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REVIEW

The role of multicriteria decision making in the supply chain: Literature review

El rol de la toma de Decisiones Multicriterio en la Cadena de Suministro: Revisión de literatura

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ABSTRACT

Introduction: the evaluation of supply chain performance has gained significant relevance due to recent events that have transformed its operational dynamics, as well as the advent of Industry 5.0. This new era introduces advanced technologies, such as digital twins, which, when combined with multicriteria models, can identify and prioritize key factors to enhance performance evaluation. These tools have the potential to optimize strategic decision-making in an increasingly dynamic and competitive environment.
Method: a systematic literature review was conducted following the PRISMA framework, analyzing 45 articles published between 2019 and 2024. The sources included scientific databases such as SCOPUS and Web of Science. The search employed terms related to multicriteria models, supply chain, Industry 4.0, and digital twins. Articles were selected based on predefined inclusion and exclusion criteria.
Results: findings revealed that multicriteria methods are widely used to evaluate efficiency, sustainability, and resilience in supply chains. Additionally, digital twins emerged as key tools for real-time monitoring, risk management, and process simulation. However, technological, financial, and regulatory barriers were identified, hindering their practical implementation.
Conclusions: the combination of advanced technologies with multicriteria approaches represents a promising solution for improving supply chain performance. Future research should focus on developing hybrid models, promoting organizational training, and establishing international standards to ensure effective adoption. These initiatives will enable organizations to address the challenges of an increasingly complex global environment, strengthening the resilience and sustainability of supply chains.

Keywords: Multicriteria Decision-Making; Supply Chain; Industry 4.0; Industry 5.0; Digital Twins.

RESUMEN

Introducción: la evaluación del desempeño en la cadena de suministro ha cobrado mayor relevancia debido a los acontecimientos recientes que han transformado su forma de operar, así como por la llegada de la Industria 5.0. Esta nueva era introduce tecnologías avanzadas, como los gemelos digitales, que, en combinación con modelos multicriterio, pueden identificar y priorizar los factores clave para mejorar su evaluación. Estas herramientas ofrecen el potencial de optimizar la toma de decisiones estratégicas en un entorno cada vez más dinámico y competitivo.
Método: se realizó una revisión sistemática de literatura basada en el modelo PRISMA, analizando 45 artículos publicados entre 2019 y 2024. Las fuentes incluyeron bases de datos científicas como SCOPUS y Web of Science. La búsqueda utilizó términos relacionados con modelos multicriterio, cadena de suministro, Industria 4.0 y gemelos digitales. Los documentos fueron seleccionados bajo criterios de inclusión y exclusión predefinidos.

Resultados: los hallazgos destacaron que métodos multicriterio usan ampliamente para evaluar eficiencia, sostenibilidad y resiliencia en cadenas de suministro. Además, los gemelos digitales emergieron como herramientas clave para el monitoreo en tiempo real, gestión de riesgos y simulación de procesos. Sin embargo, se identificaron barreras tecnológicas, financieras y normativas que dificultan su implementación práctica.
Conclusiones: la combinación de tecnologías avanzadas con enfoques multicriterio representa una solución prometedora para mejorar el desempeño de la cadena de suministro. Futuras investigaciones deben desarrollar modelos híbridos, promover la capacitación organizacional y establecer estándares internacionales para garantizar una adopción efectiva. Estas iniciativas permitirán enfrentar los retos de un entorno global cada vez más complejo, fortaleciendo la resiliencia y sostenibilidad de las cadenas de suministro.

Palabras clave: Toma de Decisiones Multicriterio; Cadena de suministro; Industria 4.0; Industria 5.0; Gemelos Digitales.

INTRODUCTION

Supply chain performance has been a topic of great relevance for the research community. This is due to the various events that have drastically impacted the global supply chain, such as the financial crisis of 2008, the decision of the United Kingdom to end its alliance with the European Union in 2016, and the SARS-CoV-2 pandemic,[1] as well as the emergence of the various Industrial Revolutions over time, and the arrival of Industry 5.0, since it involves great challenges for industry and companies.[2]

Various models for the evaluation and measurement of technologies have been present over time, models such as decision-making, seek to use the opportunities offered by technology based on conceptual or quantitative models, which propose a set of metrics and performance.[3]

Considering the above, the importance of measuring efficiency, effectiveness and complexity in supply chains requires the calculation, evaluation, comparison and implementation of performance measurement systems that, through indicators, can quantify the importance of the factors.[4]

Similarly, the arrival of the industrial revolutions have marked the beginning of great changes, such as mechanization, mass production, automation, among other aspects, however, the next industrial era not only represents new ways of operating, but also helps to strengthen methods that currently exist to have clearer and more verifiable projections when wanting to model an event with the help of new technologies.[2]

In this order of ideas, the arrival of I 5.0 not only seeks to improve this type of process, but also integrates the cyber-physical systems of each stage of the supply chain, allowing the observation of their behavior to detect improvements.[5]

New challenges in the supply chain directly impact its performance, which has led companies to seek innovative solutions based on emerging technologies. One of these prominent solutions is the use of digital twins, tools that allow monitoring, analyzing and optimizing supply chain operations in real time.[6]

A digital twin is defined as a virtual representation of a physical object, process or system that enables real-time monitoring, analysis and optimization of operations.[7] This technology has transformed the way risks are managed in the supply chain, providing better response times and generating significant competitive advantages.

