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Application of New Technologies in Supply Chain Digital Transformation: A Systematic Literature Review and Future Research Directions

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Abstract

This systematic review critically evaluates the application of new technologies such as digital twins, digital platforms, smart contracts, and supply chain control towers in supply chain digital transformation (SCDT). It aims to fill the gap in the existing literature by exploring their roles, challenges, and future trends, thereby providing academia and practitioners with strategic insights for successful implementation and enhanced digital project outcomes. Employing the PRISMA framework, this study scrutinizes a select cohort of 73 out of 10,847 articles from the Scopus and Web of Science (WOS) databases over the past decade. It systematically categorizes and analyzes the literature to trace publication trends, geographical distribution, current status and keywords, and future trends. The review identifies several new technologies increasingly pivotal in modern supply chains. The researchers delve into less explored areas, such as digital twins, smart contracts, and supply chain control towers (SSCT), highlighting their potential to revolutionize digital transformation. The analysis reveals these technologies as new trends with significant implications for future supply chain management (SCM). This review provides new insights into uses and predicts trends in technology development. It offers a forward-looking perspective that lays a foundational framework for subsequent research and practical deployments in digital transformation.

Keywords: Digital Supply Chain, Supply Chain Digital Transformation, Digital Twins, Digital Platform, Supply Chain Control Towers

Introduction

With the continuous advancement of science and Industry 4.0, supply chain digital transformation (SCDT) has emerged as a critical focus in academia and industry. SCDT involves

leveraging digital capabilities to improve supply chain processes, products, and assets, enhancing efficiency, customer value, risk management, and competitive advantage (Sabri, 2023). Huliahina (2022), examines concepts such as "digitalization," "digitization," and "digital transformation," highlighting that digital transformation fundamentally rethinks business processes and their interaction with the environment, emphasizing its critical need in supply chains.

The COVID-19 pandemic and localized conflicts have exposed vulnerabilities in traditional supply chains. Ngo et al. (2023), observe that digital transformation is vital for reducing disruption risks during global crises. Gong (2023), notes that SCDT helps enterprises identify best practices and improve overall performance. Liu (2021), stresses the importance of researching SCDT, citing technology as a pivotal direction.

The process of SCDT faces many challenges, and technical challenges include the impact of real-time data analytics on supply chain operational efficiency and decision-making capabilities (Patil et al., 2023), insufficient supply chain transparency affecting supply chain visualization and traceability (Vafadarnikjoo et al., 2023), the complexity and procedures of supply chain systems impacting business interconnectivity and collaborative efficiency (Shehadeh et al., 2023), and the security demands and challenges posed by single technological solutions, necessitating integrated multi-technology approaches (Kaur et al., 2024). Previous studies on new technologies in supply chains have mostly focused on individual technologies such as big data (Lu, 2021), the Internet of Things (IoT) (Ullah et al., 2023), or artificial intelligence (AI) (Yousif Alsharidah & Alazzawi, 2020), which limits a comprehensive and holistic analysis. While there are some studies on technology integration, most research discusses the integration of IoT, big data, or blockchain (Pratap et al., 2024; Tsolakis et al., 2023). Considering new technologies and the latest technological solutions, such as digital twins, smart contracts, and SCCT, there is still a significant research gap in analyzing or integrating these new technologies. This paper addresses the issues above by researching the current status of new technologies, enhancing the understanding of their roles in SCDT. It identifies their applications, highlights limitations, and proposes research questions:

1. What are the publication trends in SCDT research over the past decade?
2. What is the geographic distribution of SCDT research, and what effects have these changes had on the research focus?
3. What new technologies are currently popular in SCDT?
4. Which new technologies are the future trends of SCDT?

The structure of this paper is as follows: the next section presents a literature review, followed by an overview of research methods and strategies. Subsequently, the analysis and results are outlined, followed by a discussion of the findings. Finally, conclusions are drawn, with the final section providing recommendations for future research directions.

Literature Review

With the arrival of the Volatility, Uncertainty, Complexity, and Ambiguity (VUCA) era, market demand volatility and uncertainty have increased, and changes in the external environment have intensified their impact on customer demands, presenting multiple challenges for supply chains. Adopting advanced technologies for digital transformation in supply chains is not only

about choosing the right technological solutions but is also crucial for maintaining a competitive edge.

