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Supply Chain Optimization Through Digital Transformation: A Literature Survey

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PREFACE

Starting this thesis has been both exciting and intimidating. Although I am only at the beginning of this academic journey, the process has already challenged me to think critically, manage my time better, and engage with a wide range of complex topics related to supply chain and digital technologies.

I have started gathering materials and building a clear structure for my work, and I already feel that this process will push me to grow both professionally and personally. I look forward to exploring the topic more deeply and translating my research into something meaningful.

I would like to thank my thesis supervisor in advance, along with my lecturers, peers, and family members who have encouraged me to take this first step. Their support has been essential in getting me started with confidence and clarity.

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Abstract

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As professionals across various fields have noted, digital transformation has become a driver for improving supply chain management. In this thesis, the focus is on how contemporary digital innovations like Artificial Intelligence, the Internet of Things (IoT), blockchain, and robotic process automation have been incorporated to improve supply chain efficiency, visibility, responsiveness, and overall effectiveness.

The purpose of the study was to analyse the scope of scholarly work considering digital transformation in supply chains, determine recurring concepts, strategies, and tools, along with their defining issues, primary constituents, and unaddressed research problems. This was useful to understand how digitally focused initiatives are trying to impact the traditional models and frameworks in their basic structures.

A systematic review of the literature was completed based on reviewed articles published during the last ten years. This study targeted desktop research; therefore, empirical case studies or technical implementation studies were not included. As stated in the findings, there is evidence that a large number of organisations have adopted some aspects of digital tools; however, gaps in the strategic integration of these tools pose great challenges. Furthermore, the results highlight that the lack of clearly defined performance objectives, coupled with rigid organisational change frameworks, impedes the effectiveness of digitisation initiatives.

This thesis aims to enhance the understanding of the existing academic landscape and construct pragmatic propositions for subsequent investigations.

Keywords: supply chain, digital transformation, optimization, literature review, IoT, AI

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List of Abbreviations

Abbreviation	Full Form / Explanation
AI	Artificial Intelligence
API	Application Programming Interface
C2C	Cash-to-Cash (Cycle)
ERP	Enterprise Resource Planning
IoT	Internet of Things
JIT	Just-In-Time (inventory system)
KPI	Key Performance Indicator
MEIO	Multi-Echelon Inventory Optimization
ML	Machine Learning
RFID	Radio Frequency Identification
RPA	Robotic Process Automation
S&OP	Sales and Operations Planning
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference (model)
SKU	Stock Keeping Unit
SLR	Systematic Literature Review
SME	Small and Medium-sized Enterprise

1 Introduction

Amid the fast-changing global business scenario, supply chains are no longer just cost minimizers, they have redefined themselves into weapons that directly affect the competitiveness of a company. At the beginning, supply chains used only manual methods of operation, non-compatible information systems, and decision-making that was only reactive. Nevertheless, the manifold complications of globalisation paired with unpredictable disturbances like the Covid-19 pandemic, political conflicts and environmental laws have made the deficiencies of traditional models of supply chains more obvious.

Companies have started to apply digital transformation so that they can improve the efficiency of their supply chain system. The development and application of novel technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, machine learning, robotic process automation (RPA), and advanced data analytics have been a major cause for the shift to intelligent, faster, and more flexible supply chains. These advancements empower supply chain actors by making real-time sharing of data, anticipating the future, and achieving the full traceability of the supply chain possible; eventually, all the gains from these are increased accuracy in forecasting, fewer costs, and better customer loyalty.

In the first place, the focus will be on describing the phenomena that are the driving force of how the digital revolution in the supply chain is turning the wheels of operations. Even though digital instruments are only increasing in number and are becoming more sophisticated, the reality is there is still a need for a thorough examination of this end to see precisely how these technologies are applicable to solving the issues of the supply chain.

Although digital transformation in supply chains enjoys an extensive recognition of the benefits by people, the literature still remains scattered. Scholars usually pay attention to one specific technology, one industry, or use just performance metrics in their studies which don't give a complete picture. Besides, quite a lot of companies can't reach tangible benefits from their digital investments because

they deal with problems such as the challenges of integration, the lack of strategic alignment, or the organization's unreadiness.

This sort of knowledge which is fragmented and sometimes contradictory will be a difficulty for both researchers and practitioners. The call for a systematic review and synthesis of existing academic literature to recognize the technology adoption in supply chain, the implementation strategies, and the measurable impacts has escalated exponentially. Understanding these patterns can facilitate the smooth transition of theory to practice and thus be a deciding factor in the subsequent research that is more coordinated. This is why it is necessary for companies in supply chain decide to invest in digital transformation which may lead to improved performance during subsequent periods.

The main goal of this work is to perform a structured literature review to examine how digital transformation affects the supply chain in a better way. By doing an in-depth analysis of the relevant academic papers, this work is intended to achieve the following:

- Digital technologies that are most frequently mentioned in supply chain optimization are to be identified.
- The study is to be split into the following technologies that dictate the efficiency, responsiveness, visibility, and sustainability of the supply chain.
- Discover those problems, hazards, and obstacles which prevent the application of the technology given the examples from the text.
- Key points, the lack of knowledge, and the new trends that could be the basis of a new academic study, should be searched for through recurring themes in the literature in conjunction with the various gaps in the field of study.

The research will concentrate on the secondary data sources only, and it will use neither the fieldwork nor the primary data collection. The primary purpose of it is to offer a synthesized academic view rather than to create or test a specific technological solution.

To make it clear what the goals are and to retain coherence throughout the project, the following research questions have been put forward:

- RQ1: What digital technologies have been commonly employed in the most recent academic papers to improve the performance of supply chains?
- RQ2: How have these technologies been beneficial in increasing supply chain performance (e.g., in terms of speed, cost, accuracy, flexibility)?
- RQ3: What obstacles and difficulties are present when people want to go digital from their supply chains, as found in the literature?
- RQ4: What are the gaps that still exist in academic research on this topic and their suggested directions for future research? What are the main reasons for these recommendations?

These questions will be the focus of the literature search, analysis, and synthesis, thereby guaranteeing that the findings of this thesis are relevant, to the point, and in conformity with the general aim of understanding the influence of digital transformation on supply chain optimization.

