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The Role of Digital Twins in Supplier Selection Criteria: Review and Research Directions

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Abstract

In the digitalization era, digital twins improve supply chains by increasing productivity, cutting expenses, and guaranteeing customer response. Their connection to supply chains is still little understood, though. Several studies have investigated the interplay between supplier selection criteria, innovation, dynamic capabilities, and digital twins. Examining the role of digital twins in supplier selection is the goal of this paper. Through a methodical study of the literature, the author fills this gap by examining 39 chosen papers out of 3218 articles. evaluating how supplier selection criteria are affected by digital twins. According to the results, digital twins are mostly employed in the planning, manufacturing, and delivery processes; source and return procedures have seen less investigation. By facilitating just-in-time production, streamlining information, reducing waste, and optimizing logistics, they enhance lean methods. Nonetheless, there is a lack of research on supplier relationship management, customer relationship management, and top management commitment. For supplier selection to be efficiently utilized during decision-making, the digitisation part, which for this study is the digital twin, must be integrated into the organisations.

Keywords
Artificial Intelligence, Digital twin, Manufacturing, Literature review, Supplier selection criteria

1. Introduction
The potential use of digital twins (DTs) in supply chains encourages the application of data integration theory to practice. A key technological requirement for creating a digital twin for supply chains is establishing a database-based, cross-enterprise data integration platform. Despite the differences between the definitions of a digital twin provided by academics and industry, both may overlook the importance of focusing on its process-related aspects. Digital twins are revolutionising supplier selection processes by offering real-time simulation, predictive analytics, and enhanced decision-making capabilities. DT technology can be utilized for information exchange to enhance decision-making and collaboration across various sectors and enterprises (Kapil, Raut, Nayal, Kumar, and Akarte, 2024). Utilizing digital twin systems to guarantee the information security of businesses involved in supply chains.

A review of recent literature suggests that there is a growing interest in integrating digital twins into supply chain evaluation frameworks, despite research on the subject still being in its early stages (Qi *et al.* 2021). Fundamentally, a digital twin is a growing digital representation of the past and present behavior of a physical object or process, which helps improve company performance (Evangeline, 2020). Digital twins examine the competitive dynamics between upstream and downstream organisations in the supply chain to simulate organisational collaboration at the strategic, tactical, and operational levels. However, according to Grieves (2014), the digital twin pioneer, a digital twin needs a physical system, a virtual counterpart, and a two-way link. Additionally, the definition by Grieves (2014) underlines the real-time application scenario as crucial, as digital twins bring the most value when deployed in a real environment, making an influence on a live system, rather than being applied in a lab setting on synthetic data.

A digital twin is not just another sensor-enabled Internet of Things (IoT) solution; it is distinct from conventional computer-aided design (CAD) (Holdowsky, 2015). However, Qi et al. (2021) states that DTs are a byproduct of emerging technologies like big data, virtual reality, and the Internet of Things. These technologies enable new product management approaches, which in turn present several technical constraints. Digital twins can be designed for various objectives and in a wide range of contexts. Kapil et al. (2024) demonstrate how organisations may improve their capacity to monitor and control assets, materials, and processes by utilizing DT for traceability. This can lead to increased productivity, fewer risks, better resource and operation scheduling, and adherence to legal and quality requirements. The digital twin is one such idea that has the potential to enhance supply chain performance and visibility. In the modern sectors, digital twin technology presents an innovative approach and a vital resource for driving innovation. In their systematic review of the literature on digital twins, Jones Snider, Nassehi, Yon, and Hicksset (2020) identified traits of a digital twin and pointed out research needs. The authors do not explicitly discuss machine learning or artificial intelligence, however, ideas such as predictive maintenance and improved control systems are emphasized as components of a digital twin.

For a conventional supply chain (SC), digitisation presents both significant potential and risks. To maintain their competitive advantages, leading businesses have already started converting conventional SCs into digital formats. Consequently, digital technologies and tools (DTTs) should be integrated with the conventional SC to better address risks and disruptions (Li, Zhang, Liu, Zhang & Jasimuddin, 2023). Digital supply chains can integrate digital twins into their operations, allowing businesses to model, track, and enhance supply chain operations using digital twins (Buyukozkan & Gocer, 2018). Digital transformation plays a crucial role in the manufacturing sector, delivering several benefits to SC management. Utilizing enabling technologies such as IoT, AI, RFID, ML, and sensors to leverage DT in SC has been studied in order to address various SC issues pertaining to quality, food waste, production planning and scheduling, supplier selection, risk management, inventory and cash management, performance evaluation, and information sharing amongst businesses as illustrated in Figure 1.

