system integrity. These challenges are progressively regarded as essential components of digital supply chain architecture rather than mere afterthoughts. (Chidozie et al., n.d.)

The architecture can be effectively conceptualized in layers: sensing, integration, intelligence, and orchestration. Sensors and RFID collect data; cloud and ERP systems integrate it; analytics and AI analyze it; and control towers, automation, and partner platforms provide coordinated actions throughout the network. This stratified structure aligns with the descriptions of the digital supply chain stack found in the referenced literature, despite variations in terminology across different articles. Li et al. (2023), Oubrahim et al. (2023), He et al. (2024), Model-Generated

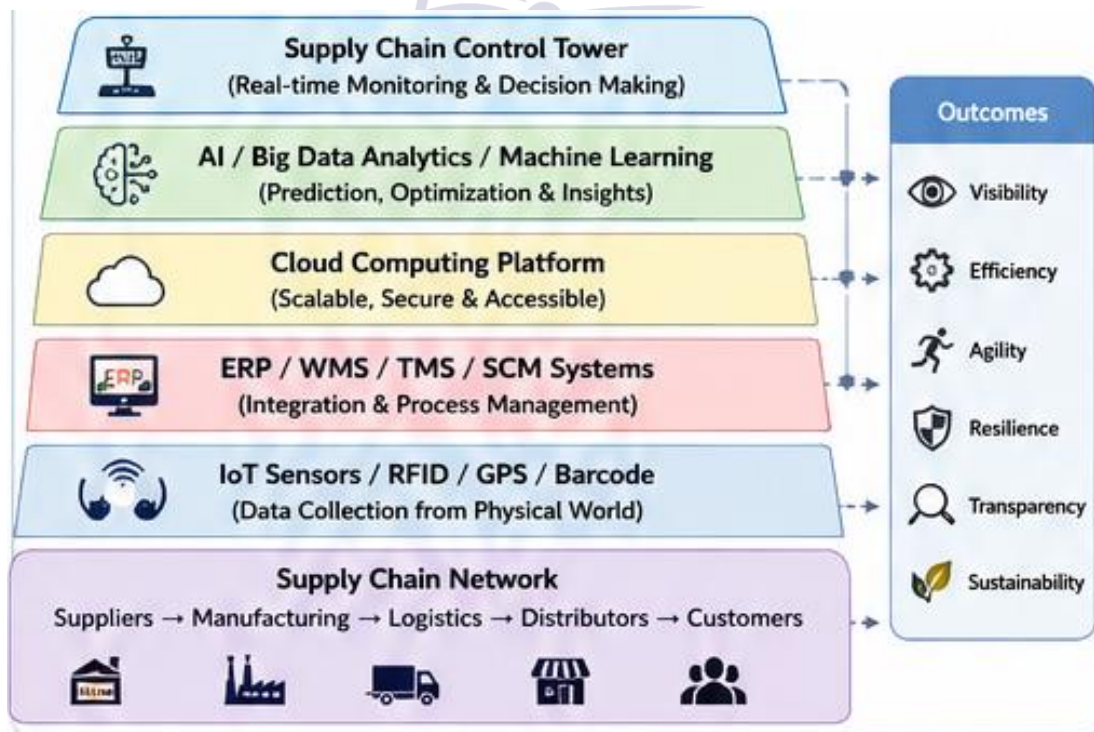


Figure 2: Layered Architecture of Digital Supply Chain

3. Reshaping Supply Chain Processes and Business Models through Digital Transformation

Digital transformation transitions supply chain management from isolated function execution to integrated, data-driven coordination throughout the whole network. It also transforms the company model by including data, digital services, and partner integration into the value creation process, rather than solely focusing on cost reduction.

Digital transformation initially alters supply chain processes by rendering them significantly more data-driven. Rather of depending predominantly on periodic reports, rigid plans, and postponed changes, companies can utilize real-time data collecting and processing to enhance production planning, logistics, inventory management, and daily decision-making. This transitions supply chain management from reactive oversight to expedited sensing and response, more

information accessibility, and more prompt delivery to clients. In this context, conventional supply chain management methodologies are being transformed into data-driven frameworks, wherein information processing is pivotal for enhancing efficiency, reducing costs, and improving profitability. Jing et al. (2024), Oubrahim et al. (2023), Yang et al. (2021), Nguyen et al. (2017)

A second significant alteration pertains to process visibility and control. Digital technology enable companies to monitor inventory, shipments, and production with more precision, hence improving decision-making and facilitating timely intervention when issues occur. This can transform supply chain management from retrospective tracking to real-time performance management, encompassing event-driven monitoring and remedial measures.