This thesis emphasizes the scholarly neglect of understanding the role of digital transformation in optimizing a supply chain. The focus of this research is limited to the literature analysis of published peer reviewed journal articles, conference papers, and industry whitepapers from 2010 to 2024. Only works written in English and available through academic databases like IEEE Xplore, ScienceDirect, and Google Scholar were considered.

The study focuses on digital technologies, namely Artificial Intelligence (AI), Internet of Things (IoT), blockchain, cloud computing, and robotic process automation (RPA), with regard to their impact on the supply chain performance indicators: efficiency, visibility, responsiveness, and sustainability.

As such, this research does not encompass:

- Empirical case studies or interviews with supply chain professionals.
- Cost-benefit analysis on the implementation of digital tools.
- Inter-sectorial analysis (e.g., manufacturing vs. retail) unless drawn out from literature under review.

These aspects may restrict the applicability of the findings to certain industries or contexts of operation. This study seeks to present a consolidated academic perspective instead of tailored, detailed guidance for specific organizations.

This thesis consists of seven sections.

- Section 1 is the Introduction which outlines the subject, discusses the background and rationale, describes the research problem, objectives, scope, and research questions, and explains the structure of the thesis.
- Section 2 is the Method and Material that outlines the approach to research in this study, detailing the literature review, selection criteria, and a reliability and validity discussion.
- Section 3 consists of Literature Review / Current State Analysis. It will exhibit some academic sources that were reviewed and classified to identify technological enablers, their impacts on supply chain performance, and the challenges reported.
- Section 4 is the Theoretical Background that describes key supply chain theories, models, and other concepts that are necessary to interpret the results.
- Section 5 is the Results and Analysis section that introduces the main findings, emphasizing technological trends, recurring themes, and gaps in the literature.
- Section 6 is the Discussion and Conclusion in which analyses and findings are discussed, research questions are mitigated, and answers alongside recommendations for future studies is provided.

2 Method and Material

This research focuses on exploring the contribution of digital transformation to the optimization of a supply chain through the structured literature review methodology tied to qualitative research features. Due to the rapid rate of technological evolution and the increase in published academic work surrounding the topic, a systemized approach was necessary for the credibility and focus of the research.

Peer-reviewed journal articles, academic conference papers, whitepapers, and industry reports published in the years 2010-2024 formed the materials for this study. The Primary Sources were taken from academic databases like IEEE Xplore, ScienceDirect, SpringerLink, ACM Digital Library, and Google Scholar, which are reputable in the field of engineering, Information technology, and supply chains.

Relevant literature was selected by coming up with keywords which included “logistics IoT,” “AI supply chain management,” and “blockchain supply chains.” Filters such as language, date, and subject area were utilized with boolean operators to streamline results. The searches were adaptive, allowing for new terms to be added based on previously uncovered clues during initial skims.

Only publications in English that contained a significant academic discussion or some form of empirical analysis were included. Focus was placed on studies that examined supply chain processes in relation to digital technologies. Non-scholarly content was excluded for purposes of rigor, which included opinion pieces, blogs, and non-peer-reviewed publications. Articles that solely discussed non-supply-chain uses of digital instruments or did not demonstrate clear outcome-based performance results were also excluded. After eliminating duplicates and disregarding unrelated titles, I examined the abstracts of the remaining articles to evaluate their relevance to the research objectives. Relevant articles were then procured in their entirety for detailed reading. The goal was to extract information such as the digital technology employed, the supply chain process impacted, the quantifiable performance enhancements, and any of the discussed implementation challenges.

This thesis employs a systematic literature review (SLR) methodology which provides an ordering and evidential approach to the gathering and synthesizing of findings from disparate scholarly works. The SLR approach is tailored to suit studies that have to address exploratory research questions and where the existing evidence is plentiful empirically but highly fragmented. In the case of digital transformation in supply chains, which is an interdisciplinary, fast evolving topic, the structured and transparent SLR is vital in assuring that there is no “shallow” deep analysis.

The choice in adopting the SLR method stemmed from a blend of factors, primarily to assess and consolidate an extensive volume of contested academic knowledge. Additionally, this approach was helpful in discerning highlighted technological drivers, adoption patterns, operational outcomes, and barriers across various paradigms in different industries. This is different from concentrating on a specific case or doing primary fieldwork, thus enabling the research to address a broader spectrum of industries, digital geographies, and types of ICT solutions. The initial stage of the review consisted of drafting a review protocol which acted as a guide for the research milestones. In this protocol, the scope of research objectives was drafted, along with the specific research questions to be answered, relevant databases to be identified, the development of search strings, and the criteria for inclusion and exclusion of articles to be set. By utilizing protocol, an unstructured form of bias which might stem from subjective judgment was minimized during article selection, evaluation, and throughout the research phase.

The design of the search strategy aimed at achieving the most pertinent literature that would also be of a higher echelon in quality. The keywords utilized include “digital transformation,” “supply chain optimization,” “AI in logistics,” and “blockchain supply chain,” which were enhanced through the use of Boolean operators and were searched on IEEE Xplore, ScienceDirect, SpringerLink, ACM Digital Library, and Google Scholar. Additional filters set were academic language to English, document type to peer-reviewed articles and conference papers, and publication date from 2010-2024.

An initial set of studies was created after the search phase, and these studies underwent a screening process. Steps of this screening process include reviewing titles and abstracts within the scope of the research, as well as full text review. During this phase, the relevant articles were evaluated to determine analytic depth, clarity of conclusions, relevance to the digital supply chain, and alignment with the research objectives.