Previous research has explored a variety of technologies for digital transformation, including platforms, big data analytics (BDA), blockchain, AI, and the IoT. Digital platforms in Europe have significantly facilitated the digitization of supply chains, enhancing the global operational capabilities of businesses (Thomassey & Zeng, 2021). Industry 4.0 and platform ecosystems are key in multinational manufacturing firms, driving digital transformation (Das & Dey, 2021). BDA promotes supply chain innovation by extracting insights from large data sources and providing practical strategies and insights for manufacturing managers (Bhatti et al., 2022). Additionally, BDA has realized the digital transformation of traditional supply chains, improved information conversion efficiency (Wu et al., 2020), and aided the transition of the Indian manufacturing industry from traditional to digital supply chains (Tambuskar et al., 2023). Blockchain and IoT optimize processes and enhance operational efficiency (Idrissi et al., 2022). Integrating AI with IoT (AIoT) optimizes the supply chain decision-making process, subsequently analyzing the cybersecurity and infrastructure challenges it brings (Nozari et al., 2022).

Furthermore, digital twin technology shifts from post-event data analysis to predict future developments and supports the physical integration of larger interconnected networks, enhancing the intelligence of supply chains (Kaivo-Oja et al., 2020). Additionally, the supply chain digital transformation (SCDT) technology implemented by large manufacturing companies shows that intelligent supply chains result from the joint development of system management and technology (Vlachos, 2023). Machine learning technology has been integrated into supply chain decision-making tools, aiding in more intelligent, scientific supply chain decisions (Mahraz et al., 2022). In contrast, Robotic Process Automation (RPA) improves beef quality safety in the beef supply chain (E-Fatima et al., 2022). Decision support models for additive manufacturing have accelerated SCDT and performance improvement (Chowdhury et al., 2023). RFID technology has solved warehousing location issues, enhancing the digitization and intelligence level of the logistics supply chain (Pan & Liu, 2021). However, technology encounters numerous barriers and challenges during the digital transformation process. Insufficient IT infrastructure and high investment costs in digital technologies are significant impediments (Özkanlısoy & Akkartal, 2021). In small and medium-sized enterprises implementing Industry 4.0 and sustainable development, lack of technical expertise and cybersecurity issues are the main barriers (Machado et al., 2021). Although in-depth analyses of individual technologies have been conducted, there remains a deficiency in the research on the exploring of new technologies and technology integration. Further and more in-depth research is needed in subsequent studies. Using technology in SCDT provides crucial support for enterprises to cope with complexity and maintain competitiveness.

Methodology

Search Strategy

This study employed the systematic literature review (SLR) method to ensure a more systematic and scientific approach to analysis. The selection of the SLR method aids in scientifically identifying, extracting, analyzing, and filtering literature to comprehensively understand the planning field (Van Dinter et al., 2021). After deciding on the methodology, developing a clear research strategy is crucial, followed by setting specific research objectives

and providing a detailed explanation of inclusion and exclusion criteria. Some operational standards require step-by-step explanations. Once relevant information has been established, data search and collection are carried out in predefined databases, where articles are selected and assessed for relevance to ensure the selected articles strictly meet the set criteria. Then, a comprehensive analysis of the final articles is conducted according to the research objectives, which may involve multiple analysts or discussions to finalize (Rasool et al., 2022; Rushiana et al., 2023).

In this study, the standard protocol of the SLR is followed to ensure a more scientific and accurate research evaluation (Khan et al., 2003). Considering factors such as data scale, quality, discipline, and focus, the authors, like most researchers, have chosen Scopus and WOS for database selection because these databases provide comprehensive information descriptions (Pranckutė, 2021). Research indicates that merging these two databases allows for more reliable document analysis (Echchakoui, 2020). Selecting Scopus and WOS for searches helps efficiently and effectively retrieve literature related to "supply chain digital transformation technologies," meeting the requirements for efficient retrieval and accurate data collection to support high-standard review processes.

Sample Identification

The literature search strategy the researchers developed and employed in this study is based on a keyword-driven approach (Bhattarai et al., 2022; Rethlefsen et al., 2021). Under the guidance of this strategy, the researchers identified search strings related to approximate "technologies in supply chain digital transformation." All relevant keywords are listed in Table 1, combined using the Boolean operator "OR." The research emphasizes the importance of standardized search strategies, Boolean operators, and database indexing fields in article retrieval strategies (Nylander et al., 2021). The study also used an asterisk "*" to address variations in terminology, ensuring comprehensive coverage of the phrases "digital supply chain," "supply chain digitization," and "supply chain digital transformation." A novel optimization technique was developed by comparing the results retrieved from controlled vocabulary and free-text search terms to identify potential relevant candidate search terms (Bramer et al., 2018). When searching in Scopus, the researchers use the "Title-Abstract-Keyword" approach. In WoS, the researchers use the "Topic" approach to maintain the scope and quality of the search. The final search strings are shown in Table 1, including all data retrieved up to April 28, 2024.