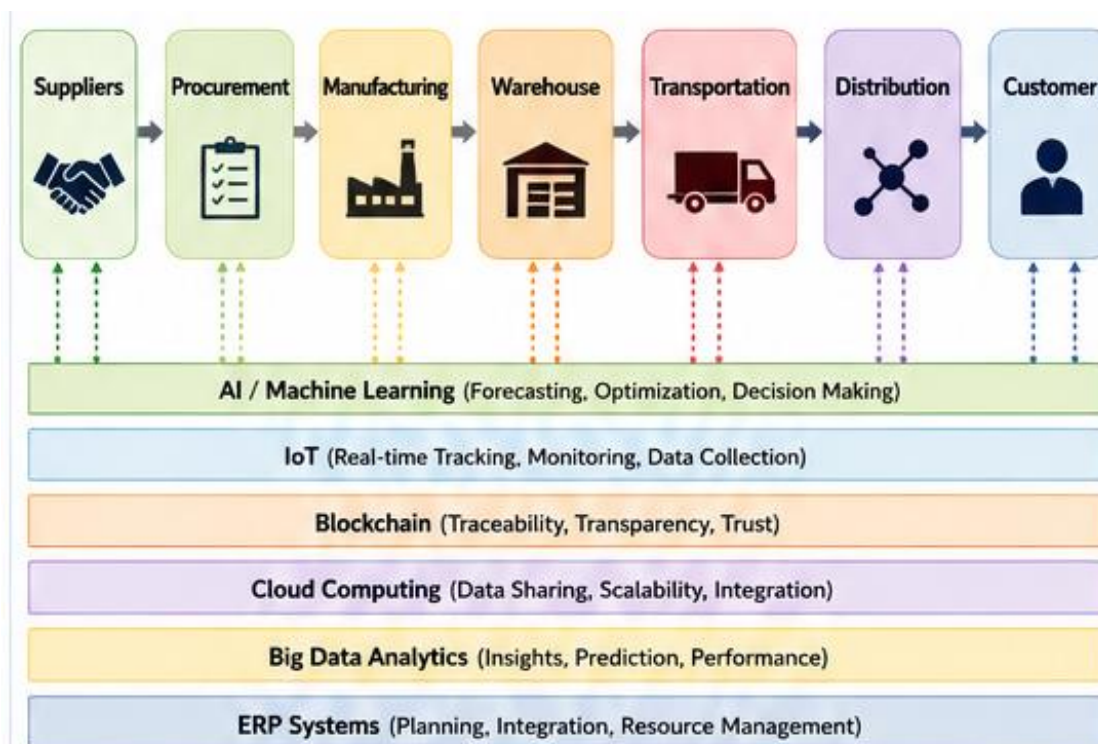


Figure 3: Core Digital Technologies in Supply Chain Management

The outcome is not merely enhanced information, but a distinct operational paradigm: companies may oversee flows continuously instead of relying

on intermittent checkpoints. (Andaloussi, 2024; Maher et al., 2022; Dweekat et al., 2018) Digital transformation alters the collaboration among

supply chain partners. Digital platforms facilitate connections among suppliers, manufacturers, distributors, and customers, thereby enhancing collaboration, accelerating communication, and promoting broader dissemination of information and resources. This implies that supply chain processes are more integrated across organizational boundaries, with coordination relying less on isolated transfers and more on coordinated network activities. This is one rationale for the correlation between digital transformation and enhanced supply chain integration, as well as improved overall performance. (Andaloussi, 2024) (Jing et al., 2024) (Oubrahim et al., 2023) On a larger scale, these process modifications also redefine the supply chain business model. Numerous studies indicate that digital technologies not only enhance existing supply chains but also facilitate the development of digital supply chains or networks as a novel phase in supply chain evolution. In this context, data serves as a direct catalyst for value creation, while digital innovations integrate with data-driven services, propelling companies beyond product-centric chains into more interconnected, adaptive, and increasingly self-organizing ecosystems. This represents a transformation in the business model, since value is derived not solely from the efficient transportation of commodities, but also from using data, services, and digital coordinating skills for competitive advantage. Nowicka (2019); Pflaum et al. (2021) Digital transformation also alters the nature of management work itself. Planning, monitoring, coordination, and problem-solving are more automated and integrated, necessitating that