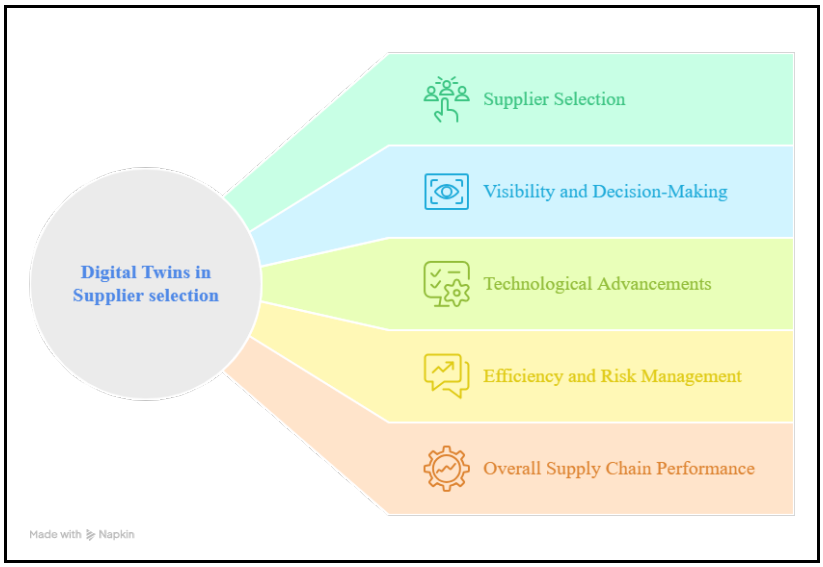

Figure 1. Theoretical research framework (Author's own compilation from Napkin AI)

Discussion by Cavalcante, Frazzon, Forcellini, and Ivanov (2019) is on applying DT to data-driven simulation for supplier performance risk under uncertainty using machine learning models. There is an illustration on how DT provides decision-makers with data-driven, real-time insights, enabling them to make better, more effective, and more efficient decisions across various sectors, including manufacturing, healthcare, and construction (Kapil et al. 2024). According to the findings, DT largely contributes value to the industrial flow management process by enhancing supplier selection, management, and production efficiency (Cavalcante, Frazzon, Forcellini & Ivanov, 2019; Li, Tsang, Wu, & Lee, 2024).

Table 1 illustrates the application of DT functions (e.g., simulation, monitoring, prediction and optimisation) to supplier selection criteria (e.g., environmental, economic, and social), aligning DT competences with environmentally

friendly purchasing and organisational performance, thereby promoting a Triple Bottom Line approach to supplier selection.

Table 1. Digital-Twin functions to a supplier selection criteria

Digital-Twin functions	**Environmental criteria**	**Economic Criteria**	**Social criteria**
Simulation	Estimates energy consumption and carbon footprint under various sourcing conditions (Zhang, Wang, Li, Pang, and Yang, 2024).	Simulates the effects of inventories, lead times, and cost-efficiency (Mojumder, 2025).	Simulates the availability of workers and labor practices (Nikolakis, Alexopoulos, Xanthakis, and Chryssolouris, 2019).
Monitoring	Monitors resource consumption, waste, and emissions in real time (Bogary, 2024).	Keeps a check on asset utilization, delivery performance, and cost variances (Papanagnou, 2019).	Observes adherence to safety regulations and labor laws (Perez and Korth, 2020).
Prediction	Anticipates environmental hazards, such as pollution and the effects of climate change (Astarita, Guido, Haghshenas, and Haghshenas, 2024).	Forecasts market trends and the financial health of suppliers (Badakhshan, and Ivanov, 2025).	Predicts the reputational risks associated with social non-compliance (Zoltick, and Maisel, 2023).
Optimisation		Maximizes value by maintaining a balance between cost, quality, and delivery (Martínez-Olvera, 2022).	Recommends suppliers who have a high level of diversity or community involvement (Kamble, Gunasekaran, Parekh, Mani, Belhadi, and Sharma, 2022).