Since theories related to this topic are still under development and there is no clear proposal defining its applicability, this paper aims to address the following research questions:

- **RQ 1:** How can Industry 4.0 principles be integrated with multi-criteria models to optimize performance evaluation in the supply chain?
- **RQ 2:** What challenges does combining emerging technologies with multi-criteria models imply in complex and subjective decision-making within the supply chain?
- **RQ 3:** What is the role of new-age trends in developing effective methodologies for supply chain performance measurement?

The paper will describe the methodology used for the systematic literature review and present a detailed analysis of the findings to answer the questions raised. In addition, future research directions will be discussed and an innovative framework for supply chain performance management, based on the application of multi-criteria models, will be proposed.

METHOD

This section is based on concepts derived from three main lines of research: the evolution of industrial revolutions, supply chain performance through multi-criteria analysis, and the incorporation of digital twins.

These concepts provide a comprehensive theoretical basis for analyzing the integration and impact of digital twins in supply chain performance assessment, supported by a multi-criteria analysis approach.

This article addresses the importance of integrating emerging technologies, such as digital twins, into supply chain performance assessment using multi-criteria models. To this end, a systematic literature review will be conducted under the PRISMA framework, structuring the content into background on existing methods, methodology, descriptive analysis, discussions, and conclusions.

A systematic approach was adopted to review the literature related to the implementation of multicriteria models and emerging technologies for measuring supply chain efficiency. This process included identifying relevant studies, extracting data, and selecting sources based on previously defined eligibility criteria. The search design was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles, as indicated in the following sections.

Strategic search

The search was carried out in various academic databases, such as SCOPUS and Web of Science, supplemented with Google Scholar to identify outstanding studies. Key terms such as: (Multicriteria OR Decision-Making OR MCDM OR Multicriteria OR "Decision Making"), ("Supply Chain" OR "Supply Chain"), ("Industry 4.0" OR "Industria 4.0"), ("Digital Twins" OR "DT"). This approach allowed us to collect and manage relevant information to identify trends, research gaps and graphical representations of the findings, providing a clear framework for the analysis.

Inclusion and exclusion criteria

The inclusion criteria for this research considered exclusively articles written in English or Spanish. Those published in other languages were excluded in order to facilitate a systematic search and minimize errors arising from the translation or interpretation of information. In addition, only articles whose focus was directly related to the supply chain in the business field were selected, discarding those that addressed applications in other contexts, such as the use of digital twins in the medical sector or environmental issues. This analysis covered studies published between 2019 and 2024. Table 1, presented below, summarizes the search protocol used in this research.

Table 1. Search summary for the protocol

Seeker	Amount	Search strategic	Keywords	Language	Guy
Scientific Web Pages	12,200	Topic (search by title, abstract, keywords)	(Multicriteria OR Decision-Making OR MCDM OR Multicriteria OR "Decision Making") AND ("Supply Chain" OR " Supply Chain ") AND ("Industry 4.0" OR "Industry 4.0") AND ("Digital Twins" OR "DT")	Spanish, English	Articles
Elsevier, Springer, Taylor & Francis, IEEE, MDPI, etc.	280				