managers discern suitable digital innovations for supply chain requirements and effectively amalgamate technology into functional operational models. The transformation encompasses not merely tools or workflows, but also the architecture, governance, and evolution of supply chains throughout time. (Nowicka, 2019; Yang et al., 2021)

4. Benefits both strategically and operationally

Digital transformation can enhance day-to-day supply chain operations and the longer-term business position. Better decisions, lower costs, higher flexibility and resilience, stronger customer value and stronger competitive performance are the main gains reported in the literature. Improved decision making and smarter management. One common benefit is that digital transformation improves the way firms analyze data and make decisions. Smarter internal decisions, stronger planning and more intelligent supply chain management, instead of manual judgment or delayed reports, are made possible by better data processing and deeper process insight. (Cui et al., 2023; Ozkanlisoy et al., 2021; Sadeghi et al., 2021) More efficient operations and lower supply chain costs. Digital transformation can also be used by firms to allocate assets more effectively, reduce costs of managing supply chains, improve production behavior, and raise overall efficiency of processes. In operational terms this means less waste, better coordination and more effective execution throughout the chain. (Ozkanlisoy et al., 2021)(Cui et al., 2023)(Stroumpoulis et al., 2024)



Figure 4: Benefit of Digital Transformation in Supply chain Management

Faster. More responsive. In literature, digital transformation is related to more flexible supply chains that can more easily adjust to fluctuating demand, customer needs and operating conditions. This is strategically important, as flexibility allows firms to respond more rapidly and compete in more uncertain markets. (Ozkanlisoy et al. 2021) more value and experience for the customer. Digital transformation enables companies to better meet the individual needs of customers and improve the customer experience. In supply chain terms, this often translates into improved service, more timely fulfillment, and supply chain processes that are more closely aligned with market demand. 10.3.4.3. (Ozkanlisoy et al., 2021) (Sadeghi et al., 2021) Competitive Advantage and improved business performance Many studies conceptualize the digital transformation as a competitive advantage. The mechanism is not just cost cutting but also improved operating models, increased performance, accelerated sales processes, and higher profit margins over time. (Ou, 2024) (Sadeghi et al., 2021) (Ozkanlisoy et al., 2021) More innovation and access to new business

models Digital transformation can also improve existing operations, enhance firms' innovation capability and support new and more efficient business models. This is strategically important because it enables firms to create value in new ways, rather than just optimizing existing processes. (Ozkanlisoy et al., 2021) (Luo, 2022) (Cui et al., 2023) More resilient and able to absorb risk. Improved resilience is a key strategic gain. The studies referred to state that digital transformation allows firms to absorb better shocks, respond to market change and enhance supply chain competitiveness under risk. That means that digitalization matters not only for efficiency, but also for continuity and recovery. (Luo, 2022)(Ou, 2024) Better financial performance and growth potential. Some studies report positive effects on key financial indicators, profit margins and wider firm performance. This means that digital transformation can deliver measurable business value, not just process improvement within operations. (Ou, 2024) (Sadeghi et al., 2021) Sustainable performance and market position support. The combination of digital transformation and sustainable supply

chain policies allows firms to improve simultaneously economic, social and environmental outcomes. Benefits reported included improved business performance, operational excellence, better public image, stronger social bonds and increased market share. (Stroumpoulis et al., 2024) More access to resources that enable the development of supply chains.

Another study also found that digital transformation could reduce financing constraints and improve innovation ability, which indirectly promotes supply chain development. This is useful as it shows that some of the benefits come through stronger organisational capacity and not just through direct process gains. (Cui et al. 2023).