Existing research (Espinosa-Jaramillo, Zuta, Koneti, Jayasundar, Zegarra, & Carvajal-Ordoñez, 2024; Cavalcante, Frazzon, Forcellini & Ivanov, 2019) acknowledge that AI-driven technologies can improve digital-twin applications in supply chain virtualisation through improved simulation, monitoring, prediction, and optimisation. However, a large portion of this knowledge is still practitioner-led and has inadequate empirical backing and scholarly theorization. Therefore, future studies should investigate how supply chain digitisation might be systematically strengthened by enhanced AI integration, offering both operational and strategic insights.

1.1 Objectives

With an emphasis on the manufacturing sector, this literature-based study aims to critically analyse the digital twin in relation to supplier selection criteria. The objectives of the study are to identify the criteria, operational, and contextual elements that impact supplier selection and decision-making in the manufacturing sector by integrating available literature. Though digital twins have the potential to revolutionize supply chain management and Industry 4.0, less is known about their function and influence on supplier selection, as stated earlier.

The following are research questions;

- What is the current state of digital twin technologies applications in supplier selection criteria?
- What is the role of a digital twin in enhancing supply chain performance?
- What are the future research and research directions for supply chain management using the digital twin?

An overview of recent research on the use of digital twins in supply chain and manufacturing is shown in Table 2 outlining research objectives and conclusions, showing the type of the research paper.

Table 2. An overview of recent studies on the use of digital twins in supply chain and manufacturing.

Author(s) & Year	Objective(s) of the study	Conclusion	Type
Jesus, Vitor, Dimitra Kalaitzi, Luciano Batista, and Nestor & Leal Lopez, 2024	Review and generalize the notion of DT to apply to supply chains, aligned with a review of enabling technologies.	The conclusion and criticism suggest that while the technology is helpful and revolutionary, it must be viewed differently and used in conjunction with other technologies to meet a much broader range of needs. Applications must, above all, always consider the Internet-based, electronic data exchange model and only use blockchains when absolutely necessary.	Systematic literature review paper
Guo & Mantravadi, 2025	The research reviews the current literature to fill the gap by shedding light on its applications and motives. Studying how digital twins are utilized in supply chains is crucial for understanding their context and the challenges they pose for lean supply chain management.	The digital twin improves supply chain connectivity, optimization, and cooperation across various stakeholders by digitally mapping real-world entities. Through the use of digital twins, organisations can increase resource efficiency, fulfill orders on schedule, cut lead times, and better manage risks. According to our investigation, the digital twin has the potential to enhance supply chain performance and facilitate lean management.	Literature review paper
He & Bai, 2021	This paper examines both technologies and discusses the sustainability of intelligent manufacturing to gain a comprehensive understanding of intelligent manufacturing that utilizes digital twins.	A comprehensive proposal for the framework of digital twin-driven sustainable intelligent manufacturing was submitted.	Literature review paper
Li, Zhang, Liu, Zhang & Jasimuddin, 2023	To use simulation models offered by DT to assess supplier selection.	DTs contribute to multi-criteria decision-making by modeling the performance of suppliers in the context of uncertainty.	Empirical case study paper
Marmolejo-Saucedo, 2020	To assess the behavior or efficacy of the digital twin in specific situations in order to increase its efficacy. The digital twin paradigm, when applied to machines, goods, and even entire company ecosystems, can optimize the present, uncover information from the past, and even forecast the future performance of various sectors examined.	This study presents a tool for supply chain decision-making based on the concept of a digital twin. To do hypothetical multi-scenario analysis, the suggested tool incorporates dynamic simulation approaches, linear mixed-integer optimization models, and facility location models. Support various industries in establishing a conceptual foundation for the components that the supply chain digital twin design should incorporate.	Empirical case study paper

2. Methods

To determine the current status of research on the use of digital twins as supplier selection criteria in the manufacturing sector, the author conducts a comprehensive literature review. In this section, the author outlines the methods used to identify pertinent research, the procedures followed, the data extraction process, and the eligibility screening criteria. To manage the various stages of the literature, the research design adhered to the generally recognized Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework (Moher et al., 2009). This included identifying the research question, searching, screening, charting, and synthesizing the data. The evaluation procedure was created to include research from the fields of operations management and Industry 4.0.