Table 1
Keywords and Searching Query String

	Digital supply chain	supply chain digitization	supply chain digital transformation
Key words	3D Printing	3D Printing	3D Printing
	Additive Manufacturing	Additive Manufacturing	Additive Manufacturing
	Artificial Intelligence	Artificial Intelligence	Artificial Intelligence
	Augmented Reality	Augmented Reality	Augmented Reality
	Big Data Analysis	Big Data Analysis	Big Data Analysis
	Block chain	Block chain	Block chain
	Cloud Computing	Cloud Computing	Cloud Computing
	Control Towers	Control Towers	Control Towers
	Digital Platforms	Digital Platforms	Digital Platforms
	Digital Supply Chain Twin	Digital Supply Chain Twin	Digital Supply Chain Twin
	Internet of Things	Internet of Things	Internet of Things
	Machine Learning	Machine Learning	Machine Learning
	Robotic Process Automation	Robotic Process Automation	Robotic Process Automation
	Smart Contracts	Smart Contracts	Smart Contracts
	Supply Chain Visibility	Supply Chain Visibility	Supply Chain Visibility
	Virtual Reality	Virtual Reality	Virtual Reality
	Wearable Technology	Wearable Technology	Wearable Technology
	Technology	Technology	Technology
Search query string	3D Printing OR "Additive Manufacturing" OR "Advanced Robotics" OR "Artificial Intelligence" OR "Augmented Reality" OR "Big Data Analysis" OR "Block chain" OR "Cloud Computing " OR "Control Towers" OR "Digital Platforms" OR "Digital Supply Chain Twin" OR "Internet of Things " OR "Machine Learning" OR "Robotic Process Automation " OR "Smart Contracts" OR "Supply Chain Visibility" OR "Virtual Reality" OR "Wearable Technology" OR technolog*		

Selection and Evaluation Process

In the selection and evaluation process, the study proceeded with the following steps for screening and handling. Initially, a preliminary keyword search was conducted in the Scopus and WoS databases, retrieving a total of 3,184 and 7,663 publications, respectively. Using a filtering method (Khan et al., 2003), the results were narrowed down to 2,988 and 6,580 publications. Subsequently, the language was restricted to "English" and articles were filtered by type, further narrowing the selection to 1,309 and 4,775 publications. Publications were then categorized by research field (Figure 1), resulting in 1,232 and 3,282 publications. After merging and removing duplicates, the dataset comprised a total of 3,965 articles. Title screening excluded 775, leaving 3,190 articles for abstract screening. This process identified 890 relevant articles. A rapid review of their titles, abstracts, and contents helped exclude articles not closely aligned with the topic, retaining only those focused on new technologies in SCDT. Ultimately, the researchers identified 73 articles emphasizing the application of new technologies in SCDT and future research directions. These articles not only highlighted the application of new technologies in SCDT but also pointed out future research directions.