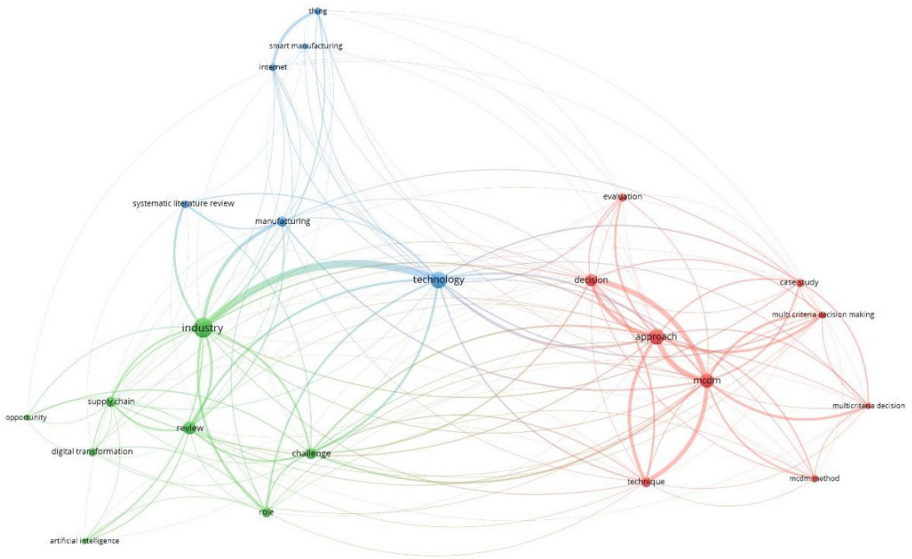
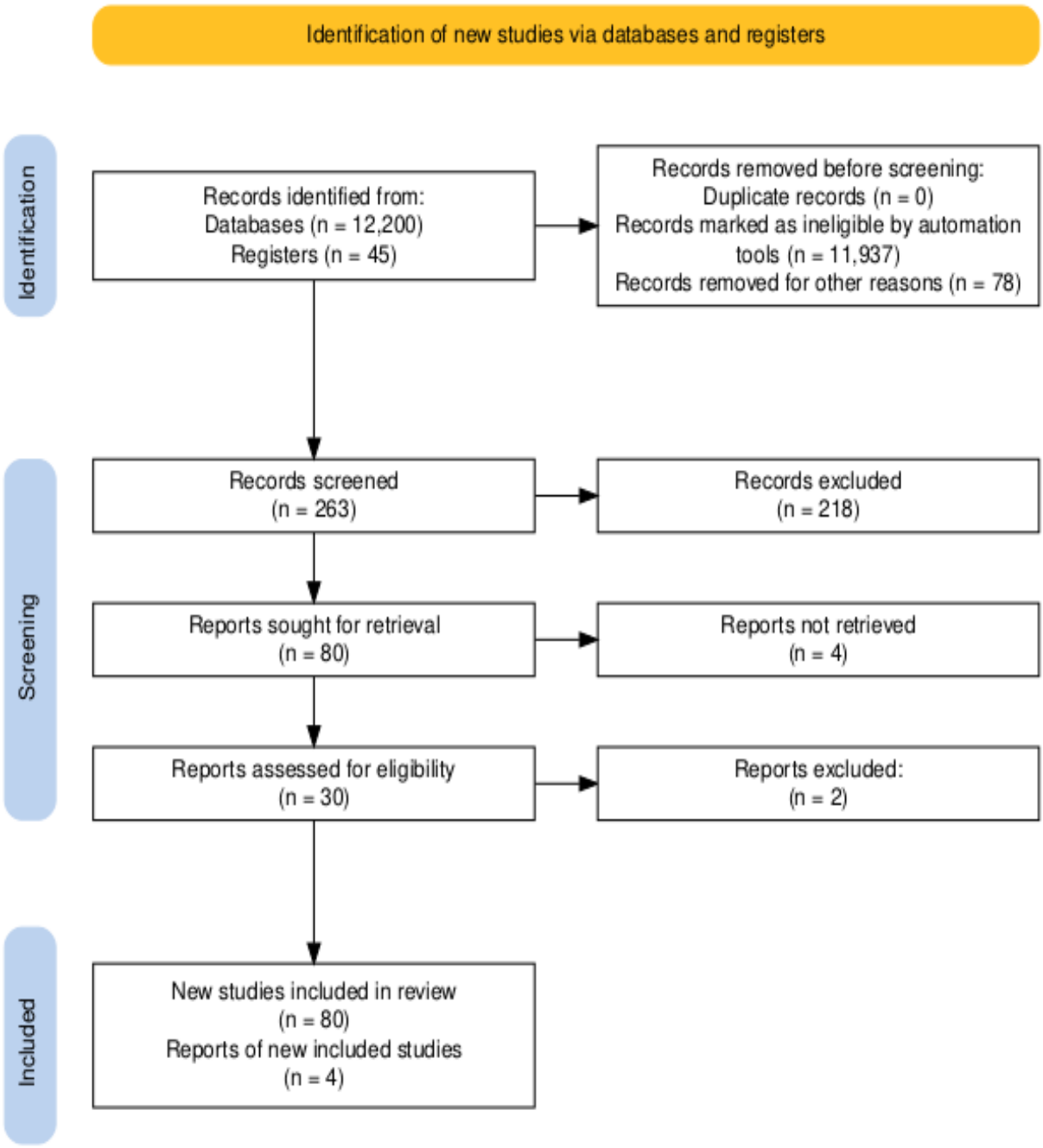


Figure 1. Occurrence and strength of terms

Figure 1 presents the most frequently occurring words and the connections between their related terms. Among the most notable relationships are the connections between “Technology” and “Industry”, “Technology” and “Decision”, as well as “Industry” and “Change”. It is worth highlighting the relevance of an emerging term identified as “Digital Transformation”, which is closely linked to the transformations in industrial operations, driven by the arrival of the new technological era. This concept underlines the impact of digitalization on the evolution of the industrial environment and its adaptation to current demands.

RESULTS

Figure 2 presents the results of the PRISMA model through a flow chart, which precisely details the number of items selected and discarded during the analysis process. In parallel, Table 2 provides a summary of the literature related to the study topic, allowing us to identify opportunities for the development of more effective methods that contribute to the evaluation of performance in the supply chain. This approach allows a comprehensive understanding of current trends and gaps in research, facilitating the design of innovative solutions in this area.