5. Implementation challenges, barriers and requirements

Digital transformation of the supply chain is difficult. It necessitates that companies change systems, people and investment logic all at once. The biggest barriers are integration issues, data security risks, a large initial investment requirement, skills shortages and resistance to change. Therefore a clear strategy, phased investment and strong management change are often key to success. One of the biggest challenges

is integrating with legacy systems. Many companies do not begin from scratch. They need to integrate new digital applications with legacy ERP, logistics, warehouse and partner systems, creating interoperability and system integration issues. This is particularly challenging when the supply chain includes many firms with different data standards and technologies. (Nasereddin, 2024) (Kadam et al., 2025) (Yang et al., 2025) Data security and trust become key operational risks. As supply chains share more data across platforms, devices and partner networks, companies are increasingly vulnerable to data security issues. Data security is a major concern, as the literature points out repeatedly, so digital transformation demands not only new tools but also good governance, access control and protection of shared information. (Nasereddin, 2024)(Suresh et al., 2024)(Kadam et al., 2025) Adoption can be hampered by the high up-front cost. "Digital transformation usually requires an investment in infrastructure, software, integration, training, and process redesign before the benefits are fully realized. This makes cost management a real barrier, particularly for firms that have to justify large initial outlay while still running the current ship. (Nasereddin, 2024)(Yang et al., 2025)

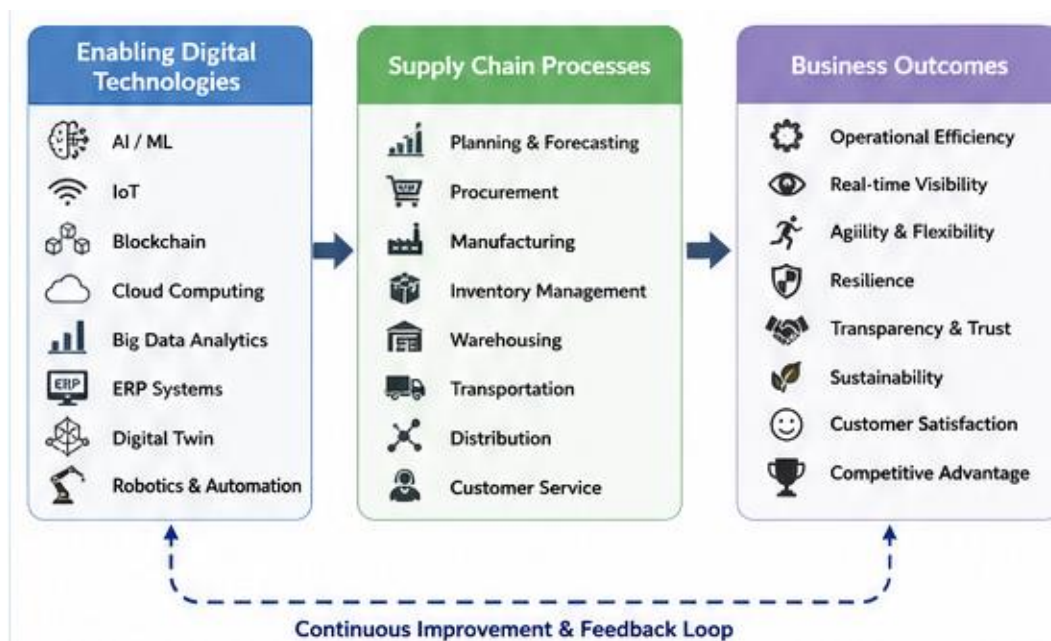


Figure 5: conceptual framework for Digital Transformation in supply Chain Management

Resistance to change is a people issue, not just a technical issue. Even with the technology at their disposal, employees and managers may resist new workflows, automation and data-driven decision models. That is why several studies mention the need for management change. If people do not accept new roles, new routines or new ways of working with partners, implementation might fail. (Nasereddin, 2024) (Chandra et al. 2024) (Suresh et al. 2024) Execution suffers from lack of skills. A lot of companies need people who can bridge analytics, digital systems, operations and supply chain coordination, but they don't always have those capabilities in-house. Talent shortages therefore create a practical bottleneck, particularly when firms adopt AI, IoT, predictive analytics or blockchain without having enough trained staff to manage and use them properly. (Suresh et al., 2024; Yang et al., 2025) But the pressure to keep innovating creates implementation tension. Digital transformation is not a single installation. Firms are under constant pressure to upgrade tools, improve processes, and respond to rapid technological change, which can stretch budgets, leadership attention, and organizational capacity. (Kadam et al., 2025)