The search was conducted by the author using several internet databases, including Web of Science and Scopus. Additionally, while recognizing the similarities with the primary databases, the author conducted searches on Google Scholar to find notable research in the chosen topic. Titles and abstracts relevant to the databases chosen are part of the search technique. identified the articles using search terms like "digital," "supply chain," "supplier selection," "criteria," and "twin."

Peer-reviewed, English-language articles were chosen based on the inclusion criteria. Articles under five pages and those written in languages other than English were excluded due to the exclusion criteria. To ensure the caliber and comprehensiveness of the chosen research and to examine more significant contributions on the use of digital twins and assessments in supplier selection, it was decided to include articles that were longer than five pages. Since most of the journals indexed in the databases the author considered are in English, the author pointed out from earlier research that limiting to only English was a common practice in systematic reviews. To prevent potential translation errors and misinterpretations, the author excluded studies that were not written in English. Articles that utilise digital twins outside of the manufacturing sector have also been excluded. For instance, a large number of papers that were found examined the digital twin for agriculture and health issues, but they did not fit the inclusion requirements. This analysis includes articles from 2020 to 2024, and Table 3 provides more details on the search string and process (Table 3).

Table 3. Overview of Literature Search Strategy

Electronic database	**Quantity**	**Search strategy**	**Keywords**	**Language**	**Type**
Web of Science	7158	Topic Abstract Keywords	Digital twin AND supply AND Manufacturing AND Supplier criteria OR evaluation OR value chain OR Selection	English	Conference paper Reviewed article or article
Scopus	2331				

Author's own compilation

To conduct the data screening, a methodical approach was used using the PRISMA framework. The various steps in the procedure are shown in Figure 2. The following are the various stages of the review process for the use of digital twins in supplier selection.

Identification phase: After removing duplicates (n = 569) from a total of 2887 studies imported from three databases for screening, we had 2318 studies left for additional screening.
Screening phase: The author eliminated 2219 irrelevant papers that did not meet the requirements for using digital twins to solve supplier selection problems after screening articles based on their titles and abstracts. There were 99 studies left over from this step that needed to be screened during the eligibility phase.

There were 99 studies left over from this step that needed to be screened during the eligibility phase.
Eligibility phase: Only chosen papers with full text access were considered eligible in this two-step process. Articles with fewer than or equal to five pages (n = 21) were not included in Step 1. Articles (n = 40) unrelated to the supplier selection criteria were eliminated in Step 2. Thirty-eight (38) studies in all that satisfied the qualifying requirements

were then added for the final analysis. To ensure rigor and consistency, the author independently assessed the eligibility of the chosen publications as part of the screening procedure.