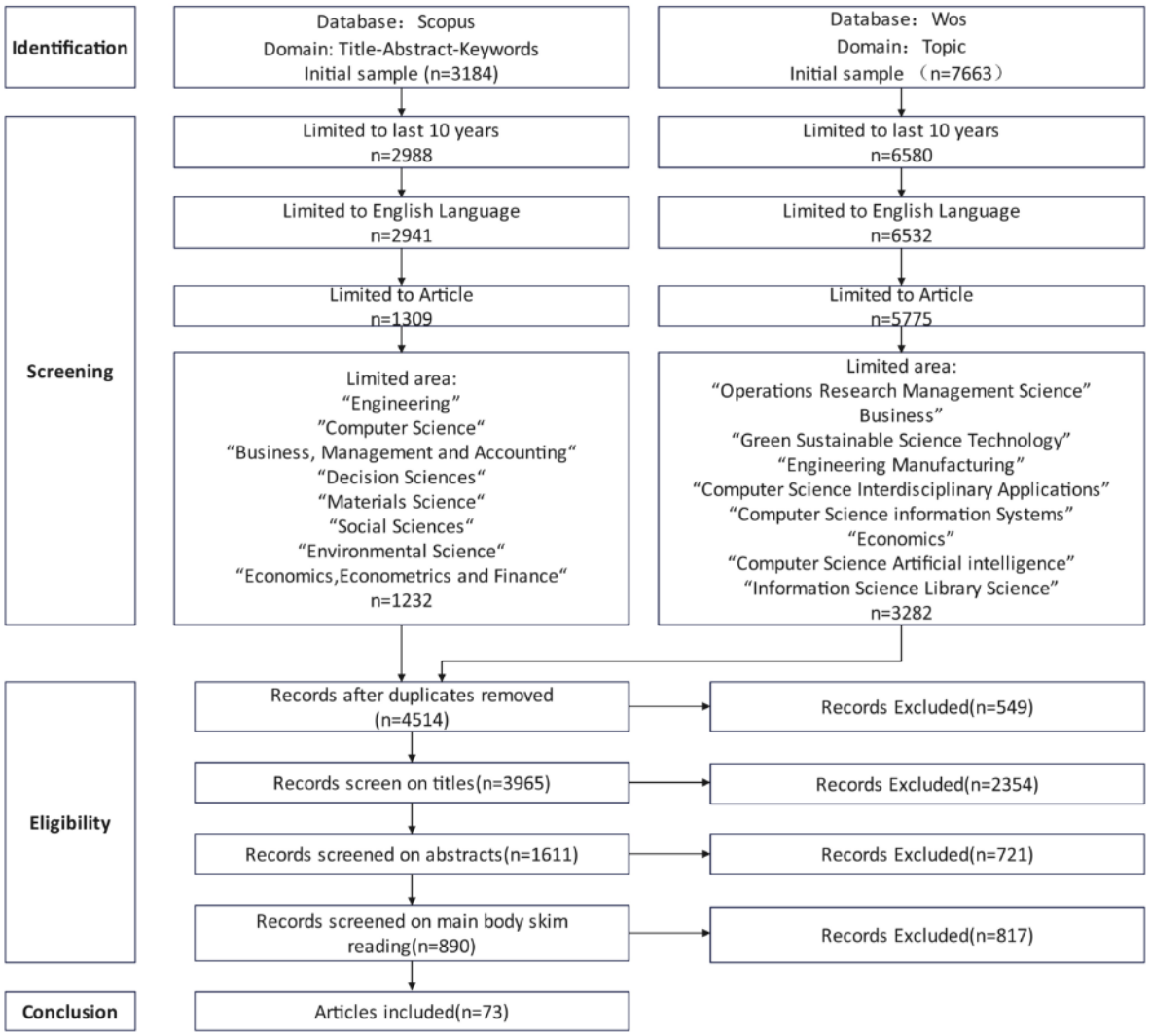

Figure 1. The Process of Searching the Literature

Quality Assessment

To ensure the quality of the screening results, The researchers focused on the number of citations in the papers, as citations can often indicate a paper's quality(Thelwall et al., 2022). Both researchers used identical screening steps and methods, compared their results, and identified 26 articles presenting differing perspectives. A consensus was reached after thorough discussions. While this study relies on data from the WOS and Scopus databases, which might only encompass some relevant literature, their authoritative nature justifies their selection. These databases offer higher quality and more reliable content than other sources.

Results

Publication Trend

As seen in Figure 2, the exploration of technological factors critical for SCDT began in 2008. Interest in this area has surged since 2015, marked by a growing amount of research. This reflects the evolving needs of supply chain development alongside technological progress, prompting the widespread application of new technologies across various business segments. The review includes the initial studies from 2019 that primarily focused on new technologies. The research volume has notably increased, from four papers in 2019 to 26 in 2023. By April

2024, 14 more papers have been published, and projections suggest that the annual total will surpass 40. This trend underscores a significant increase in scholarly engagement with this research domain.