Following the screening process, each relevant study underwent data extraction and categorization. Systematic recording was conducted on the digital technologies discussed within the articles. This included the supply chain process impacted (procurement, manufacturing, logistics, distribution), the industry sector, organization type, reported results, cost, lead time, visibility, among others, and the challenges of implementation. Analysis of the collected data was first performed using thematic analysis, which consists of organizing the findings into predefined categories. This includes sequences of technology introduction, strategic advantages gained, operational impediments encountered, and the critical success factors for execution. Analysing grouped findings assists to refining conclusions that advance the scholarly dialogue on the subject. Importantly, the review process was conducted in a way that was evidentially sound, methodologically coherent, and transparent. All steps of the process were documented as maintaining the research design—from the selection of keywords to the final thematic coding—so that other scholars could follow and replicate the work. This level of accuracy increases the study's credibility and trustworthiness alongside the comprehensive analysis performed in the study. These gaps are gaps of existing literature that the thesis tries to fill, by undertaking the rigorous approach described above, and aims to be the foundation for further work in digital transformation of supply chains.

As this is a literature-based study, ensuring reliability and validity are considerations throughout the entire research process. In academic research, reliability deals with the repeatability and consistency of the entire research process, and validity deals with how accurate, credible, and relevant the findings are in relation to the research questions posed. In systematic literature reviews,

these two aspects are essential in upholding scholarly rigor and providing objective and reliable research outcomes.

To increase reliability, the search strategy, inclusion/exclusion criteria, and data extraction protocol were identical for all databases used including IEEE Xplore, ScienceDirect, SpringerLink, ACM Digital Library, and Google Scholar. There was no bias in the selection of the articles as they were reviewed using a predetermined framework, therefore the data selection and data analysis steps of the review were not subject to shifting norms or subjective standards. Accurate records were kept of decisions made regarding which articles to include, which to exclude, as well as the reasons provided for each decision, submissions needed to meet each of the research questions. Meeting this documentation standard ensures that the research can be replicated, something that underscores academic reliability. When considering validity, a number of steps were taken to ensure that results achieved were accurate and meaningful in regard to the study objectives. Only peer-reviewed journals and credible academic sources were used because such sources go through a formal quality verification process before publication, which contributes to the scientific rigor of the data being analysed.

In addition, every key finding included in this thesis was, to the extent possible, cross-validated against multiple sources. For instance, whenever a certain advantage of a digital technology was reported, like improved supply chain visibility through IoT, attempts were made to check whether unrelated other studies documented similar claims. This combined with other contexts, helps add to the credibility of the findings due to their different contexts.

No matter how these strategies were applied, the work does recognize the challenges that come with researching based on literature. One prominent challenge is the possibility of publication bias. Studies that have positive outcomes tend to be published more often which could lead to a disproportionate amount of literature dealing with positive outcomes and underreported challenges and failures within initiatives aimed at digitizing and transforming business

processes. This leads to an unreasonably positive perception concerning the adoption of technology and its perceived value in the supply chain industry.

A lack of primary data serves as another limitation. The absence of interviews, surveys, or direct observations from actual organizations means that the study is contextually shallow and lacks insight from data that has not been processed into an abstract form. Also, the use of secondary data implies that the study has to depend on other researchers' data which could be biased and poorly done.

Regardless, these limitations are alleviated by the orderly and methodical approach taken in the review of the literature accompanied by adherence to the review's ethics, mathematics, and logic underpinning the work. Such boundaries enhance the evaluation and outcome by relying on academic reputation demonstrating that the study seeks to achieve rigorous assessment and validity of claims regarding digital transformation in supply chain management.

3 Literature Review

From rigid, linear models to extremely dynamic, networked ecosystems, deliver chain optimization has seen considerable change in recent years. Although increasing performance even as decreasing expenses and risks continues to be the center goal of supply chain optimization, the techniques for doing so have drastically altered due to transformations in digital generation, analytics, and worldwide interconnection.

For deliver chain optimization, the Supply Chain Operations Reference (SCOR) model stays a essential paradigm. Planning, sourcing, manufacturing, handing over, returning, and permitting strategies are all included inside the SCOR model, which was created by means of the Supply Chain Council and is now controlled by APICS. However, using real-time analytics and multi-echelon inventory optimization (MEIO) procedures has significantly improved the SCOR model in recent years. MEIO allows agencies to have higher strategically placing of inventory across distinct deliver chain stages at the same time as accounting for lead instances, service ranges, and demand fluctuation. As end result, there's much less surplus inventory, fewer stockouts, and better deliver chain performance average (APICS., 2018). Following the COVID-19 pandemic, supply chain resilience has emerged as a main concerning situation for agencies all over the world. Despite being within your budget, traditional just-in-time (JIT) systems turned out to be extraordinarily vulnerable to interruptions. Consequently, corporations have been the use of digital control towers—centralized structures that offer real-time, end to end deliver chain visibility—in more numbers. These manage towers use advanced analytics and statistics from numerous resources to track key overall performance indicators (KPIs), spot viable interruptions, and advocate corrective measures. A corporation's capability to proactively reduce dangers is substantially stepped forward by using this real-time understanding, which also facilitates rapid decision-making (Forbes., 2024).

The utility of Machine learning algorithms to anticipate feasible disruptions is a noteworthy development in reduction in risk. These algorithms foresee events

like delays, demand spikes, or stock shortages weeks in advance with the aid of analyzing historical records, weather patterns, geopolitical trends, and supplier performance. This allows groups to take preemptive measures earlier than a disruption takes place, which includes rerouting shipments, finding substitute suppliers, or editing manufacturing schedules (Zhu and Cheng, 2024). The incorporation of circular economic system principles into supply chain design is another important region of improvement. Businesses are the use of Internet of Things (IoT) generation to help reverse logistics techniques in response to developing regulatory demand and environmental consciousness. Effective monitoring of return items, which might be ultimately recycled or reconditioned, is made feasible by means of IoT sensors integrated into products and packaging. This creates new income streams through resale or remanufacturing in addition to reducing material and electronic waste (Islam and Huda, 2018)

Hyper-personalization has also emerged as a forceful differentiation in client marketplaces. AI-driven demand sensing is being used by businesses to predict customer options at finer levels, such as location, channel, or even individual customers. According to E2open (2024), this improves prediction accuracy and allows groups to customize merchandise and transport techniques to satisfy precise client needs, increasing consumer happiness and reducing overproduction. Essentially, technology integration, predictive abilities, environmental attention, and customer-targeted techniques outline contemporary supply chain optimization. In addition to improving performance and provider degrees, these trends assist businesses in developing extra sturdy and sustainable supply chains. Supply chains are present process digital transformation thanks to variety of present-day technologies that enhance resilience, visibility, agility, and efficiency. Digital twins, blockchain, robotic manner automation (RPA), the Internet of Things (IoT), Artificial intelligence (AI), and machine learning (ML) are some of the most revolutionaries. These technologies are transforming traditional supply chain operations into intelligent, self-sufficient systems that may make decisions in actual time and evolve continuously.