Source: Haddaway NR, Page MJ, Pritchard CC, McGuinness LA [39]
Figure 2. Flowchart

Table 2. Summary of the most recent literature review found for this research

Authors	Objectives of the documents	Opportunities identified in the context of Supply Chain performance
Deploying Industry 5.0 drivers to enhance Sustainable supply chain risk resilience [40]	Importance of developing strategies that integrate sustainable supply chain risks (SSCRs) and Industry 5.0 principles, in order to reduce production costs and strengthen interaction within supply chains.	• Define I 5.0 as an approach that prioritizes sustainability, humanization and resilience in industrial transformation. • The importance of sustainability in sustainable supply chain risk management (SSCRs) and supply chain resilience (SCRE) is highlighted.
Cyber-physical internet based intelligent operation platform for off- site construction supply chain management. [41]	The paper presents an intelligent operation platform based on cyber- physical internet for supply chain management.	• Key features of Internet- based cyber-physical platform. • Importance of adopting advanced technologies such as the Internet of Things (IoT) and digital twins, which can lead to a digital transformation in the industry.
Impact of Industry 4.0 on supply chain performance. Prod Plan Control [42].	Explore and analyze how Industry 4.0 enabling technologies impact supply chain performance.	• Identify key technologies. • Propose an integrated framework • Investigate interconnectivity. • Suggest future research • directions.
Digital twin applications for overcoming construction supply chain challenges.[43]	Identify the role of Digital Twins (DT) in overcoming the challenges facing the construction supply chain (CSC).	• Identify current challenges in CSC. • Exploring the contributions of Digital Twins. • Provide examples from other industries. • Suggest directions for future research.
Building supply- chain resilience: an artificial intelligence-based technique and decision- making framework.[1]	Propose an integrated decision-making framework that uses artificial intelligence (AI) techniques to improve supply chain resilience(SCRes).	• Identify and Analyze AI Techniques. • Develop a Decision- Making Model. • Providing a Practical Framework for Businesses. • Contribute to Literature.
Conceptualization of a 7-element digital twin framework in supply chain and operations management.[6]	Develop a conceptual and methodological framework for the creation of a digital twin of the supply chain that facilitates the management of disruption risks.	• Integrating Data and Models. • Improving Resilience. • Improving Resilience.
Enhancing the order-to-delivery process with real- time performance measurement based on digital visualization.[44]	Increase understanding of the implications of using digital twins in innovation processes within organizations	• Investigate the Impact. • Provide a conceptual framework. • Identify Business Opportunities. • Contribute to Literature.
A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. Prod Plan Control.[45]	It indicates the concept of a supply chain digital twin (SC twin) as an innovative tool to manage disruption risks and improve resilience in supply chains in the context of Industry 4.0.	• Visibility in Real Time. • Analysis Predictive and Reactive. • Resource Optimization. • Improved Decision Making. • Adaptation to Changes Dynamic.
Industry 4.0: a supply chain innovation perspective.[46]	Addresses the transformation that the Fourth Industrial Revolution (I4.0) is generating in supply chain management	• Definition of Digitalization. • Supply Chain Innovation (SCI). • Use Case Analysis. • Differences between Companies .

The present study can be represented through an analysis based on the trend of the main research on the subject of study, as shown in figure 3. While figure 4 shows the main publishers that have the greatest contribution in these areas of study, within which the main ones are Elsevier, Mdpi, Springer, IEEE, Taylor & Francis.

Literature review

Evolution of industrial revolutions through the supply chain.

The evolution of industrial revolutions has generated significant transformations in the way of operating in the industry.[8] The First Industrial Revolution marked a milestone with the invention of the steam engine, driving technological changes that revolutionized production and society.[9] The Second Industrial Revolution brought with it the electrical era, as well as advances in the chemical, air and land industries, consolidating a stage of technological and industrial expansion.[10] The Third Industrial Revolution, known as the era of knowledge

and technology, promoted the development of electronics, bioengineering, computers, telecommunications, software and robotics, laying the foundations for the automation and modernization of production processes.[11] Finally, the Fourth Industrial Revolution is characterized by digitalization, which has caused an exponential growth of digital technologies.[12] This period integrates physical and digital systems through the Internet of Things and interconnected services, allowing industries to reach higher levels of flexibility and autonomy. The opportunities presented by this new industrial revolution bring with them: 1) Fewer barriers between inventors and markets, 2) a more attractive role for AI, 3) Integration of different techniques and domains or a fission, 4) Improving the quality of life, and 5) Life linked to the Internet.[13] Even though these latest industrial revolutions are not yet fully implemented, meaning that their application is still being explored, it is important to highlight that the basis of I 4.0 technology is based on human productivity, while I 5.0 focuses on humans, sustainability, and resilient manufacturing systems.[14] Similarly, I 5.0 should be seen as a framework for socio-digital transformation that aims to integrate social values, which implies a responsible use of I 4.0 technologies to promote sustainability objectives.[15]

