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The Importance of Digital Transformation (5.0) in Supply Chain Optimization: An Empirical Study

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Abstract

The topic of digital transformation in supply chain optimization has garnered considerable attention in recent years due to its importance. The purpose of the study was to offer empirical evidence and insights into the advantages and obstacles linked with digital transformation in supply chain management. To investigate the effects of digital transformation on supply chain optimization, the research employs a hybrid methodology and comprehensive approach that includes a thorough literature review, the creation of a theoretical framework, and the presentation of empirical findings through various case studies using the predefined selection criteria. The case analyses highlight crucial elements that support effective digital transformations, including real-time data analytics, teamwork, blockchain technology, digital twin augmented and virtual reality and collaborative robots. The practical implications from the findings of this study, proffers insights that can be extremely helpful for professionals in various industrial sectors and businesses planning similar digital transformation journeys. This empirical study with regards to the implication of Digital transformation 5.0 on supply chain management is novel to the body of literature. It is however necessary to conduct more study to confirm the results, apply them to a wider range of businesses, and investigate different aspects of digital transformation in supply chain optimization.

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1. Introduction

In today's fast-paced and intensely competitive business landscape organizations are increasingly understanding the importance of digital transformation in fueling efficiency agility and competitiveness across various sectors. Supply chain management stands out as a critical area where digital transformation has a pivotal role. By leveraging digital technologies and data driven strategies businesses can transform their supply chain processes, gain invaluable insights enrich operation capabilities and effectively cater to constantly evolving customer demands. It is quite difficult for the conventional supply chain management approaches to satisfy the needs of the fast-paced corporate environment of today. The emergence of Digital Transformation 5.0, which comprises of cutting-edge tools like blockchain, Internet of Things, and artificial intelligence, presents a strong chance to revamp and improve supply chain procedures. Nevertheless, there is a conspicuous lack of empirical studies examining the true impact

and efficacy of Digital Transformation 5.0 in actual supply chain scenarios. By undertaking an empirical analysis of the significance of Digital Transformation 5.0 in supply chain optimization, this study seeks to close this knowledge gap and offer insightful advice to companies looking to improve their resilience and competitiveness in an increasingly digitalized environment.

Supply chain management (SCM) is the strategic coordination and management of all activities encompassed in the flow of goods, services, information, and finances from the initial sourcing of raw materials to the ultimate delivery of products or services to end customers. It involves planning, execution, control, and monitoring across multiple organizations and stakeholders within the supply chain (Zhang et al., 2023).

The deficiency of real-time information and openness is one among the primary drawbacks with conventional supply chain management. But with the help of revolutionary technologies like the Internet of Things (IoT), cloud computing, and



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big data analytics, organizations can now capture and analyze enormous amounts of data across the supply chain. Organizations may then quickly make data-driven decisions by gaining real-time insights into inventory levels, manufacturing plans, transportation, and demand patterns. Better coordination, less delays, fewer disruptions, and improved supply chain performance are all benefits of more visibility (Hamidu et al., 2023).

Incorporating digital innovations into multiple facets of a company's activities, procedures, and strategies to fundamentally alter how it runs and provides value to its customers is known as digital transformation. Utilizing digital tools, technology, and data is necessary to promote innovation, increase productivity, improve customer experience, and maintain competitiveness in a quickly changing digital environment (Chin et al., 2023). Digital transformation provides a broad variety of initiatives and initiatives that can differ between businesses and organizations. Customer experience, business processes, data analytics, supply chain and logistics, cutting-edge technologies for product development, business models, and workforce empowerment are some of the key areas where digital transformation may have a significant impact (Kraus et al., 2021; Feliciano-Cestero et al., 2023). Adopting disruptive technologies is a key component of the digital transformation process since it helps to improve societal welfare, productivity, and profit (Ebert and Duarte, 2018).

The purpose of this study is to present empirical evidence and insights on the advantages and difficulties of supply chain management's digital transformation. To investigate the function and effects of digital transformation on supply chain optimization initiatives, a number of case studies were used in an empirical analysis. In the context of Industry 5.0, "digital transformation" relates to the fusion of modern digital technologies with human-centered strategies to promote innovation and value creation in all industrial sectors (Skobelev and Borovik, 2017). The fourth industrial revolution, known as Industry 4.0, laid the foundation for Industry 5.0, which stresses collaboration between humans and machines to increase profitability, effectiveness, and personalization (Danuso and da Silva, 2022).