AI and ML are valuable to the virtual transformation of deliver chains. One fundamental software is predictive upkeep, which uses AI algorithms to research real-time sensor records from machinery and gadget. These models can hit upon anomalies and expect equipment failure before they occur, allowing scheduled protection that reduces unplanned downtime by up to 35% (Insider, 2025). This approach not only ensures smoother operations but also reduces maintenance costs significantly. Another transformative use is in **dynamic routing**. For instance, UPS's On-Road Integrated Optimization and Navigation (ORION) system leverages machine learning to determine the most efficient delivery routes. The system has saved UPS over 10 million gallons of fuel annually and significantly cut down on carbon emissions and operational costs (Tracr™).

Cognitive automation, another AI application, is revolutionizing inventory management. Retailers such as Walmart use AI-powered bots to scan and monitor inventory shelves, achieving up to 99.8% accuracy in stock counting. This ensures optimal stock levels, minimizes shrinkage, and enhances customer satisfaction through product availability.

Internet of Things (IoT)

The Internet of Things enables real-time data collection and communication across supply chain assets, significantly enhancing operational control. One high-impact application is cold chain monitoring, where temperature-sensitive goods—such as food and pharmaceuticals—are tracked in transit. IoT sensors continuously monitor environmental conditions, triggering alerts for deviations. This technology has led to a significant reduction in spoilage and waste, enhancing food safety and compliance (Tech, 2024).

In asset tracking, IoT technologies provide continuous visibility over goods in transit and in storage. This has led to improved logistics coordination, reduced theft or loss, and even lower insurance premiums for companies due to the enhanced traceability and accountability (IAIS., 2023).

Blockchain Technology

Blockchain offers immutable, decentralized records of transactions, bringing transparency and trust to supply chains. **De Beers' Tracr platform** uses blockchain to authenticate the provenance of diamonds, tracing them from mine

to retail. This not only assures consumers of product legitimacy but has also reduced certification times from weeks to just a few days (Tracr™).

Another prominent example was the **Maersk-IBM TradeLens** platform, which aimed to digitize and secure international shipping documentation. While TradeLens was eventually discontinued due to scalability and adoption challenges, it demonstrated the potential of blockchain to reduce documentation costs by up to 45% and improve cross-border trade efficiency (Maersk, 2022).

Robotic Process Automation (RPA)

RPA enables the automation of repetitive, rule-based tasks within business processes. For example, Procter & Gamble used RPA to automate over 90% of their purchase order processing. This resulted in a drastic reduction in manual errors—from 8.2% to just 0.4%—and led to faster procurement cycle times (Werbinska-Wojciechowska and Rogowski, 2025).

Digital Twins

A digital twin is a virtual model of a physical process, system, or product that allows simulation and performance analysis. Boeing uses digital twins to optimize aircraft production lines. These simulations help engineers identify potential inefficiencies and test process changes virtually, leading to a 25% reduction in rework and quality control costs (Kabashkin, 2024).

Impact of Digital Tools on Supply Chain Efficiency

The integration of digital tools in supply chain management has significantly enhanced operational performance across industries. From reducing lead times and costs to fostering sustainability and transparency, these technologies have ushered in a new era of supply chain efficiency. Between 2018 and 2024, organizations that invested in digital transformation reported quantifiable improvements in key performance areas, as well as strategic gains in collaboration and agility.

Quantifiable Improvements (2018–2024)

Lead Time Reduction

The decrease in lead times for production and transport has been one of the most obvious outcomes of digital transformation. The use of additive manufacturing, also referred to as three-D printing, in the car industry has enabled agencies to create intricate parts as needed without requiring a whole lot of expensive

equipment's. This has decreased lead instances by using as much as 60% and substantially shortened production cycles, mainly in low-extent production and prototyping (AddComposites., 2025). Nowadays, automakers employ 3-D printing to reduce transit delays, localize production, and react quicker to part shortages. Computer vision technologies are transforming logistics inside the retail sector. Pallet scanning and sorting have been computerized way to AI and superior photo popularity technologies, which have simplified pass-docking processes. This has increased warehouse efficiency and accelerated the flow of commodities. Businesses that use those answers have proven improvements in dock-to-stock cycle times of 30–40% (Simpson and Qasim, 2025).

Cost Optimization

digital technologies are essential for lowering inventory costs. Static predictions are frequently used in traditional inventory systems, which can result in stockouts or overstocking. AI-driven inventory management systems, on the other hand, dynamically modify safety stock levels based on real-time supply and sales data. To maintain ideal inventory levels, these systems examine supply interruptions, seasonality, and demand trends. As a result, businesses have improved service levels and reduced inventory holding costs by up to 25% (E2open., 2024).

Sustainability Gains

Sustainability in the Environment is another essential place of influence. By deciding on the best transport routes, route optimization algorithms, which are fueled via real-time site visitors and environment information, allow logistics corporations to lessen fuel utilization. By maximizing vehicle masses and decreasing idle periods, those AI-primarily based technologies considerably lower greenhouse fuel emissions. Logistics corporations who have implemented these solutions have, on common, reduced their carbon emissions with the aid of 15–20%, consistent with recent enterprise surveys (KPMG, 2024).

Strategic Impacts

Digital tools are changing supply chain management's strategic elements beyond operational information. The utility of blockchain technology to enhance provider

collaboration is one such development. Blockchain enables obvious transaction documentation and best checks throughout the supply chain via supplying a safe, unchangeable document. This openness ensures regulatory compliance, lowers battle, and builds stakeholder self-belief.