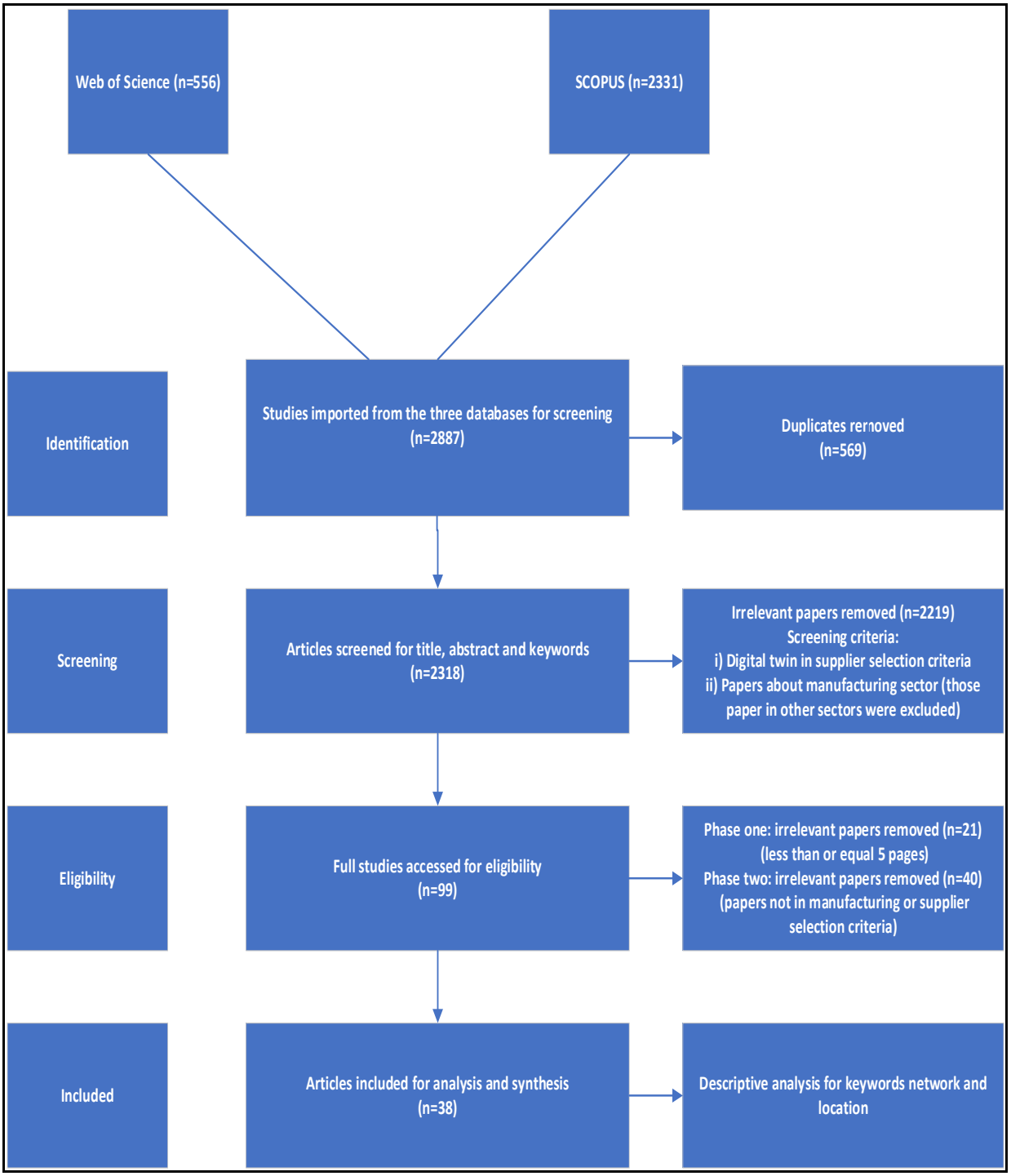

Figure 2. PRISMA Flowchart of Study Selection and Screening

The goal of the data extraction and synthesis procedure was to use a descriptive approach to analyze the results from the included articles:

Analyzing descriptively: To offer a descriptive analysis of the literature, a keyword analysis was conducted. Keywords associated with the digital twin of supplier selection criteria were investigated, providing information on their distribution and frequency over time. The author was able to graphically represent the prevalence and influence of specific themes within the field, as well as the regions active in these areas of research, by using a quantitative approach that methodically records and tracks the occurrence of keywords in the literature. This method enables the comprehension of trends and patterns using data, thereby contributing to a comprehensive understanding of the study area.

The author synthesised the data from many articles and managed the references using Google Scholar. The PRISMA process enabled a methodical description of the review process, ensuring that all crucial components were adequately covered.

The line graph in Figure 3 shows a distinct and steady increase in the quantity of documents released between 2020 and 2024, from roughly 150 to 850. There is a fairly linear growth of 150 documents every year, which suggests that scholarly interest and productivity are ongoing. The increase from 600 in 2023 to 850 in 2024 points to a potential increase in research effort, which may be brought on by changes in legislation, greater financing in related fields, or technological breakthroughs. The cumulative rise of the five-year momentum indicates a maturing field of study, which may be connected to new technologies like 4IR integration, smart supply chains, or digital twins.

The Scopus database's number of published papers per year are displayed in Figure 3. Given that a good number of papers on the subject were released in 2020, it is evident that the digital twin in supply chain management is of interest to scholars and practitioners for development. Recent years have seen a sharp rise in the quantity of published papers, suggesting that this subject is receiving more attention.

The top five fields for published publications in the Web of Science database are displayed in Figure 4. Engineering manufacturing, material science, physics, computer science and business economics are the top five research fields, according to the Web of Science database classification.