The rest of this article is arranged as follows: Section 2 presents a description of the research design and methodology. Section 3 presents literature review which covers digital transformation in industry 5.0 and supply chain optimization in industry 5.0 and a brief review of related literature. Section 4 presents the empirical results from the various case studies under study. Section 5 presents the results and discussion. Finally, section 6 gives an overview of the conclusions, practical implication for industry professionals and companies, and future research.

2. Research Design

The research methodology utilized in this work is a combination of literature review, theoretical framework development, and empirical studies based on case analyses. Figure 1 shows the research design diagram and the process involved.

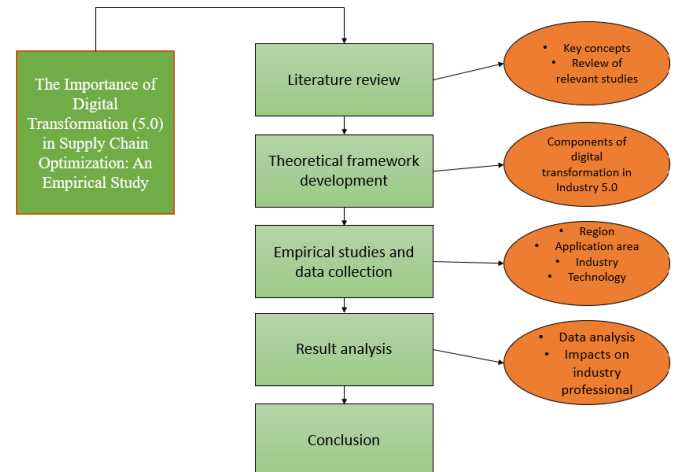


Fig. 1. Research methodology diagram

The research seeks to highlight the significance of digital transformation in the competitive corporate environment of today. It demonstrates how important digital transformation is for boosting productivity, adaptability, and competitiveness in a range of industries, with supply chain management receiving particular attention. Also, this section introduces key concepts such as Industry 5.0, digital transformation components, and the role of disruptive technologies in the transformation process. Finally, the literature review compares various recent studies, highlighting the gaps the research work aims to fill.

We establish a theoretical framework by discussing the components of digital transformation in Industry 5.0. It covers aspects such as Human-Machine cooperation, customized goods and services, data integration and analytics, digital twins, cybersecurity, skills development, and workforce adaptation. The theoretical framework serves as the basis for understanding how digital transformation, especially in the context of Industry 5.0, can impact supply chain optimization.

The empirical evidence are presented through case studies that are selected from relevant studies that are selected from relevant studies obtained from google scholar between the year 2021 to 2023, to investigate the function and effects of digital transformation on supply chain optimization initiatives. Each case study is summarized, providing details on the author, country/region, industrial sector, and application area. The studies cover a range of topics, including the use of technologies like AR & VR, blockchain, AI, digital twins, and data analytics in diverse industries such as automotive, logistics, agriculture, mold-making, health, and footwear. The empirical studies aim to demonstrate how real-world organizations have implemented digital transformation in their supply chains and the outcomes they have achieved.

The results highlight key findings from the case studies, emphasizing the positive impacts of digital transformation on supply chain optimization. The discussion covers the implications of the case studies, including the importance of real-time data and analytics, collaboration, employee involvement, and change management in successful digital transformations.

The conclusion section presents a summary of the significant importance of digital transformation in supply chain optimization. It emphasizes the integration of advanced technologies and the transformative effects on traditional supply chain management practices. Future research directions are suggested, including analyzing dynamics between businesses and suppliers, exploring factors influencing the implementation of digital transformation, and investigating the environmental and societal effects of supply chain digital transformation.

In summary, the research methodology involves a comprehensive approach that combines a thorough literature review, development of a theoretical framework, and the presentation of empirical evidence through case studies to explore the impact of digital transformation on supply chain optimization.

3. Literature Review

Digital transformation in Industry 5.0 seeks to use digitalization to improve human capacities and create an improved connection between people and robots. Figure 2 presents some very important components of digital transformation in the fifth industrial revolution.