Businesses who use blockchain for settlement administration and provider onboarding, for instance, have visible improvement in responsiveness to quality issues, extra traceability, and faster dispute resolution (Systems, 2024). Additionally, this tech is crucial for enhancing traceability in industries like meals and pharmaceuticals, in which end- to-end visibility is necessary for compliance and protection.

Gaps Identified in Current Research

Although the global supply chain environment has benefited substantially from digital transformation, there are nonetheless some of gaps that prevent this promise from being fully realized, in step with current academic and enterprise take a look at. If left unattended, these deficiencies may also limit the long-term viability, inclusivity, and scalability of digital supply chain projects.

Technology Integration Debt

Technology integration debt is one of the maximum enduring issues that organizations, especially the ones in the production industry, must address. Many corporations use old systems that are not made to work properly with current digital technologies like blockchain, cloud-based analytics, and Internet of Things (IoT) systems. Data silos prevent end to end visibility and limit automation abilities in the ensuing fragmented IT system. This technical debt delays real-time choice-making and increases preservation expenses and operational complexity (KPMG, 2024). The difficulty is made worse in multi-supplier setups by the absence of standardized records formats and application programming interfaces (APIs).

Skills Mismatch

The contemporary workforce's mismatch in skills represents a second notable gap. Professionals with expertise in fields like Machine Learning, data

visualization, and coding languages like Python, R, and SQL are in more demand as companies pass in the direction of information-pushed deliver chains. Many deliver chain teams, however, are poor in those areas, which results in less than perfect usage of state-of-the-art analytics and decision-guide tools (KPMG, 2024). This deficiency compromises the excellent of insights obtained with the aid of digital technologies further to having an impact on deployment. and in growing and non-urban areas, where get access to technical education is more restrained, the disparity grows.

Measurement Limitations

The restrained focus of contemporary overall performance measuring techniques represents any other research need. Numerous research use discrete key performance indicators (KPIs), such stock turnover, lead time reductions, or cost savings, to evaluate virtual supply chain solution. Despite their importance, these measures from time to time forget about systemic outcomes, like as the long - term outcomes of digital transformation on carbon footprints, dealer resilience, or client happiness (KPMG, 2024). This narrow awareness hinders the introduction of comprehensive frameworks for choice-making and leads to disjointed adoption approaches that disregard the interdependencies in the supply chain environment.

4 Theoretical Background

Small and medium-sized organizations (SMEs) are nevertheless significantly underrepresented in studies and adoption plans related to digital transformation. These corporations typically have little IT assist, antiquated generation, and tight budgets. As a end result, they find it tough to adopt technologies that want initial capital and technical knowledge, such blockchain, IoT, and real-time statistics analytics. (KPMG, 2024) claims that SMEs regularly lack the bandwidth necessary to keep data interoperability with larger companions or deal with cybersecurity issues. Supply chain inclusivity is threatened by using this digital gap, which additionally makes people greater vulnerable, particularly at some stage in instances of world upheaval like the COVID-19 epidemic or geopolitical crises. With the incorporation of digital technology and data-driven insights, supply chain performance evaluation has undergone transformative change in the modern- day. The Supply Chain Operations Reference (SCOR) model remains one of the maximum vital core frameworks. Plan, Source, Make, Deliver, and Return are the five center areas that make up SCOR, an prepared approach for assessing supply chain operations that became first created by means of the Supply Chain Council and is now maintained through APICS (APICS., 2018). But as digitization has extended, this paradigm has modified notably to stay relevant in the context of Industry 4.0.

Extended SCOR Framework

Digital key performance indicators (KPIs) that show off the capacity of smart technology have been included into the new SCOR framework. For example, Predictive Order Accuracy Scores, which use Machine learning algorithms to predict the likelihood of efficient delivery commitments, have changed extra conventional measurements like order success time and wonderful order prices. Because companies can proactively manage expectations and inventory issues, this no longer only improves transparency but additionally effects in higher customer retention rates (APICS., 2018).

By enabling organizations to gauge responsiveness, agility, or even environmental sustainability, virtual KPIs expand the model's use past

operational performance. In addition, the SCOR model includes cybersecurity resilience measurements, that are becoming more and more critical in related virtual ecosystems.

Next-Gen Metrics

One of the most notable developments is the evolution of the Cash-to-Cash (C2C) Cycle metric, which is being changed via next-technology metrics as supply chains become more data-driven. Traditionally, the C2C cycle measures the time among when a cooperation pays for stock and while it receives charge from clients; but, in digitally enabled surroundings, this has been stronger by Dynamic Working Capital Algorithms, which analyze actual-time financial transactions and outside market situations to optimize coins flows.

Table1: *Comparison of Traditional Metrics and Their Digital Supplements in Supply Chain and Working Capital Management (KPMG, 2024)*

<i>Traditional Metric</i>	<i>Digital Supplement</i>	<i>Impact</i>
<i>Cash-to-Cash Cycle</i>	Dynamic Working Capital Algorithm	Enhanced liquidity
<i>Inventory Turnover Ratio</i>	AI-based Demand Sensing	Reduced stockouts and waste
<i>Order Fulfillment Time</i>	Predictive Dashboards	Increased service reliability

Real-time selection-making and strategic agility are made feasible by means of these digital measures, which can be crucial inside the volatile and uncertain surroundings of nowadays. They also make it possible to include non-conventional value drivers, which includes dealer diversity index or carbon emissions consistent with shipment, which give a extra comprehensive, stakeholder-centric perspective on supply chain overall performance.

Supply chain control is evolving from a reactive role to a predictive, transparent, and relatively automated manner due to the confluence of virtual technologies which includes artificial intelligence (AI), the Internet of Things (IoT), blockchain, and robotic process automation (RPA). These technologies are fundamental enablers that transform the structure and good judgment of supply chains, now not simply accessories.

AI Implementation Framework

Machine learning, a subset of artificial intelligence, has emerged as an important tool for logistics planning, inventory optimization, and demand forecasting. One popular model is the Random Forest Regressor, which makes use of price information, seasonality tendencies, beyond sales, and even social media indicators to accurately forecast future demand. This model functions by building an ensemble of decision trees and averaging their outputs, thereby reducing overfitting and improving generalizability (Simpson and Qasim, 2025).