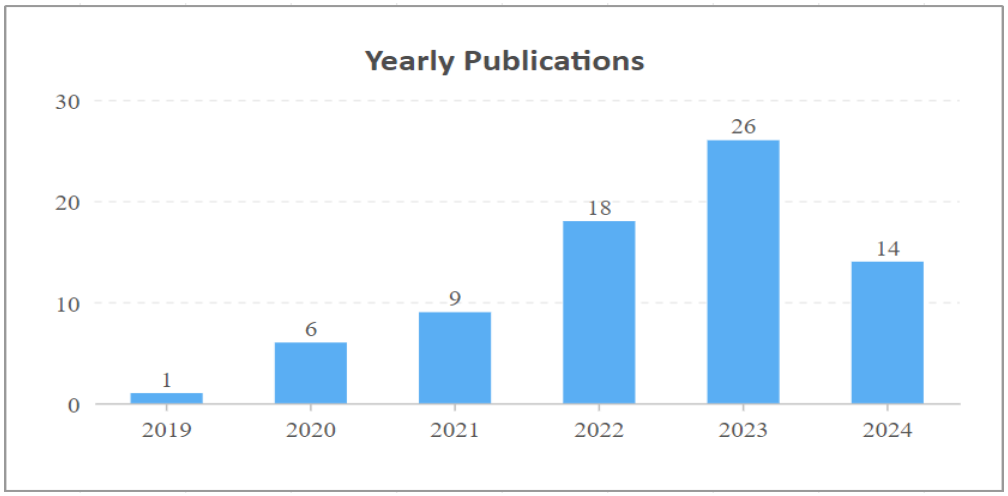

Figure 2. Yearly Publications

Geographical Distribution

As Figure 3 illustrates, it presents the geographic distribution of all selected articles. Among these 73 articles, the analysis indicates a widespread distribution involving Asia, Europe, Oceania, and the Americas, with scholars from continents worldwide researching this direction. Geographical analysis reveals that the category with the most articles, numbering 23, involves international collaboration across multiple countries. Additionally, there are 21 articles, the second-highest category, where the researchers did not specify any country. These scholars discuss new technologies' universal applicability and potential global impact rather than being confined to specific geographical regions. Data analysis also reveals that the cumulative number of articles from Asian countries, including China, India, Malaysia, and Vietnam, totals 17, notably exceeding the numbers from Europe, the Americas, and Oceania. Furthermore, the analysis indicates that China and India, with 6 and 4 articles, respectively, have a significantly higher number of studies than other countries, including the United States, Canada, and France.

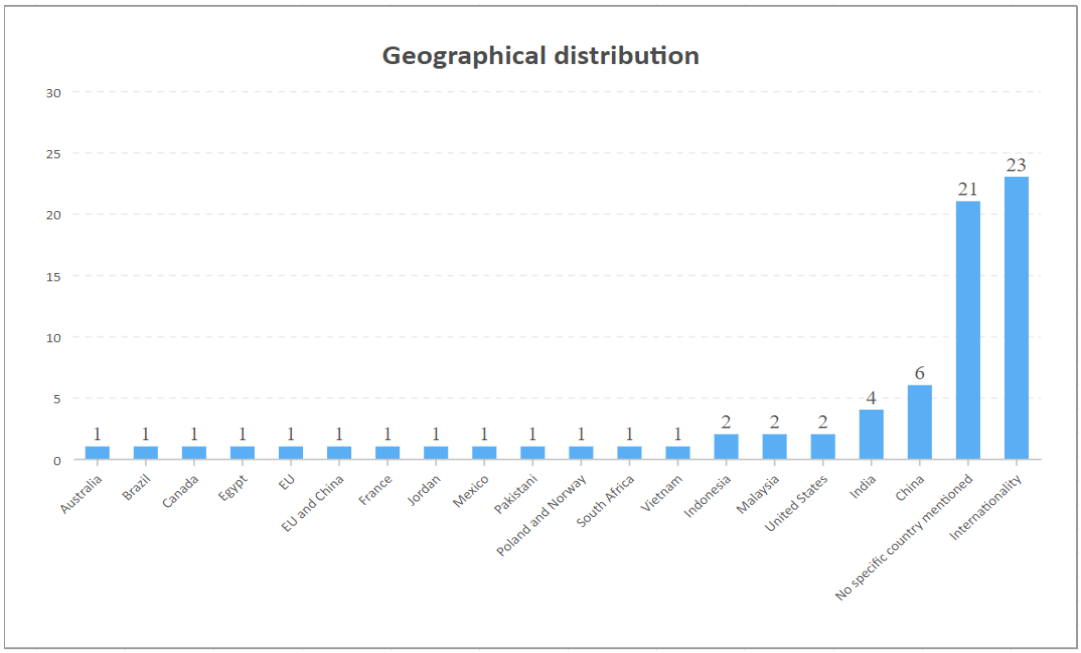

Figure 3. Geographical Distribution

New Technologies and Trends

As Figure 4 illustrates, an analysis conducted with VOSviewer on the author and index keywords within 73 articles is visually represented, and these technologies are commonly used in the digital supply chain. The larger display frames of specific terms indicate a higher frequency of occurrence. This visualization highlights those terms related to “digital supply chain,” “supply chain digitization,” and “supply chain digital transformation” that appear prominently, suggesting their frequent mention in the literature. Although digital twins, digital platforms, smart contracts, and SCCT are displayed with smaller frames, their visibility indicates a growing interest in these technologies, pointing towards the significant potential for further research and development in these areas.