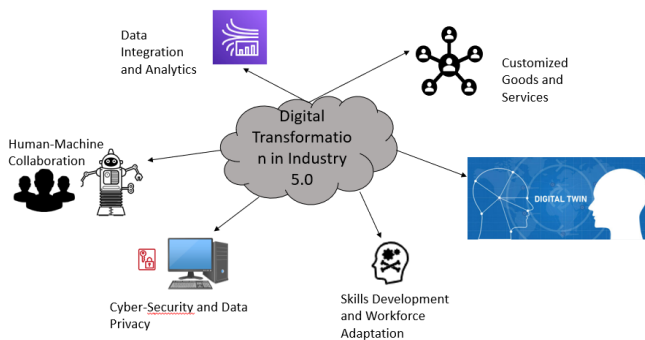


Fig. 2. Components of digital transformation in industry 5.0

A brief description some crucial elements of digital transformation in the context of Industry 5.0 is presented as follows:

- **Human-Machine Cooperation:** Industry 5.0 focuses on the relationships and cooperation between people and machines at work. Artificial intelligence (AI), the Internet of Things (IoT), and robotics are all examples of digital technologies that are used to automate repetitive jobs and increase productivity while allowing people to concentrate on sophisticated decision-making, inventiveness, and resolving issues (Romanov et al., 2022; da Assis Dornelles and Frank, 2022).
- **Customized Goods and Services:** Large-scale customization and modification of goods and services are made possible by the digital revolution. Digital design tools, data analytics, and 3D printing are examples of advanced technologies that enable the manufacturing of extremely unique and personalized goods that are catered to specific client needs (Li et al., 2017)
- **Data Integration and Analytics:** Industry 5.0 depends on the collecting and processing of enormous volumes of

data from numerous sources, including sensors, machines, and human inputs. This is known as data integration and analytics (Madzik et al., 2023). To extract useful insights from data, advanced machine learning algorithms and statistics are used. This improves decision-making, enables predictive maintenance, and optimizes manufacturing processes (Danuso and da Silva, 2022).

- **Digital Twin:** Digital twins are an integral element of Industry 5.0. They are virtual analogues of actual assets. Instantaneous tracking, simulation, and process optimization of industrial operations are made possible by these digitized imitations, which boost productivity, decrease interruptions, and enhance quality control (Mihai et al., 2022; Alojaiman, 2023).
- **Cybersecurity and Data Privacy:** As Industry 5.0 adopts more digital technologies, guarding delicate data and maintaining cybersecurity becomes vital. To protect priceless intellectual property, customer data, and operational data, strict cybersecurity safeguards and data privacy laws are put in place (Pasandideh et al., 2022).
- **Skills Development and Workforce Adaptation:** Industry 5.0's digital transformation calls for an emphasis on improving the skills of the workforce in order to interact effectively with state-of-the-art technologies. To provide staff members with the essential digital skills and promote a culture of constant learning and flexibility, instructional and educational activities are put into place (Leng et al., 2022).

3.1. Advantages of Digital Transformation in supply chain 5.0

Within the ever-changing context of contemporary business, supply chain has become an indispensable element capable of catapulting enterprises to unprecedented levels of efficacy and marketability or acting as a roadblock impeding advancement. The digital transformation of supply chains was made possible by the introduction of digital technological innovations with the onset of the fourth industrial revolution. As Supply Chain 5.0 takes off, the benefits of digital transformation in the supply chain become even more evident and revolutionary. Some of them are highlighted below:

- **Improved Visibility:** Instantaneous monitoring and record-keeping of inventory, shipping, and logistical procedures are made possible by technological innovations. Organizations can gain a complete understanding of their supply chain because to this increased visibility, which facilitates better decision-making, proactive problem-solving, and greater cooperation with partners, suppliers, and clients (Shi et al., 2023).
- **Enhanced Efficiency:** Supply chain processes that are automated and digitalized expedite operations and do away with human labor. As a result, cycle times are sped up, errors are decreased, and operational efficiency is raised. Robotics, autonomous driving, and IoT sensors are some of the technologies that can streamline transportation, inventory management, and warehousing operations while

lowering costs and boosting productivity (Twaris et al., 2022).