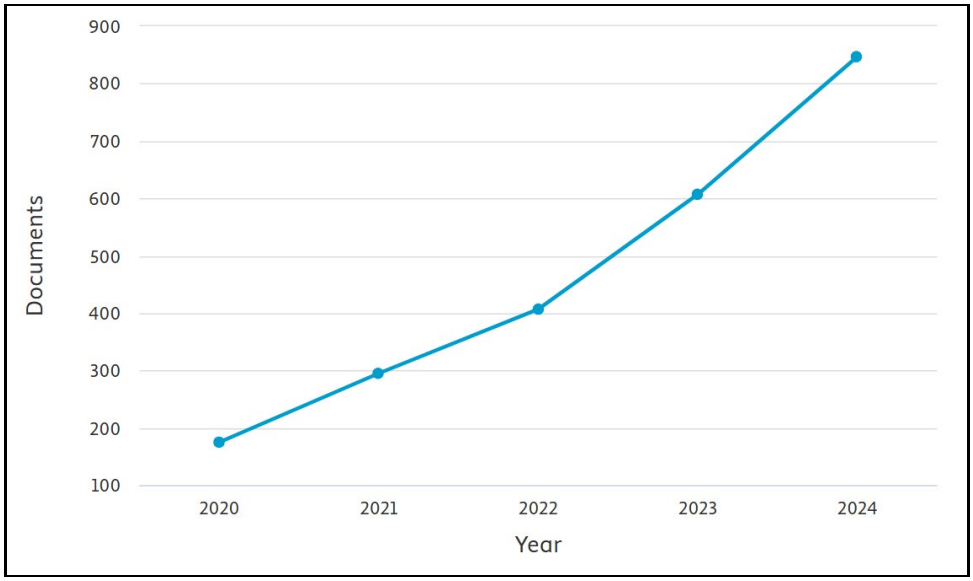

Figure 3. The number of published documents per year.

Notes: The statistical results of published documents from the years 2020–2024 were collected from the Scopus database

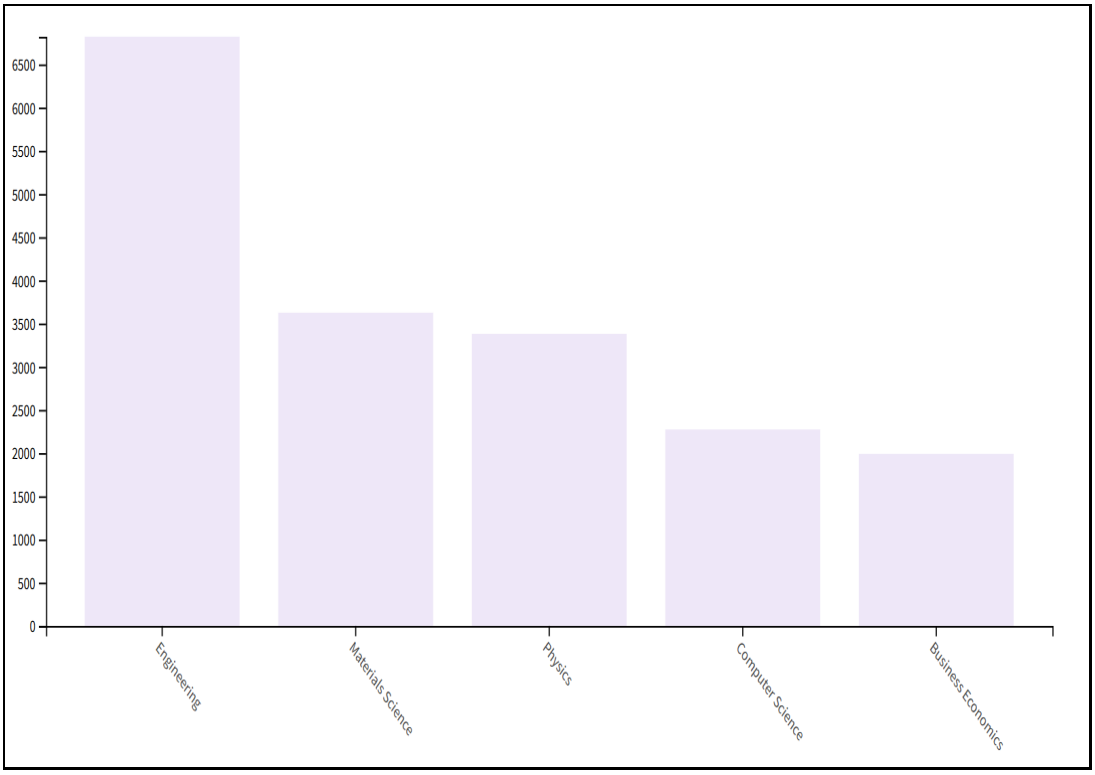

Figure 4. The top five fields of the published documents. Notes: The statistical results of the top fields of the published documents from the Web of Science database.