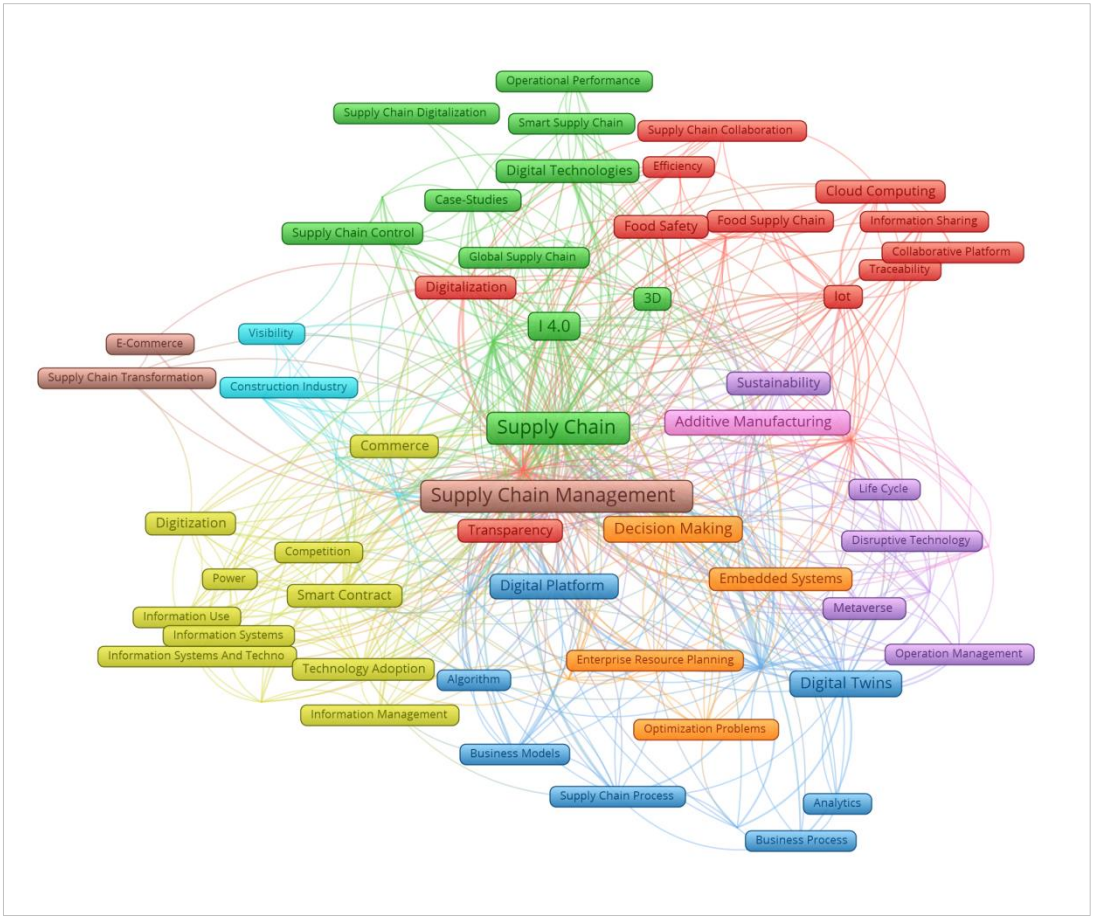

Figure 4. New Technologies Keywords and Trends

Findings and Discussion

The systematic review of selected articles has uncovered the widespread research direction, with a time frame ranging from 2019 to 2024, from Asia to Europe and the Americas, indicating a global study phenomenon in SCDT. This interest transcends any single geographic region, with many studies encompassing multiple countries or cross-regional scopes, such as analyses of interviews with international experts in 18 different domains regarding blockchain transformation (Della Valle & Oliver, 2021), studies on large multinational corporations across five industries adapting to cloud computing and 3D printing technologies (Makris et al., 2019), and research on eight cases implementing digital platforms for global supply chain management (Marrucci et al., 2022). These studies emphasize the researchers' focus on the multinational potential and benefits when exploring new technologies.