Implementation is about careful planning, not ad hoc technology adoption. The studies consistently highlight the need for firms to have a clear transformation roadmap linking technology choices to business goals, supply chain priorities and expected returns. This means in practice to prioritize, to sequence projects and not to make the mistake of buying technologies before defining the operating problem to solve. (Nasereddin, 2024; Chandra et al., 2024). Success is contingent on strategic investment. Benefits from digital transformation depend on scale, integration and sustained use, so firms need conscious, long-term investment, not just isolated pilots. Successful implementation is described in the literature not as a technical procurement but as a strategic investment choice. (Chandra et al., 2024)

It is important to have a full implementation strategy. The most common message is that firms need to manage technology, people, process and risk together. The likelihood of an organization's success increases when planning, cost control, security, capability building and change management are brought together into one cohesive transformation program. (Nasereddin, 2024)(Chandra et al., 2024)(Suresh et al., 2024)



Figure 6: Major challenges implementing in Digital Transformation

Papers	Challenges Identified	Barriers Described	Methodologies Used	Technology Focus	Outcomes Documented
Nasereddin, 2024 Uncertain Supply Chain Management (18 citations)	Data protection challenges, necessity of change management	Data protection difficulties, necessity of change management.	Comprehensive analysis of literature, case studies, data examination from multiple sources	Blockchain, AI, big data analytics, IoT, 5G connectivity.	Increased productivity, insight into best practices, competitive advantage.
Kadam et al, 2025 Journal of Economics, Finance and Accounting Studies (4 citations)	Data security concerns, system interoperability, pressure to innovate.	Data security concerns, system interoperability, pressure to innovate.	Explores integration of emergent technologies in supply chains.	IoT, Artificial Intelligence, Machine Learning, Blockchain	Visibility, accuracy, efficiency improvements, real-time data collection, predictive analytics.
Yang et al, 2025 Proceedings of the 2025 International Conference on Economic Management and Big Data Application	Technology integration, cost management, talent shortage.	Technology integration, cost management, talent shortage.	Theoretical analysis, SPSS analysis, actual data examination.	Big data, artificial intelligence, Internet of Things, blockchain.	Improvement in supply chain efficiency, cost reduction, increased customer satisfaction.

6. New avenues for research and development

The next wave of research is shifting from individual tools to how full supply chain digital transformation actually takes place. A critical open space is developing and testing holistic frameworks that connect strategy, technology adoption, operations, resilience and agility across the entire supply chain.

A major research trend is towards holistic transformation models.

Many individual technologies and use cases have been studied in the literature, but an important research front is the understanding of digital transformation as a full supply chain change process and not as a set of separate technology projects. Recent review work suggests that the field does not have a holistic view of supply chain digital transformation and calls for more synthesized models and frameworks that explain strategic technology adoption across supply chain operations. (Dasanayake et al., 2025).