This paper acknowledges some existing limitations. First, there is still much to learn about how AI-driven tools may improve digital-twin applications for supply chain virtualisation, which is a potential direction for further research. Second, despite their substantial influence on supply chain digitalisation and optimisation, geopolitical factors such as; trade conflicts, regulatory changes, and regional instability were not included for in this research paper. Future research may incorporate these viewpoints to provide a more complete assessment of digital-twin adoption in complicated global situations.

3. Conclusions

The following section presents the findings and addresses the research issues raised in the study. This research has demonstrated that digital-twin applications in supplier selection remain limited, with most studies stressing simulation and monitoring but insufficient empirical validation. In terms of supply chain performance, digital twins improve efficiency, resilience, and predictive capacities, but integration with AI tools opens up new possibilities for effectiveness. Lastly, unexplored topics like sustainability indicators, geopolitical implications, and the methodical integration of AI into digital-twin frameworks should be the focus of future research. Together, these insights answer the guiding research questions by clarifying the current state, demonstrating the role of digital twins in performance enhancement, and outlining a forward-looking research agenda.

Key findings from the literature

RQ1: What is the current state of digital twin technologies applications in supplier selection criteria? Across a wide range of sectors, including pharmaceuticals, health care providers & services, chemicals, machinery, electrical equipment, automobiles, automobile components, food products, commercial services & supplies, textiles, apparel & luxury goods, consumer staples distribution & retail, technology hardware, storage & peripherals, and building products, there is a dearth of research on the use of digital twins in supply selection criteria. Multiple research investigations have explored the application of the digital twin concept in various supply chain processes, focusing on the SCOR framework's plan, make, and delivery phases. Only a small number of studies have examined the use of digital twins in supply chain and logistics, indicating that this area has received comparatively less attention. Digital

twins enhance supply chain connectivity, optimization, and collaboration across various stakeholders and levels by digitally representing physical entities.

RQ2: What is the role of a digital twin in enhancing supply chain performance?
All of the evaluated studies support the importance of the digital twin in enhancing performance and supply chain management. It has been discovered that the digital twin supports each of these pillars. It facilitates JIT manufacturing, eliminates waste, optimizes supplier management databases, streamlines information flow, and encourages continuous improvement. The digital twin enables organizations to respond effectively to changes and disruptions in their organizational environment, facilitating smooth information flow and engagement across supply chain partners. Additionally, the digital twin has played a crucial role in enhancing supply chain performance indicators, as outlined in the SCOR framework. It improves cost optimization, responsiveness, agility, efficiency, and dependability in asset management. Businesses may increase resource efficiency, fulfill orders on schedule, save lead times, and better manage risks by utilizing digital twins.

RQ3: What are the future research and research directions for supply chain management using the digital twin?
The review's conclusions have significant ramifications for further investigation. There is still no consensus on the composition and subsequent applications for digital twins for digital supply chains, despite the substantial discussion of their uses in supplier selection criteria for industrial industries. Prominent academics have recently determined that the DT layer virtualizes two things. Firstly, it virtualizes the SC itself, together with its partners, such as manufacturers, suppliers, and merchants. The second is the digitization of the particular SC instance, which involves two paths: downward, actuating on the product (e.g., changing the number of orders in response to external events), and upward, querying the product's current status during its journey (for visibility, e.g., tracing parts).

Final observation is that digital-twin functions collectively show the transformative potential of digital twins in contemporary supply management and innovation when they combine simulation, monitoring, prediction, and optimization into a cohesive framework that advances both theoretical and applied research by enabling risk-free experimentation, continuous performance tracking, anticipatory modeling, and efficiency-driven refinement.

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Biography

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