- **Better Customer Experience:** By enabling quicker order fulfillment, precise delivery tracking, and individualized interactions, digital transformation enables businesses to offer a superior customer experience. Companies may predict client demand, adapt products and services, and provide targeted recommendations with artificial intelligence and data analytics, ultimately increasing client contentment and commitment (Aslam et al., 2020).
- **Fast and Adaptable Supply chain:** Supply chain operations are made more flexible and adaptable by digital technologies. Identifying demand trends, maximizing inventory levels, and improving demand forecasting precision are all made possible by data analytics and predictive modeling (Xian et al., 2023).
- **Making decisions based on data:** As the supply chain ecosystem undergoes a digital revolution, enormous amounts of data are produced. Organizations can use these insights to help them make wise decisions by utilizing advanced analytics and machine learning. With the use of these insights, the supply chain can be continuously improved while also supporting strategic planning, streamlining procedures, finding possibilities to cut costs, and optimizing workflows (Modgil and Agrawal, 2023).
- **Enhanced Collaboration:** Digital tools and applications make it easier for supply chain stakeholders to collaborate and communicate in real time. Real-time information sharing is made possible by cloud-based platforms, collaborative websites, and shared databases, enabling suppliers, manufacturers, distributors, and clients to successfully communicate, share updates, and plan activities. Stronger partnerships are cultivated, communication gaps are closed, and the performance of the supply chain is improved (De Giovanni, 2023).
- **Sustainability and Environmental Impact:** By lowering debris, improving transportation, and increasing energy efficiency, digital technology can support sustainability activities. Organizations may discover possibilities for eco-friendly activities, like optimizing packaging, lowering carbon emissions, and setting recycling strategies in place, with the help of real-time monitoring and analytics. Supply chain operations are better able to meet regulatory standards, consumer expectations, and sustainability goals thanks to digital transformation (Ghobakhloo et al., 2023).

All things considered, supply chain in industry 5.0's digital transformation has several benefits, including improved customer experience, higher agility, increased efficiency, and data-driven decision making. These advantages allow businesses to expand, obtain a competitive edge, and prosper in a market that is continually changing.

Supply Chain Optimization in Industry 5.0

Operations and supply chain management are often seen as cost centers, labor-intensive, and heavily reliant on human resources. Supply chain operations are characterized by considerable output variability, which is exacerbated by laborers who are adept at various levels of work (Dwivedi et al., 2023).

This has made streamlining supply chain operations a constant challenge. It is difficult to achieve an ideal result in supply chain activities due to variations in worker knowledge, skill, and ability. With the incorporation of cutting-edge technology and the seamless interaction between humans and machines, the Fifth Industrial Revolution, also known as Industry 5.0, is expected to completely transform the industrial sector. Supply chain optimization is essential for attaining resilience, competitive advantage and operational excellence as firms embrace this revolutionary era (Iyanov, 2023). In the framework of Industry 5.0, we examine the primary innovations as well as methods that promote supply chain optimization. See figure 3.

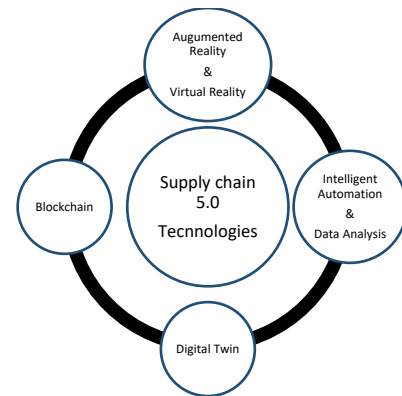


Fig. 3. Innovations for supply chain optimization in industry 5.0

From figure 3, the innovations that drive supply chain enhancement are blockchain, augmented and virtual reality, digital twin, and intelligent automation and data analysis. These technologies are further highlighted in the subsections below:

- **Intelligent Automation**

Through the integration of human and machine capabilities, Industry 5.0 ushers in the next phase of intelligent automation. The improvement of supply chain operations is greatly aided by robotics, artificial intelligence, and machine learning. Cobots (collaborative robots) and autonomous robots increase the effectiveness of fulfillment of orders, logistics, and material handling procedures. Predictive analytics, demand forecasting, and real-time decision-making are made possible by AI and ML algorithms, which facilitate increased customer responsiveness and simplified inventory management (Lv, 2023).

- **Digital Twin**

Supply chain optimization can be greatly aided by the use of digital twins, which are virtual versions of actual assets, systems, and processes. Businesses are able to monitor performance, acquire real-time information, and uncover bottlenecks or inefficiencies by building a digital twin of the entire supply chain. Digital twins enable companies simulate scenarios, improve workflows, and foresee the effects of changes before putting them into practice in the real world by utilizing statistical analysis, simulation capabilities, and IoT sensors. This sort of technology improves flexibility, lowers risks, and promotes ongoing development (Iyanov, 2023).