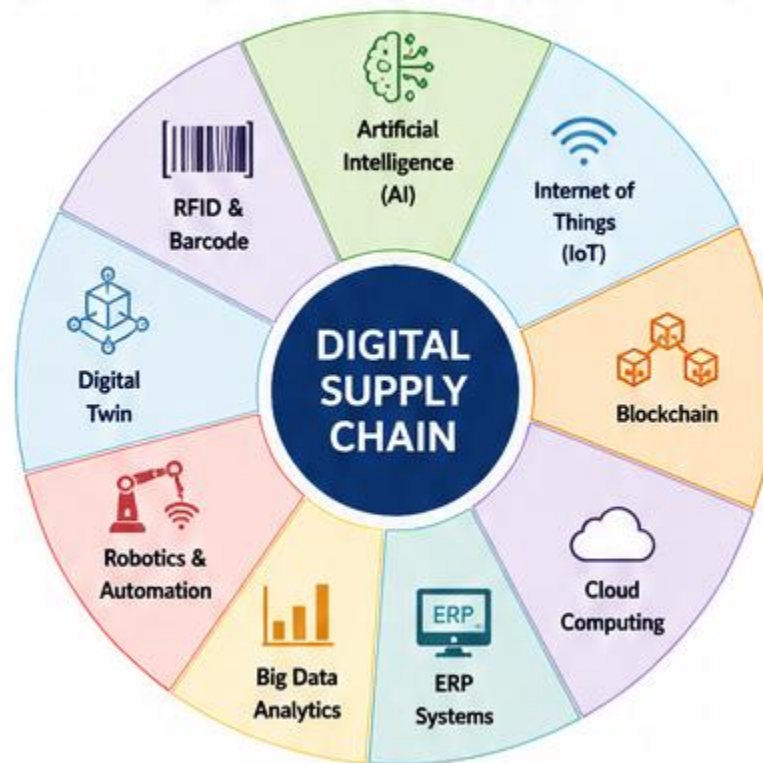


Figure 7 :Core Digital Technologies in supply chain Management

More work is needed to define pathways from strategy to execution.

A practical research question is how firms transition from digital ambition to staged implementation in real supply chains. This includes how they select technologies, order adoption, match investments to supply chain objectives and avoid piecemeal efforts. Recent work in the literature on mapping explicitly emphasizes the need for frameworks linking strategy to operational adoption. (Dasanayake et al., 2025)

Resilience and agility are becoming core issues, not side issues.

A new perspective is to view digital transformation as a means of creating supply chain resilience and agility in times of disruption, rather than simply a productivity or automation project. This suggests the need for more future research on which digital capabilities matter most in the face of uncertainty, and how they should be combined across the network. (Dasanayake et al., 2026)

Integration across functions and across firms is still an open research area.

Since many studies investigate digital instruments in separate supply chain functions, there is an increasing research need to investigate cross-functional and inter-organizational transformation in a more integrated way. That means taking it all the way through sourcing, production, logistics, and partner coordination, not just as functional pilots. (Dasanayake et al 2025)

The comparison and assessment of frameworks will probably increase.

A second research agenda is not just to propose transformation frameworks but also to compare them, to validate them in practice and to test which kind of models fit to different industries, supply chain structures and levels of digital maturity. The 2025 review is useful in that it synthesizes existing models, but also suggests that this area remains to be organized and assessed

. (Dasanayake et al., 2025,) More maturity and governance research is likely to be the next step.

As companies move beyond pilot projects, researchers will likely focus on digital maturity, transformation governance and the development

of capabilities over time, including how companies manage coordination, investment and organizational learning across the supply chain.

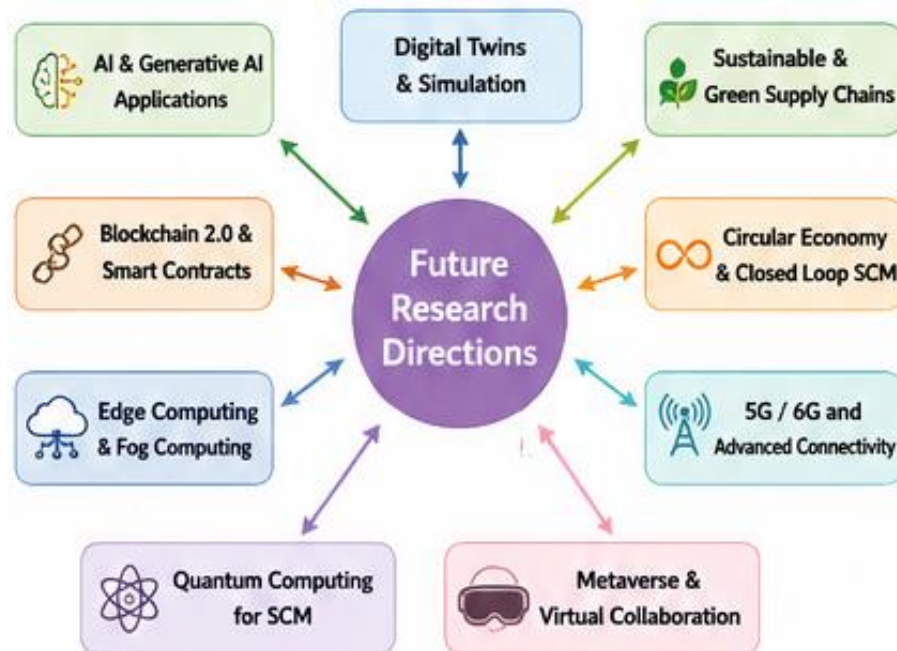


Figure 8: Future Research direction in digital supply chain

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