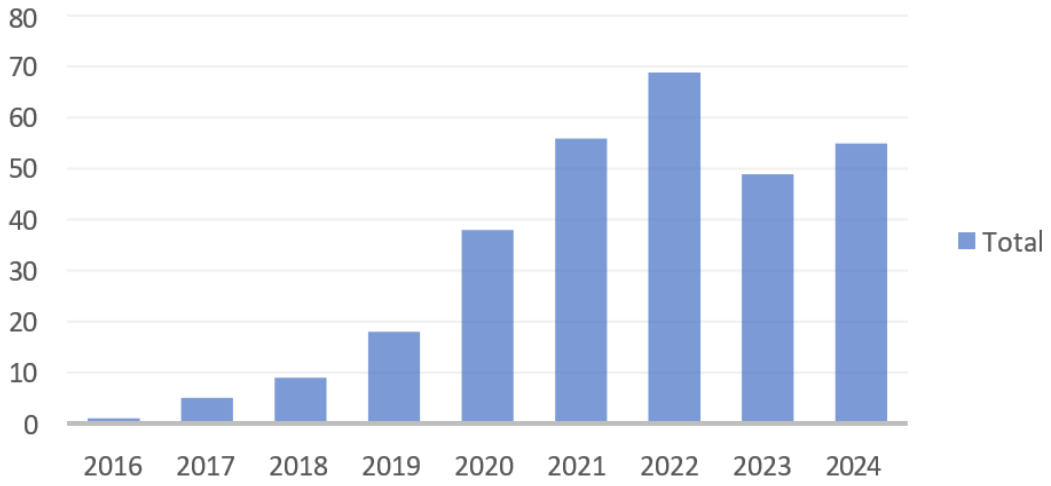


Figure 3. Search summary for the protocol

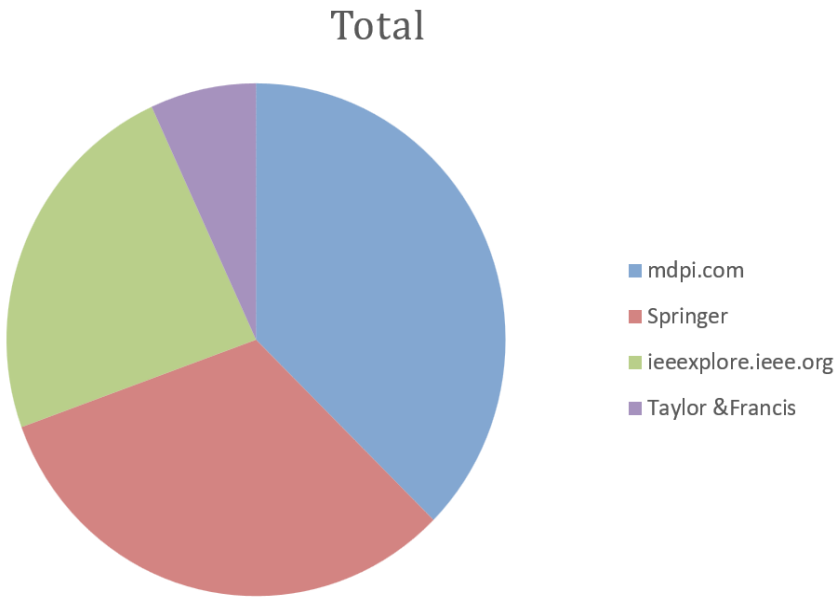


Figure 4. Main publishers

Likewise, it is of great importance to recognize that, in addition to integrating new technologies and tools that facilitate and improve human quality, these new industrial revolutions bring with them the improvement

of cybersecurity strategies, for the prevention of risks, fraud or interruption of operations, ensuring data protection, and reducing both voluntary and involuntary risks.[13]

Supply chain performance under multicriteria analysis.

Considering that supply chain performance and its evaluation is a topic of geat interest to the research community due to its complexity and the multiple factors involved, this study explores quantitative and qualitative models that allow measuring the efficiency and responsiveness of these chains. The application of these models in a practical context can help companies to identify more accurately the key elements to optimize their operations management.[16]

The supply chain as an object of study of this topic, refers to a network of organizations that work together to transform raw materials into finished products to be delivered to the final destination, this network involves suppliers, manufacturers, distributors, retailers and customers, which is focused on coordinating and optimizing the processes necessary to satisfy demand effectively and efficiently.[17]

For this reason, the use of technology to gather information on market demand and facilitate data exchange is key to your operations. By integrating these elements, a complete evaluation of the components involved is allowed, which helps to identify the real capabilities of the process and optimize its performance.[18]

In this way, the importance of measuring the performance of the most important elements to evaluate effective management has become a priority for companies in order to level the process to obtain and maintain competitive advantages.[19]

In recent decades, there has been an attempt to take advantage of the opportunities offered by technology to measure CS performance. Some research presents conceptual or quantitative models for evaluation, and most of them propose conceptual models that indicate a set of performance metrics.[3]

Some literature reviews indicate that the importance of the efficiency, effectiveness and complexity of supply chains have imposed the calculation, evaluation, comparison and implementation of performance measurement systems that, through indicators, quantify the degree of these factors.[4]

One of the ways in which such evaluations can be carried out is by focusing on the various multi-criteria analyses that exist, since these can facilitate the identification of the main elements to consider for the evolution of performance. Various investigations propose different multi-criteria techniques to provide feasible solutions to the problems presented.

According to Prince Agarwal[20] a wide range of approaches are highlighted, from simple to more complex techniques. They evaluate the most commonly used methods and discuss which ones may be more efficient. Among the methods they identify are:

- Data envelopment analysis (DEA) analysis). Focused on system efficiency, it considers the processes and the result, or its benefits are identified as the weighted sum of the results, it is a powerful tool to evaluate efficiency in contexts where there are multiple inputs and outputs, allowing organizations to identify areas of improvement and optimize their resources.[21]
- Generality of Decision Making (Decision Making, DM). A decision-making model, in general, is a technique that helps to select the best options for companies. And these can be divided into: Mathematical Programming (MP), Artificial Intelligence Models, and multi-criteria decision-making model (MCDM) and this can be composed of different characteristics such as: problem identification, information gathering, generation of alternatives, evaluation of alternatives, decision making, implementation and evaluation of results.[22]
- Multi-Criteria Models for Decision Making (MCDM). It is a branch of operations research that explicitly evaluates numerous competing criteria for analysis and decision making. It allows the investigation of quantitative and qualitative judgments, facilitating decision making in contexts where there are multiple points of view and interested parties. It is useful for determining the impact of development actions on sustainability, incorporating conflicts between economic, environmental and social objectives. Likewise, its scientific method seeks to understand the world through the construction of an artificial model based on science.[23]
- Analytical Hierarchy Process (AHP). It requires decision makers to use a ratio scale to compare the parts of criteria to be considered, likewise, it is a decision-making technique that allows structuring a complex problem in a hierarchy of criteria and alternatives. Its structuring is based on organizing the problem in a hierarchy that includes the main objective at the top, followed by the criteria that affect the decision, and finally the available alternatives at the bottom.[24]
- Techniques for the performance of preferences by similarity to the ideal solution (TOPSIS). This method is used to classify and select alternatives based on multiple attributes, within which its main stages are: Problem formulation, construction of the decision matrix, normalization of the ratings, assignment of weights to the attributes, Calculation of weighted scores, determination of ideal and anti-ideal solutions, calculation of distances, calculation of proximity index, classification of alternatives. [25]

- Analytic Network Process (ANP). It presents a new hybrid MCDM strategy that can identify the structural links and interrelationships between the elements of the evaluation and provide support to the method to address the problem, it is especially useful in situations where the criteria are interdependent and a more flexible approach than the AHP is required. It has been applied in various areas, such as project management, supplier selection, and policy evaluation, among others.[26]
- Fuzzy Logic. Based on factors including time constraints and lack of domain knowledge, it suggests a framework based on fuzzy set theory and robust system to find sustainable solutions. Similarly, fuzzy logic works through an approach that allows handling uncertainty and imprecision in decision making.[27]
- Generic Algorithm (GA). The method includes a supply chain modeling framework, a generic algorithm optimizer, and a discrete event simulator, and is used to solve complex problems where optimal solutions are not easily identifiable by traditional methods.[28]

The application of multicriteria methods has been used by various industries applying various domains, providing great support for those who find it necessary to make complex decisions, which is why authors such as Kumar and Shubhra, 2023 [29] mention the following application examples shown in the following table 1.

Table 3. Application of multicriteria methods

Model	Application	Scope	Source
TOPSIS (Technique for Order Preference by Similarity to Ideal Solution	Business and management applications	Evaluation and classification of potential suppliers, integrating criteria such as quality, cost and level of service.	[30]
Fuzzy logic	Addressing uncertainty and subjectivity in supplier evaluation	Discusses how fuzzy logic can improve supply chain management by enabling more flexible and realistic evaluation.	[31]
AHP (Analytics Hierarchy Process)	Supply chain management	Prioritize shipments in the supply chain.	[32]
TOPSIS	Urban planning	Transport planning.	[33]
ANP (Analytic Network Process)	Supplier selection	Evaluate logistics service providers, incorporating criteria such as cost, quality and risk, and considering the interrelations between them.	[34]

In this way, performance evaluation in CS has evolved significantly with the incorporation of multi-criteria methods, providing tools that help address the inherent complexity of this process. As companies focus on optimizing their operations and maintaining competitive advantages, the adoption of the aforementioned techniques facilitates more informed and strategic decision-making.

Integration of digital twins into the supply chain.

A digital twin (DT) is described as a computational model of a physical object or system, which reflects all its functional characteristics and connections with the operational components, allowing rapid analysis and real-time decision making through accurate analysis.[35]

The idea of Digital Twins (DT) is born from the environment related to the modeling and simulation of an already pre-established process. The same one that had its beginnings in 2010 at NASA,[36] thanks to the simulation process in the Apollo 13 mission, considerably expanding its scope beyond a simulation of a process by introducing new elements, such as a virtual representation of reality in the form of a model with a much broader scope.[36]

Companies like GE have been pioneers in the use of this type of technology in 2016, which helps to use the interconnectivity of various devices, transforming the way businesses operate. Similarly, it is mentioned that the attraction of DT is its ability to produce a data- based system, replicating assets in real time, providing a fairly optimal level.[37]

It is also important to mention that digital technologies impact the creation and capture of value by transforming business models, which can facilitate the creation and collaboration between different actors, as well as allowing a more dynamic flow of information and resources.[38]

DISCUSSION

The research carried out highlight's findings related to the application of multicriteria models in the supply chain and the influence that new technologies can have in improving decision-making and prioritizing alternatives based on the data presented, as well as improving the accuracy of strategic decision-making.