- **Blockchain technology**

Supply chain management benefits from never-before-seen transparency, traceability, and security because to blockchain technology. Blockchain allows for end-to-end transaction visibility and is decentralized and immutable, guaranteeing the accuracy and legitimacy of data. By automating and enforcing agreements amongst supply chain parties, smart contracts, backed by blockchain, reduce delays, discrepancies, and costs associated with administration. These innovations improve trust, facilitate seamless communication, and streamline operations like product tracing, inventory management, and procurement (Zhang et al., 2023).

- **Virtual Reality (VR) and Augmented Reality (AR)**

Virtual reality (VR) and Augmented reality (AR) technologies are revolutionizing supply chain operations, especially in the areas of maintenance, training, and logistics. By superimposing digital data onto the real world, augmented reality (AR) can increase accuracy and productivity by giving workers access to equipment maintenance advice, inventory information, and real-time instructions. By submerging users in virtual worlds, virtual training sessions, remote teamwork, and sophisticated scenario simulations are all made possible. In Industry 5.0 supply chains, these tools optimize training, minimize errors, and increase efficiency among employees (Akbari et al., 2022).

- **Predictive perception and Data analysis**

The huge volumes of data produced by Industry 5.0 offer enormous potential for supply chain improvement. Large datasets are analyzed using advanced analytics approaches to uncover practical insights that enable commercial decision-making. Reliable projections of demand, optimized inventory, and foresighted risk management are made possible by predictive analytics. Integrating real-time data throughout the ecosystem of the supply chain enables quick responses to market developments, cutting down on lead times and raising customer satisfaction (Karmaker et al., 2023; Iyanov, 2023).

In summary, supply chain optimization is essential for companies to remain successful in an evolving manufacturing environment as Industry 5.0 develops. Organizations may achieve operational excellence, resilience, and responsiveness by embracing intelligent automation, blockchain, AR/VR, and data analytics. Supply chains may adapt to changing market conditions, improve customer happiness, and obtain an unfair advantage in Industry 5.0 by utilizing these disruptive technologies. To take full advantage of the benefits of the fifth industrial age, organizations must engage these optimization techniques.

3.2. Review of Related Studies

In this section a review of recent relevant studies is conducted to determine the gap in knowledge that our research work aims to fill

Lee et al. (2022) examines the impact of the digital supply chain and its intermediary effect on the supply chain organization performance in a Malaysian manufacturing industry. They employed quantitative research method and partial Least Square Structural Equation Modeling (PLS-SEM) and arrived at some hypothetical conclusions. The findings when applied

by business operative can benefit the supply chain performance. However, there are few gaps as compared to our research work which will carry out a theoretical concept and empirical studies of various cases and not a generic one.

Belhadi et al. (2022) in their work analyze the separate and combined effects of different techniques such as digital business transformation, organizational ambidexterity and circular business models on the link between Industry 4.0 capabilities and supply chain performance. They used information gathered from 306 organizations across Europe, Asia, and Africa to create and test a theoretical model. It was discovered that the Digital Business Transformation moderated this link by incorporating circular ideas into business model development and enhancing supply chain performance sustainability. Regardless of the novelty, originality and relevance of the studies, there is still a gap in empirical studies and deductions for digital transformation 5.0 as the study only covered the fourth industrial revolution.

Zouri et al. (2021) carried out a study to investigate the correlation between supply chain resilience and supply chain digitalization. Quantitative research method was employed to analyze the impact of the degree of digital maturity and supply chain digital tools on supply chain optimization on the selected sample. The findings revealed that adoption of digital tools greatly impacted the overall performance of the supply chain resilience. There is a disparity from our work such that, digital tools obtainable in the fifth industrial revolution were not fully considered.

The researchers carry out a study to analyze the impact of the adoption of digital technologies on the supply chain of manufacturing firms. The study utilizes literature review method and a conceptual framework based on the drivers, process, and impact to achieve their aim. The findings imply that the suggested framework and solution could offer direction to practitioners using digital supply chain management technologies and creating suitable business plans at various stages of digital transformation (Yang et al.2021).

4. Empirical Studies

As various industries undergo significant changes due to technological advancements. It is no surprise that the supply chain industry is also impacted by digital transformation. In order to optimize their operations businesses are turning to digital tools in their supply chain processes resulting in enhanced efficiency, cost effective practices and elevated customer satisfaction levels. In this section, we will explore empirical studies conducted on how digital transformation affects the optimization of the supply chain industry.