Leading firms now integrate AI with **cloud-based enterprise resource planning (ERP)** systems, enabling real-time adjustments to procurement and production schedules. For example, Walmart and Amazon use AI to forecast daily product demand across thousands of SKUs, reducing excess inventory while maintaining high service levels (Socha, 2024).

Blockchain Architecture

Blockchain technology introduces **decentralized transparency** to global supply chains. By using **smart contracts**, which are self-executing agreements coded on the blockchain, organizations can automate payments, verify quality compliance, and enforce contractual obligations without intermediaries. These smart contracts are particularly valuable in high-value or ethically sensitive industries.

A leading example is the **De Beers Group's Tracr platform**, which traces the provenance of diamonds from mine to retail. Every transaction—whether mining, cutting, or certification—is recorded on an immutable distributed ledger accessible to stakeholders, including end consumers. This reduces the potential

for fraud, improves product authenticity, and ensures compliance with ethical sourcing standards (Tracr™).

Internet of Things (IoT)

IoT devices enhance **real-time visibility** and **asset tracking**. Smart sensors embedded in shipping containers can monitor temperature, humidity, and shock levels—critical for pharmaceuticals and perishables. These sensors feed data into centralized dashboards, enabling proactive interventions in case of anomalies. Cold chain monitoring, for instance, has significantly reduced spoilage in food logistics (Tech, 2024).

Robotic Process Automation (RPA)

RPA facilitates the automation of **repetitive back-office tasks**, such as purchase order generation, invoice matching, and shipment scheduling. Firms like **Procter & Gamble** have integrated RPA into procurement operations, achieving faster turnaround times and reduced manual errors. RPA bots also serve as digital assistants in customer service and compliance reporting, freeing human resources for more strategic tasks (Werbinska-Wojciechowska and Rogowski, 2025).

The successful adoption of digital technologies in supply chain management requires a well-structured integration strategy that balances technical implementation with organizational change management. A phased implementation roadmap ensures that digital initiatives are aligned with business goals and that disruptions to ongoing operations are minimized. Simultaneously, change management practices are essential to prepare the workforce and stakeholders for the cultural and procedural shifts required for digital transformation.

Phased Implementation Roadmap

Phase 1: Foundation

The first step in digital integration involves modernizing the core IT infrastructure, particularly the Enterprise Resource Planning (ERP) system.

Migrating to next-generation ERP platforms such as **SAP S/4HANA** provides a

flexible, real-time, cloud-compatible system capable of supporting advanced technologies such as artificial intelligence, robotic process automation, and IoT. Consolidating supply chain records, increasing end to end visibility, and speeding up decision-making are all made viable by modern ERP structures. According to (KPMG, 2024), because of advanced information integration and standardized tactics, corporations who finished ERP transformation implemented comply with-up digital technology 30% faster.

Phase 2: Optimization

After organizing a stable digital core, businesses can start piloting advanced technology. This phase consists of launching machine learning models for forecasting, imposing IoT-enabled asset monitoring, and checking out blockchain programs for provider contracts. Pilot programs should be designed with measurable key overall performance indicators (KPIs) such as forecast accuracy development, discount in stockouts, and shortened procurement cycles.

During this segment, it's important to focus on AI and system machine of deployment in high-impact areas like stock making plans and transportation logistics. This technology can appreciably enhance operational performance and resilience through enabling predictive analytics and automated responses to disruptions (KPMG, 2024). A commonplace quality practice is initially a single vicinity, product line, or feature and steadily scale primarily based on effects.

Phase 3: Expansion and Innovation

Organizations have to amplify these technologies throughout departments and regions as soon because the preliminary pilots display promise. Investing in digital twins, huge-scale RPA, and enhancing AI models using more datasets are all part of this phase. The goal is to broaden an sensible, integrated deliver chain surroundings with the aid of the belief of this phase this is proactive in preference to response.

Change Management Checklist

Implementing new technologies without a people-focused change management plan often leads to underutilization or failure. One effective tool is the **Digital**

Fluency Index, which measures the readiness of the workforce to engage with digital tools, platforms, and workflows. This index evaluates factors such as:

- Digital literacy levels across departments
- Comfort with data-driven decision-making
- Willingness to adopt new platforms
- Collaboration in cross-functional digital projects

The results can inform customized training programs and leadership engagement strategies. According to (KPMG, 2024), companies that implemented a digital fluency assessment as part of their change management process observed a 40% increase in employee adoption rates of new digital tools.

Other essential elements of a successful change management strategy include:

- **Executive Sponsorship:** Active involvement of leadership to drive cultural transformation
- **Communication Plans:** Transparent messaging around why and how changes are happening
- **Feedback Loops:** Mechanisms to collect, analyze, and act on employee feedback
- **Recognition Systems:** Incentives for digital adoption and innovation at the employee level

By aligning technology rollout with human-centered transformation, companies can build a resilient, adaptive supply chain that thrives in today's volatile and uncertain global environment.

5 Results and Analysis

Several recurrent factors which might be used to categorize studies are discovered by using a thorough synthesis of the scholarly literature on digital transformation in supply chains (SCs). One of the main elements is the kind digital technology being tested. Digital twins, blockchain, robotic technique automation (RPA), synthetic intelligence (AI), the Internet of Things (IoT), and large information analytics are some of the techniques which can be commonly used to divide up studies and research (Queiroz et al., 2020). For instance, research on AI and machine learning frequently focus on automated decision-making, demand for forecasting, and predictive maintenance (Al-Khatib, 2023). IoT research places a sturdy emphasis on sensor-based monitoring and real-time asset tracking, specifically in logistics concerning temperature-sensitive items like foods and medicinal drugs (Ben-Daya et al., 2019). Blockchain's capacity to enhance traceability and safe data exchange across SC stakeholders has drawn a whole lot of interest (Saberli et al., 2019).

The industry context serves as a 2nd categorization axis. The literature is dominated by means of manufacturing, logistics, and retail because of their heavy dependence on worldwide networks and actual-time operations. More recently, healthcare and agri-food supply chains have gained traction, especially due to challenges posed by the COVID-19 pandemic (Sun et al., 2022). The academic focus on these industries is primarily due to the high stakes associated with delays, product integrity, and traceability.