For the study of this research, a total of 45 scientific articles of great interest were identified by publishers with a high content of scientific impact. Likewise, it is appreciated how the creation of scientific content has

been gradually increasing in recent years, to which the pandemic has contributed due to its way of changing the perspective and mode of operation. Likewise, it can be highlighted that the implementation of digital twins can contribute to the development of areas, experimentation, innovations, in addition to generating new simulation opportunities.[44]

One of the main limitations observed in the study is the identification of barriers hindering the adoption of digital twins and MCDM models. While these technologies offer substantial benefits in optimizing supply chain operations, various technological, financial, and regulatory constraints continue to impede their widespread deployment. The technological challenges stem from the complexity and integration requirements of digital twins, which demand high computational power, robust infrastructure, and advanced data analytics capabilities. The financial barriers arise from the significant investment required to develop and implement these systems, making it difficult for small and medium-sized enterprises (SMEs) to adopt them. Additionally, regulatory constraints and the absence of standardized frameworks further complicate their implementation, as compliance with different industry regulations may limit the scalability and interoperability of these technologies.[2]

It is worth noting that although progress has been steady, it is noted that the methods for achieving the ambitious sustainability goals of Industry 5.0 are still unclear. However, it is suggested that companies can leverage the sustainability features of Industry 4.0 to contribute to the societal goals of Industry 5.0 in a systematic manner.

Another critical concern raised by the research is the absence of well-defined methodologies to guide companies in integrating sustainability into digital transformation strategies that create a gap between technological potential and practical execution. This ambiguity may lead to inconsistencies in implementation, where companies focus on isolated technological advancements rather than a holistic, sustainability-driven transformation.

Furthermore, the research presents an approach based on the role that new-age technologies can play in supporting complex decision-making involving the supply chain. Considering that digital twins are a highly sophisticated technology, which makes use of various technologies,[43] it can help develop hybrid models that integrate advanced technology with more dynamic and adaptive multi-criteria approaches.

Finally, the emerging trends in technology present the need to develop hybrid models that integrate new-era technologies, which may involve more dynamic and adaptive multi- criteria approaches.[47]

CONCLUSIONS

The analysis resulting from this research represents the potential that can be found in new technologies such as digital twins, which can help multi-criteria methods work together and thus be able to evaluate the performance of the supply chain in a more informed way. This new technology acts as a watershed to integrate physical and digital systems, optimizing processes, increasing resilience and improving the response capacity to unseen conflicts. However, this is still a topic in development, so its implementation could present high initial costs, as well as present barriers to adoption or resistance to change. Likewise, continuing with this field of study opens the way to continue using theoretical knowledge about the application of these technologies, the impact that it can have on multi-criteria models and the functionality in specific sectors to obtain more accurate results that help in complex decision-making. Future research should focus on developing hybrid models that integrate technological and multi- criteria approaches, as well as promoting training and the development of international standards. These efforts will enable companies to meet the challenges of a dynamic and competitive global environment, promoting more sustainable and resilient supply chains.

BIBLIOGRAPHIC REFERENCES

1. Belhadi A, Kamble S, Fosso Wamba S, Queiroz MM. Building supply-chain resilience: an artificial intelligence-based technique and decision-making framework. Int J Prod Res. 2022 Jul 18;60(14):4487-507.

2. González-Hernández IJ, Armas-Alvarez B, Coronel-Lazcano M, Maldonado-López N, Vergara-Martínez O, Granillo-Macías R. Technological development in the industrial revolutions. Ingenio Concienc Scientific College of Super City Sahagún. 2021;8(16):41-52.

3. Sánchez Jiménez L. Control and monitoring of supply chain performance indicators [Internet] [Thesis]. [Nuevo León]: Autonomous University of Nuevo León; 2021. Available at: http://eprints.uanl.mx/22263/1/1080315308.pdf

4. Afaq Y, Manocha A. Blockchain and Deep Learning Integration for Various Applications: A Review. J Comput Inf Syst. 2 Jan 2024;64(1):92-105.

5. Nagy G, Szentesi S. Revolutionizing Production Logistics: Industry 5.0's Impact. Adv Logist Syst - Theory Pract. 2024;18(2):69-86.

6. Ivanov D. Conceptualization of a 7-element digital twin framework in supply chain and operations management. Int J Prod Res. Mar 18, 2024;62(6):2220-32.

7. Tao F, Cheng J, Qi Q, Zhang M, Zhang H, Sui F. Digital twin-driven product design, manufacturing and service with big data. Int J Adv Manuf Technol. 2018 Feb;94(9- 12):3563-76.

8. Melnyk LH, Kubatko OV, Dehtyarova IB, Dehtiarova IB, Matsenko OM, Rozhko OD. The effect of industrial revolutions on the transformation of social and economic systems. 2019;

9. Thomes P. Industry—Between Evolution and Revolution: A Historical Perspective. In: Handbook Industry 40: Law, Technology, Society. Springer; 2022. p. 1119-38.

10. Kumar K, Zindani D, Davim JP. Industry 4.0: developments towards the fourth industrial revolution. Springer; 2019.

11. Rozo-García F. Review of the technologies present in industry 4.0. Rev UIS Eng. 2020;19(2):177-91.

12. Petcu I, Barbu DC, Anghel M, Radu AF, Golea DG. Shaping the Future: Between Opportunities and Challenges of the Ongoing 4 Th and the Forthcoming 5 Th Industrial Revolution. ELearning Softw Educ. 2020;3.

13. Hassoun A, Aït-Kaddour A, Abu-Mahfouz AM, Rathod NB, Bader F, Barba FJ, et al. The fourth industrial revolution in the food industry—Part I: Industry 4.0 technologies. Crit Rev Food Sci Nutr. 2023 Sep 10;63(23):6547-63.