In a study developed by Bun et al., (2021), findings in collaboration with an outside software development firm whose cliente are Polish-based industrial enterprises working in the automotive industry revealed that, prior factory floor implementations identified the two conditions (noise and Wi-Fi) as the most pertinent and problematic. As a result, these two conditions were considered as the focus for the team's improvement efforts. A series of AR and VR measures was taken

to ensure improved conditions in the factory, such as sound-proofing and better Wi-Fi coverage (Bun et al., 2021).

Das et al., 2023 aimed to pinpoint and analyze the major factors that help food grain supply chain quickly embrace Artificial Intelligence, hence enabling Agri 5.0 and circular economy in India. Then, a causal model of the selected enablers was developed using the fuzzy decision-making trial and evaluation laboratory approach. Researching enabling interactions can be unclear, but the F-DEMATEL technique helps to overcome this. According to research findings there is a substantial impact on incorporating artificial intelligence in FGSC. The findings have significant policy implications. The findings could be used to support additional funding and will help Indian decision-makers advance artificial intelligence programs.

To present an Intelligent Product Service System (IPSS) for adaptive maintenance of Engineered-to-Order industrial equipment based on AR, Angelopoulos and Mourtzis (2022) implemented the validation of the EDM module, and the AR application based on a real-life case study derived from the mold-making industry located in Greece. The results show that an increase in manufacturing process efficiency can be achieved through establishing effective communication channels between the end-user, the OEM, and the energy provider.

In another study, the main goal is to provide an innovative and comprehensive framework for supplier evaluation for the industry 5.0 era. To do this, it evaluated a global medical equipment manufacturer with headquarters in Taiwan utilizing a data-driven decision support system. The findings demonstrate how the evolution of businesses toward Industry 5.0 can be impacted by digital transformation, real-time information sharing, and organizational culture transformation (Lo, 2023).

To increase Supply Chain resiliency, Ahmed et al. (2023) attempts to identify, evaluate, and prioritize the AI-based imperatives of Industry 5.0 using an integrated and intelligent strategy that combines Pareto analysis, the Bayesian approach, and the Best-Worst Method (BWM). In the period after COVID-19, the framework was applied to Bangladesh footwear industries. The findings show that the B-BWM has been incorporated into the framework to facilitate efficient group decision-making. This aids the businesses in their choice of the best AI technologies to develop robust supply chain during the COVID-19 crisis.

Alice and Khumbulani, (2022) presents applications of a blockchain-based information system (IS) and a cloud manufacturing (CM) process system, for the supply chain management (SCM) system for a railcar manufacturer located in South Africa. The findings demonstrate that SMEs and manufacturers both benefit from the deployment of blockchain technologies, which fits within industry 5.0, where the system enhances enterprise the internet of things while enhancing employee working conditions. Through collaboration and privacy, it also enhances business to business interactions and the overall supply chain optimization.

Stewart and Ivanov (2022) suggest a design redundancy, utilizing digital twin approach. Their work addresses the risks that come with humanitarian supply chains (SCs), especially those that operate in conflict areas. This approach, which is

based on literature on agility and resilience, deals with humanitarian supply chain design and risk management. System dynamics simulation and network optimization are used to study the Yemeni logistics cluster-directed humanitarian supply chain operation. When put into practice, the findings can help decision-makers and all other important stakeholders support resilient decision-making for human supply chain managers and liaisons with sponsors.

In this article, Arunmozhi et al., (2022) examines how blockchain-based smart contracts and artificial intelligence (AI) can improve sustainable supply chain operations. Margin Indicator (MI), a revolutionary design component, is created to provide trustworthy predictive analytics results from the popular machine learning algorithms. The implementation was carried out on a Singaporean based company (ABC) that delivers autonomous vehicles within Singapore and neighboring countries in the Southeast Asian region. The created framework enhanced product traceability, transaction transparency, and sustainable economic growth for the autonomous vehicle supply chains. It is supported by the quick advancement in blockchain and Artificial Intelligence technology.

The table 1 depicts a summary of the case studies with regards to year, author, region, sector, and application area. From table 1, the current trend in digital transformation technologies is pointing toward AI, real data analytics and blockchain technology as mentioned in the introduction. It also shows that these innovations are applicable across all sectors regardless of the region.