Some research subjects are not associated with specific countries, highlighting the universal application of new technologies in global supply chain management. Research included using additive manufacturing to enhance the sustainable competitiveness of supply chains (Mohamed-Iliasse et al., 2022; Singh et al., 2023), employing Digital Supply Chain Twins to optimize supply chain resilience and avoid disruption risks (Ivanov, 2024), and applying metaverse data analytics and digital collaboration (Dolgui & Ivanov, 2023). This lack of specific national focus underscores the technologies' widespread applicability, indicating that these innovations can be effectively implemented across various global settings without geographic limitations. These instances demonstrate how new technologies provide scalable and

adaptable solutions across different regional environments, effectively addressing diverse global supply chain challenges.

Analysis reveals that Asian countries such as China, India, and the Association of Southeast Asian Nations (ASEAN) have made rapid progress in digital transformation, delving into the use of new technologies in areas like digital platform innovation (Xiang & Hou, 2023) and smart contract management in agricultural flower supply chains (Tsai & Shen, 2024). This indicates that many Asian countries are increasingly deepening their research and use of new technologies in SCDT (Gupta et al., 2020; M. Zhang et al., 2023), which is crucial for addressing common supply chain challenges, facilitating technology transfer, and fostering innovation.

The applicability of machine learning is becoming increasingly suited for supply chain development, particularly as research from the Indian region has demonstrated (Wisetsri et al., 2022). Additionally, the meat supply chain is achieving transparency and traceability through digitalization, gradually building a strong collaborative supply chain (Srivastava et al., 2024). Similarly, the use of blockchain and smart contracts in Chinese agriculture benefits the rice supply chain information supervision, providing insights into the digital transformation of the food industry (Peng et al., 2022). Moreover, research has explored integrating digital transformation and sustainable development in the supply chain, achieving a sustainable marketing and SCM synergy model supported by the metaverse, offering valuable practical guidance for building a sustainable digital economy (Zhong & Zhao, 2024). The ASEAN is leading the development of the global Halal trade and has the opportunity to become a leader in global Halal logistics, necessitating digital transformation to advance the development of the Halal ecosystem (Ramanathan, 2016). The researchers describe that with rapid development and the demand for supply chain advancement, more and more Asian countries are focusing on new technologies in SCDT and achieving digital development and performance enhancement of supply chains through transformation.

Particular attention should be paid to new technologies being adopted and gradually spreading in SCDT. Studies indicate that blockchain can advance digital supply chain platforms (Xiang & Hou, 2023) and global supply chain management digital platforms (Marrucci et al., 2022), thus integrating the functionalities of various supply chain components. Research shows that new methods of implementing digital twin technology support technical simulations and system evaluations, integrating into order fulfillment processes in manufacturing plants (Abouzid & Saidi, 2023). Digital twins can provide simulation and optimization functions conducive to data modeling and continuous interaction with AI (Perez et al., 2022). Enhancing predictive capabilities through digital twin technology and integrating it with new technologies, such as the SCCT, enhances the effectiveness of digital supply chain management (Maheshwari et al., 2023). Analysis of a large manufacturing company's implementation of SCCT technology indicates that an intelligent supply chain results from the joint development of system management and technology (Vlachos, 2023). SCCT enables the management of customer inventories and strengthens the coordination between customers and suppliers (Chen et al., 2024).

Machine learning (ML) technology is used for data mining, forecasting, and technological exploration models, especially in manufacturing and inventory planning (Rekha Sree et al., 2021). Integrating AI and ML technologies provides exceptional customer service, enabling

intelligent supply chains (Rana & Daultani, 2023). Research explores the impact of Robotic Process Automation (RPA) on procurement operations, organization, and relationships, demonstrating the successful application of RPA technology in supply chain procurement (Viale & Zouari, 2020). Findings also show that smart contracts help manage supply chain contracts efficiently and accurately (Hamledari & Fischer, 2021; Peng et al., 2022). Digital twin technology supported by Radio Frequency Identification (RFID) enhances competitiveness, showcasing the impact of digital transformation technology solutions in SCM on businesses (Voipio et al., 2023).

As the field of research evolves, it is crucial to thoroughly understand how to utilize these new technologies to mitigate real-world supply chain challenges. This study lays the groundwork for future in-depth research on the strategic implementation of these technologies, aiming to ensure efficient, resilient supply chains capable of addressing the challenges brought by an increasingly unpredictable global landscape. This research focuses on new technologies adopted in digital transformation in recent years. This study comprehensively applies technologies such as BDA, the IoT, RFID, and AI, analyzing articles related to digital twins, digital platforms, smart contracts, and SCCT. It further reveals insights into the use of these new technologies.