Geographical scope forms another classification layer. Studies often originate from regions with mature digital infrastructures such as North America, Western Europe, and East Asia (Ivanov et al., 2019). These regions not only have higher digital adoption rates but also benefit from supportive governmental policies and advanced technology ecosystems. Emerging economies are underrepresented, although a small but growing body of literature is beginning to address digital supply chain transformation in South Asia, Africa, and Latin America.

Methodologically, studies range from conceptual and theoretical models to empirical case studies and quantitative analyses. Conceptual papers propose

frameworks for digital integration, emphasizing the alignment between technology, people, and processes (Kache and Seuring, 2017). Empirical studies often rely on surveys, interviews, or case-based methods to explore the adoption, impact, and challenges of digital tools in real-world settings.

Thematically, the literature maps onto operational and strategic goals. Operationally, digital technologies support improved efficiency, reduced cycle times, and cost savings. Strategically, digital transformation is linked to supply chain resilience, sustainability, and agility (Payen et al., 2021) The shift in thematic emphasis reflects the changing nature of global supply chains—now recognized as complex, adaptive systems rather than linear models.

Recent literature reveals a noticeable evolution in supply chain paradigms. Traditional, linear models are being replaced by digitally enabled, networked ecosystems that leverage real-time data for proactive decision-making. This shift is supported by the convergence of several enabling technologies. Tasks such as demand forecasting, predictive maintenance, and dynamic pricing are seeing a growth within the use of AI and system machine learning (Al-Khatib, 2023) Particularly in cold chain logistics, IoT gadgets offer specific, real-time records concerning area, temperature, humidity, and vehicle status (Pinho et al., 2020). When used in tandem, these tools improve deliver chain visibility, responsiveness, and performance.

The relationship of environmental sustainability and digital transformation is a brand new and really tremendous trend. Digital technology is being used to sell green initiatives in addition to being cost-effective. AI-powered path optimization strategies make contributions to decrease pollution and fuel consumption (Bag et al., 2020). Sustainability claims are confirmed via blockchain-based certification structures, growing consumer self-assurance and transparency (Saberli et al., 2019) With digital twins and IoT getting used to track product lifecycles, facilitate reverse logistics, and inspire reuse and recycling, the circular economy idea is turning into more popular on this setting (Liu et al., 2017).

Another frequent subject matter is resilience, specifically within the face of world disruptions just like the COVID-19 pandemic, geopolitical unrest, and climate

calamities. The pandemic has proven how inclined global SCs are, and it has reaffirmed the need of end-to-end visibility and quick response structures. In order to facilitate state of affairs planning and real-time decision-making, digital control towers—centralized systems that combine information throughout the deliver chain—are being used more and more (Ivanov and Dolgui, 2020).

Despite great advancements, essential obstacles nevertheless exist. Integration debt from old IT structures which might be incompatible with modern-day digital technologies is one such trouble. Many groups still use antiquated Enterprise resource planning (ERP) systems that are incompatible with blockchain networks, IoT systems, and Artificial intelligence (Kache and Seuring, 2017). According to (Bag et al., 2020), a related trouble is the skill gap, as many supply chain specialists lack the technical understanding required to well integrate and use these technology..

The hurdles confronted by small and medium-sized organizations (SMEs) are disproportionately excessive. SMEs often lack the human, technical, and financial resources important for digital transformation in comparison to larger enterprises (Moeuf et al., 2018). Due to this, there is now a digital gap inside and throughout industries, with SMEs being underrepresented in both educational research and information on digital utilization.

Numerous real-world examples that display the progressive capability of digital generation in deliver chains may be discovered in the course of the literature. According to reviews, UPS's ORION (On-Road Integrated Optimization and Navigation) tech optimizes delivery routes using sophisticated analytics, saving 10 million gallons of fuel yearly at the same time as reducing emissions and enhancing operational performance (Blum, 2021). Similar to this, Walmart has used AI-powered robots to reveal stock in actual time, which has improved customer happiness and inventory accuracy (Al-Khatib, 2023).

Blockchain generation is utilized by De Beers' Tracr platform in the luxurious goods industry to guarantee the ethical source and authenticity of diamonds, boosting consumer belief and cutting down on certification delays (Saber et al., 2019). IoT sensors were utilized by businesses in the pharmaceutical enterprise

to monitor temperature-sensitive shipments, substantially reducing spoilage and improving adherence to legal requirements (Pinho et al., 2020).

In manufacturing, digital twins—virtual copies of real systems—are being applied an increasing number of to test situations earlier than they may be implemented, perceive inefficiencies, and replicate manufacturing situations. Digital twins are used in Boeing's aircraft manufacturing traces to find bottlenecks and decrease remodel, which lowers running expenses and improves product best (Liu et al., 2017)

case studies like these illustrate a dual value proposition: strategic advantages like sustainability, transparency, and consider, as well as operational advantages like cost savings and efficiency. The literature emphasizes how critical it' combine digital efforts right into a supporting technological and cultural infrastructure and in shape them with overarching organizational vision

6 Discussions and Conclusions

Key findings from the frame of scholarly studies on supply chain digital transformation are summarized in this research. The results verify that cutting-edge tendencies in supply chain operations are largely pushed by digital technologies, together with AI, IoT, blockchain, and RPA. When mixed, these instruments provide for increases in cost-effectiveness, speed, accuracy, and adaptability (Queiroz et al., 2020). Real-time visibility, predictive analytics, and improved traceability are amongst these technologies' most important advantages. Businesses are able to hold a watch on disturbances and take preemptive measures once they have actual-time visibility. Better planning and forecasting are made possible by using predictive analytics, which also lowers waste and increases service standards. Increased traceability, especially thru blockchain, promotes client trust and improves compliance. But problems nonetheless exist. A big obstacle that often necessitates high priced redesigns or workarounds is the combination of new generation with present structures. Implementation is made harder by means of supply chain professionals' lack of digital abilities. Due to resource limitation and the complexity of new technologies, SMEs mainly locate it difficult to live up (Moeuf et al., 2018).