Table 1. Results of empirical studies

Year	Author	Country/ region	Sector	Application area
2021	Bun et al.	Polland	Automotive	AR & VR
2022	Stewart and Ivanov	Yemen	Logistics	Blockchain
2022	Arunmozhi et al.	Singapore	Automobile	Blockchain and AI
2023	Das et al.	India	Agriculture	AI
2022	Angelopoulos Mourtzis	Greece	Mold-making	AR
2023	Lo	Taiwan	Health	Real-time data and analytics
2023	Ahmed et al.	Bangladesh	Footwear industry	AI

The outcomes from these cases are convincing that digital transformation plays a pivotal role in improving various aspects within this field. Based on empirical evidence obtained from these studies increased visibility into processes. Effective collaboration between stakeholders involved in the process flow along with optimized inventory management practices have been acknowledged as key areas triggering substantial improvements within organizations across diverse sectors to undertake digital transformation initiatives. Thus, making them crucial for successfully guiding decision making processes aimed at driving strategies for optimization endeavors across numerous supply chains globally.

5. Results and Discussion

From the review of related works, some gaps in existing knowledge were identified based on previous studies (e.g., Lee et al., Belhadi et al., Zouri et al.). These gaps serve as a motivation for the empirical studies conducted in thereby addressing the need for more comprehensive theoretical concepts and empirical research.

The review highlights the limitations or gaps in the existing studies, such as the absence of coverage of the fifth industrial revolution (e.g., Belhadi et al.) This was treated by understudying the works of Daas et al. and Ahmed et al. The need for more empirical studies and deductions (e.g., Zouri et al.) was sorted out by addressing the cases that focused on the latest technologies, including AI, blockchain, and real-time analytics (as seen in the summary table 1).

The results from the empirical studies directly reference and build upon the literature, showcasing how each study contributes to addressing the identified gaps or extending the existing knowledge. For example, the case studies summarized in Table 1 explicitly connect with the themes and areas discussed in the literature review.

The empirical studies also apply and validate theoretical concepts from the literature (e.g., the impact of digital transformation on supply chain resilience, as discussed by Zouri et al., thereby highlighting how important digital transformation is to advancing supply chain optimization. In these instances, the firms improved their supply chain processes by utilizing Digital Transformation 5.0 technologies including the Internet of Things (IoT), artificial intelligence (AI), blockchain, and data analytics. The adoption of these technologies led to higher operational effectiveness, visibility, improved teamwork, and increased customer happiness.

It can be inferred from table 1 that artificial intelligence is applied more in recent years regardless of the sector under study.

Real-time data and analytics capabilities were a recurring element throughout the case studies. The studies acquired useful insights into their operations by gathering and analyzing supply chain data in real-time, allowing them to spot inefficiencies, improve inventory management, and streamline procedures. They were able to proactively handle potential interruptions and make informed choices thanks to the incorporation of predictive analytics, which enhanced supply chain performance.

The case studies also revealed how important partnerships and teamwork are to successful digital transformations. Better results were attained by firms that encouraged collaboration with suppliers, clients, and other supply chain ecosystem players. Digital technologies have made collaborative platforms possible, allowing for easy information exchange, activity coordination, and synchronization. As a result, productivity and adaptability have increased.

The case studies also emphasized the significance of employee involvement and change management throughout digital transformation initiatives. Smooth adoption and acceptance of the digital tools and processes were made possible by effective change management tactics, which included clear

communication, training programs, and involvement of employees at all levels. Employers who actively involved their staff in the transformation process saw increased levels of dedication and output.

For businesses considering a digital supply chain operation change, the implications of these case studies are crucial. The findings offer useful insights and takeaways from cases drawn from the actual world. These examples show how implementing Digital Transformation 5.0 technology and relying on data-driven decision-making may boost supply chain performance in measurable ways. Likewise, while implementing digital transformation efforts, the significance of change management, collaboration, and employee engagement cannot be overstated.

Regardless of the positive impacts, it is essential to recognize the case studies' limitations. Even though numerous firms were examined, it's possible that the results don't accurately reflect all possible markets and situations. Additional case studies may be investigated in future study to strengthen and broaden the conclusions. The case studies also highlighted how digital transformation has affected supply chain efficiency. The financial impact, sustainability implications, and long-term effects of such alterations could all be the subject of more investigation.