Conclusion

As supply chains develop, the demand for digitization and digital transformation continuously increases, especially in adopting and disseminating new technologies. Although research on digital supply chain technologies is progressing, most is concentrated on widely adopted technologies such as BDA, the IoT, and AI due to differences in corporate development levels and constraints in research scope and direction. Simultaneously, there is a lack of research on new technologies like digital supply chain platforms, digital twins, smart contracts, and SCCT, which also face challenges such as intelligent decision-making, transparency, and traceability in supply chains. A comprehensive search using keywords such as "digital supply chain," "supply chain digitization," and "supply chain digital transformation" yielded 3,184 and 7,663 articles in the Scopus and WoS databases. After several stages of filtering by language, document type, and theme and thorough reading and comparison by two researchers, the sample was narrowed down to 73 articles. This paper conducted an extensive analysis of these articles, discussing annual trends, regional distribution, the current status of new technology applications, and future directions for new technologies.

Research shows that research on supply chain digitalization technologies is increasing annually and exhibiting a transnational or international trend. Furthermore, studies indicate that compared to Europe and the Americas, Asian countries increasingly demand digitization in manufacturing, agriculture, and halal logistics, rapidly enhancing supply chain performance through digitization. Although some research progress has been made, focusing on research trends, cause analysis, and impacts in different regions is still necessary.

The findings suggest adopting new technologies and innovation processes to drive SCDT toward more resilient, transparent, and efficient directions. By leveraging digital innovations, businesses can gain a competitive edge and achieve sustainable growth. The results provide practitioners and scholars with reference technological solutions and guidelines to formulate

technological implementation strategies and enhance the resilience and sustainability of supply chains, thus increasing the success rate of digitalization projects.

Future Research

From the perspective of new technologies, using new technologies can enhance supply chain performance metrics. Digital twins are considered alternatives for optimizing real-world performance in virtual environments (Gai et al., 2023), enhancing supply chain simulation and intelligent decision-making capabilities. Applying Robotic Process Automation (RPA) technology can shorten processing times, reduce human errors, lower operational costs, and improve compliance levels and data accuracy (Radke et al., 2020). Future new technologies such as digital platforms, smart contracts, SCCT, the metaverse, robotic process automation, and autonomous vehicles will have more considerable development space in the future digitalization of supply chains.

From the perspective of integrating new technologies, addressing barriers and challenges in SCDT through integrating multiple technologies. Applications in manufacturing integrate ML and AI algorithms to achieve process automation and robotic automation technologies, emphasizing the necessity of new technological skills in manufacturing (Mypati et al., 2023). Additionally, AI technology for RFID supply chain data analysis can enhance the operational efficiency of businesses (H. Zhang & Li, 2023). Research by integrating IoT technology into sustainable automotive supply chains adds value to existing knowledge on sustainability and digitalization (El Jaouhari et al., 2023). Future research will focus on collaborative development and cross-integration across different technologies on a unified platform, also emphasizing the integration of multi-technology information and combined technological solutions to address multifaceted challenges encountered in the digitalization process of supply chains, enhancing the success rate of project solutions.

From the analysis of supply digital platforms, overall digitization can be achieved through comprehensive digital planning and platform solutions. Digital platforms can enhance industry connectivity, interoperability, and efficiency (Bosi et al., 2020). The platform's design includes various technologies, traceability from the source, and sustainable design and manufacturing, effectively integrating digital transformation and intelligent agricultural technology in an open architecture (Nguyen et al., 2023). Research has proposed a "Multi-center Intelligent Manufacturing Shared Cloud Platform" solution, which achieves manufacturing sharing, supply chain sharing, and resource sharing, reducing supply chain costs, enhancing enterprise production efficiency, and accelerating industrial upgrading (J. Liu et al., 2021). Supply chain digital platforms will continue to expand their functionality and scope of application, bringing more innovative solutions and competitive advantages to businesses. Through supply chain digital platforms, real-time data analysis and decision-making are implemented, enhancing transparency and traceability, boosting risk resilience, and promoting sustainability and compliance, an important future trend.

Future research will also emphasize the successful implementation of new technologies. Studies should assess and implement digital supply chain solutions, thoroughly evaluate the facilitators and barriers to digital transformation, and explore how organizations can effectively integrate new technologies and digital platforms. This is also one of the important future research trends.

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