RQ1: Which digital equipment had been used maximum regularly?

The most usually referred to technologies are RPA, blockchain, IoT, and AI. Blockchain ensures facts integrity and transparency, IoT allows real-time tracking and environmental monitoring, RPA simplifies repetitive responsibilities, and AI and machine learning are utilized for forecasting and automation (Al-Khatib, 2023; Saberi et al., 2019)

RQ2 How has the performance of the supply chain been superior by these technology?

Measurable profits in some of essential performance metrics have resulted from these technologies. AI improves demand forecasting and dynamic routing. IoT minimizes losses and enhances traceability. Blockchain expedites regulatory compliance and authenticity verification. RPA reduces manual errors and improves processing speed (Queiroz et al., 2020).

RQ3: What are the main obstacles and challenges?

Major barriers include legacy IT systems, lack of technical expertise, and limited adoption among SMEs. Other challenges include data silos and underdeveloped metrics for evaluating digital transformation's systemic impact (Kache & Seuring, 2017; Moeuf et al., 2018)

RQ4: What gaps remain and what are future research directions?

Gaps in the literature include limited empirical data from SMEs, developing economies, and service sectors. Future research should focus on holistic integration frameworks, cross-sectoral comparisons, and longitudinal studies to assess long-term impacts. There is also a need to examine the interplay between technology, organizational culture, and employee readiness (Ivanov & Dolgui, 2020).

Limitations and Future Work

While this study offers a comprehensive synthesis of the current literature on digital transformation in supply chain management, it is important to acknowledge several inherent limitations. These constraints shape both the scope of the present analysis and the direction of future research efforts.

Reliance on Secondary Data

A key limitation of this study is its exclusive reliance on secondary sources, which may not fully capture practitioners' real-world experiences and thus shapes findings based on previous researchers' perspectives, potentially leading to incomplete understanding (Webster and Watson, 2002).

Primary empirical methods like interviews and ethnographic research offer the depth and contextual understanding that secondary data often lacks. While digital technologies such as blockchain, AI, and IoT are widely discussed, the literature tends to overlook or oversimplify the organizational dynamics, employee reactions, and change management challenges involved in their implementation.

Without direct engagement with organizations undergoing transformation, these critical aspects remain insufficiently explored (Vial, 2021).

The possible publication bias in the tested literature another essential drawback. While unsuccessful initiatives, behind schedule projects, and bad consequences are much less normally said, a success case studies and appropriate effects are generally covered in educational journals and industry media (Podsakoff et al., 2003). This prejudice might cause an unduly positive illustration of digital transformation, downplaying the real risks, costs, and problems related to such tasks.

For example, although several articles emphasize the efficiency and transparency benefits of blockchain in deliver chains, a whole lot much less studies specializes in the problems with records interoperability, legal compliance, or stakeholder resistance that would save you a successful implementation (Francisco and Swanson, 2018). As a result, practitioners and policymakers seeking to learn from the literature may be misled by an evidence base that is biased toward best-case scenarios.

Large multinational companies and advanced economies, especially in North America, Western Europe, and East Asia, dominate the literature on digital transformation in supply chains, while SMEs and firms in emerging countries are significantly underrepresented (Nouiri et al., 2020), This skews findings, limiting their generalizability and overlooking the unique challenges faced by resource-constrained businesses, such as limited access to capital, technology infrastructure, and skilled personnel. SMEs play a crucial role in global supply chains but often lack the scale, financial resources, and expertise to implement advanced digital solutions, and their exclusion from empirical research hinders a comprehensive understanding of digital transformation at all supply chain levels (Nambisan et al., 2019). Similarly, supply chains that perform in regions with fragmented markets or insufficient infrastructure can need radically distinct digital strategies, which are not thoroughly included by means of present

The literature lacks longitudinal studies on the long-term impacts of digital transformation, focusing mainly on short-term gains like cost reduction rather than effects on organizational learning, agility, or resilience (Pagani and Pardo, 2017). Few integrated frameworks assess social, economic, and environmental outcomes together, despite the need for a holistic triple bottom line approach (Elkington and Rowlands, 1999).

Future Research Directions

Future studies should focus on a few crucial areas in order to overcome these constraints and progress the subject.:

a) Approaches to Primary Data Collection and Mixed Methods

More empirical research primarily based on unique data are desperately needed. Organizational lifestyle, leadership styles, and worker perceptions that impact the effectiveness of digital transformation may be uncovered the use of qualitative strategies which includes focus groups, interviews, and case studies. Through the discovery of statistically huge patterns and correlations, quantitative strategies along with surveys and performance analytics can enhance these insights. A deeper, and more complete view of transformation procedures will be obtained by means of combining these techniques (Creswell and Clark, 2017).

b) Taking into Account Various Organizational Contexts

In order to improve the generalizability of the results, SMEs and organizations from developing economies should be actively included in future research. It would be easier to discover context-specific drivers and inhibitors of digital transformation if comparative studies are conducted across various business sizes, sectors, and geographical areas. It is crucial to comprehend these differences in order to create inclusive and flexible digital strategies.

c) Longitudinal Studies

Long-time period studies is needed to understand how digital transformation unfolds over the years. Longitudinal studies can reveal whether initial benefits are sustained, whether new risks emerge, and how organizations evolve their capabilities and governance structures in response to ongoing digitalization.

Such studies would also help identify best practices for scaling and institutionalizing digital innovations.

d) Development of Integrated Evaluation Frameworks

There is an opportunity to develop multi-dimensional assessment models that incorporate financial performance, operational metrics, environmental impact, and social outcomes. These frameworks should also consider the ethical implications of automation, algorithmic decision-making, and data governance. A balanced scorecard approach or a sustainability maturity model could be adapted for this purpose (Kaplan and Norton, 1996, Baumgartner and Ebner, 2010).

e) Interdisciplinary and Cross-Sector Collaboration

Given the complexity of digital transformation, interdisciplinary research that combines insights from information systems, operations management, human resource development, and sustainability science is particularly valuable. Collaboration with industry practitioners and policymakers can also ensure that research addresses real-world challenges and informs evidence-based policy and strategic decision-making.

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