6. Conclusion and Future Research

In this study, highlights of the significant importance of digital transformation (5.0) in supply chain optimization were examined. The integration of advanced technologies, such as human machine cooperation, cybersecurity and data privacy, predictive analytics, digital twin, blockchain technology, intelligent automation, and the Internet of Things, has revolutionized traditional supply chain management practices and pave the way for new avenues for operational efficiency, cost reduction, and enhanced customer experiences. As organizations implemented digital transformation initiatives, they were able to improve their supply chain processes and make decisions based on data. A key finding from this study shows that digital transformation allows for real time data collection, analysis, and sharing, which enhances visibility and responsiveness in the supply chain.

Practical Implications for Industry Professionals and Organizations

Some practical implications deduced from the findings of this study include:

- **Adoption of Digital transformation 5.0 Technologies:** The Internet of Things (IoT), blockchain, artificial intelligence (AI), and data analytics are among the Digital Transformation 5.0 technologies that industry experts are urged to embrace. The case studies illustrate that the implementation of these technologies results in increased customer happiness, enhanced teamwork, visibility, and operational performance.
- **Enhanced Collaboration and Communication:** It is stressed that cooperation and teamwork are essential components of effective digital transformations. It is recommended that industry professionals foster collaboration

among suppliers, clients, and other stakeholders in the supply chain ecosystem. Increased productivity and adaptability are achieved through the easy flow of information, coordination of activities, and synchronization made possible by digital technology in collaborative platforms.

- **Strategic Supplier Appraisal:** According to the literature review improved supplier selection, evaluation, and performance tracking made possible by contemporary technologies can improve supply chain performance. Industry experts should choose and evaluate suppliers carefully, considering how digital technology might enhance these procedures.
- **Real-time Data and Analytics for Informed Decision-Making:** Companies and industrial key players can now monitor inventory, demand, and logistics in real time. Enabling them to identify disruptions early on. Manage risks effectively. And optimize their operations accordingly. This increased visibility also promotes collaboration and communication among supply chain stakeholders leading to improved coordination and quicker problem resolution.
- **Continuous Learning and adjustment:** Industry experts are encouraged to engage in continual learning and adaptation due to the rapid evolution of digital technology. Organizations may maintain their competitiveness and innovation in supply chain management by keeping up with the newest developments in artificial intelligence, blockchain, and real-time analytics.
- **Planning accuracy for Organizations:** By leveraging these technologies, companies can enhance their demand planning accuracy, minimize stockouts, reduce excess inventory, and optimize their transportation costs. The study of Alice and Khumbulani, (2022) revealed that the organization experienced significant improvements in these areas, leading to reduced operational costs and improved customer satisfaction.

Additionally, digital transformation makes it possible to implement cutting-edge technology like blockchain, which can improve supply chain security, authenticity, and accountability. Businesses can use blockchain to build secure archives of transactions, confirm the legitimacy of products, and trace things across the supply chain. This not only aids in the prevention of counterfeit goods and ensures legal compliance, but it also enables businesses to grow consumer loyalty and improve brand recognition.

The practical consequences, taken together, point to a deliberate and comprehensive approach of digital transformation that prioritizes employee engagement, technology adoption, teamwork, and a broader understanding of the effects on society and the environment. These insights can help experts in the industry make better decisions and develop plans for supply chain operation optimization.

Future Research

The practical case studies in this paper, highlighted the significance of digital transformation (5.0) in supply chain optimization, but there are still a number of directions for future study that can extend a better understanding and reveal novel insights. Potential areas for study include:

- Analyzing the dynamics and interactions between businesses and their suppliers in the context of digital transformation activities. The performance of the supply chain can be enhanced by better supplier selection, appraisal, and performance monitoring made possible by modern technologies, according to this study.
- Examining the elements that assist or impede the implementation of effective digital transformation programs in various businesses and sectors. Further research can explore the function of organizational culture and leadership in advancing digital transformation, as well as the essential success factors, difficulties, and solutions for overcoming change resistance.
- Investigating the effects of supply chain digital transformation on the environment and society. This study can look at how digital technology can be used to advance sustainability, lower carbon emissions, and guarantee moral behavior along the entire supply chain.

By focusing on these areas of research, we can learn more about the function and effects of digital transformation on supply chain optimization and find new ways for organizations to gain an edge in the dynamic business environment.

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