14. Lei Z, Shi J, Luo Z, Wan J. Intelligent manufacturing from the perspective of industry 5.0: application review and perspectives. IEEE Access. 2024;

15. Ghobakhloo M, Mahdiraji HA, Iranmanesh M, Jafari-Sadeghi V. From Industry 4.0 digital manufacturing to Industry 5.0 digital society: a roadmap toward human-centric, sustainable, and resilient production. Inf Syst Front. 2024;1-33.

16. Jabir I. MCDM and Logistics and Transportation. 2020;

17. Riadh H. Contribution of logistics diagnosis to cost minimization: The case of a subsidiary of the automotive industry. J Sustain Dev Transp Logist. 2018;3(3):55-68.

18. Torres Vergara JI. Multicriteria model for the evaluation of the performance of the resilient and sustainable supply chain [Thesis]. [Nuevo León]: Autonomous University of Nuevo León; 2021.

19. Christopher M. Logistics and supply chain management. Pearson Uk; 2022.

20. Agarwala N. Promoting Circular Economy in the shipping industry. J Int Marit Saf Environ Aff Shipp. 2 Oct 2023;7(4):2276984.

21. Henao CAR, Serna OLL. Data envelopment analysis and its applications in sustainability. Ingeniare. 2021;(31):11-9.

22. Bhushan N, Rai K. Strategic decision-making. In: Strategic Decision Making: Applying the Analytic Hierarchy Process. Springer; 2004. p. 3-10.

23. Quintero AG, Serranomoya ED, Von CMH. Multicriteria methods and processes for evaluation. Blue Moon. 2013;(36):285-306.

24. Silva-López GC, Solís-Centurión M, Recalde-Ramírez JL, López MM. Application of the analytical hierarchy process (AHP) in the selection of logistics technology. In: IV Argentine Symposium on Industrial Informatics and Operational Research (SIIIO 2021)- JAIIO 50 (Virtual mode). 2021.

25. Chakraborty S. TOPSIS and Modified TOPSIS: A comparative analysis. Decis Anal J. 2022;2:100021.

26. Khan AU, Ali Y. Analytical hierarchy process (AHP) and analytical network process methods and their applications: a twenty year review from 2000-2019: AHP & ANP techniques and their applications: Twenty years review from 2000 to 2019. Int J Anal Hierarchy Process. 2020;12(3).

27. Jovčić S, Průša P, Dobrodolac M, Švadlenka L. A proposal for a decision-making tool in third-party logistics (3PL) provider selection based on multi-criteria analysis and the fuzzy approach. Sustainability. 2019;11(15):4236.

28. Lambora A, Gupta K, Chopra K. Genetic algorithm-A literature review. In: 2019 international conference on machine learning, big data, cloud and parallel computing (COMITCon). IEEE; 2019. p. 380-4.

29. Sahoo P, Saraf PK, Uchil R. Identification of challenges to Industry 5.0 adoption in Indian manufacturing firms: an emerging economy perspective. Int J Comput Integr Manuf. :1- 26.

30. Taherdoost H, Brard A. Analyzing the process of supplier selection criteria and methods. Procedia Manuf. 2019;32:1024-34.

31. Apeji UD, Sunmola FT. Sustainable supply chain visibility assessment and proposals for improvements using fuzzy logic. J Model Manag. 2023;18(3):701-26.

32. Imran N, Mubarik MS, Naghavi N, Khan SA. An application of multi-criteria data management approach for prioritization of unwarranted causes of delay in international shipments. Int J Integr Supply Manag. 2022;15(3):233-52.

33. Dimitriou D, Sartzetaki M. Performance assessment modeling for managing transport enterprises based on modified fuzzy TOPSIS analysis. Oper Res. 2022;22(5):6037-53.

34. Gupta A, Singh RK, Mangla SK. Evaluation of logistics providers for sustainable service quality: Analytics based decision making framework. Ann Oper Res. 2022;315(2):1617-64.

35. Fuller A, Fan Z, Day C, Barlow C. Digital twin: Enabling technologies, challenges and open research. IEEE Access. 2020;8:108952-71.

36. de Prada C, Galán-Casado S, Pitarch JL, Sarabia D, Galán A, Gutiérrez G. Digital twins in the process industry. Rev Iberoam Automática E Ind. 2022;19(3):285-96.

37. Gupta S. Digital Twins: Advancements in Theory, Implementation, and Applications. SpringerNature;

38. Nambisan S, Wright M, Feldman M. The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. Res Policy. 2019;48(8):103773.

39. Haddaway NR, Page MJ, Pritchard CC, McGuinness LA. PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimized digital transparency and Open Synthesis. Campbell Syst Rev 2022 Jun 1;18(2):e1230.

40. Hsu CH, Wu JZ, Zhang TY, Chen JY. Deploying Industry 5.0 drivers to enhance sustainable supply chain risk resilience. Int J Sustain Eng 2024;17(1):1-28.

41. Yin L, Li T, Li G, Besklubova S, Zhong RY, Zhao S. Cyber-physical internet based intelligent operation platform for off-site construction supply chain management. Enterp Inf Syst. 2024;18(6):2346743.

42. Fatorachian H, Kazemi H. Impact of Industry 4.0 on supply chain performance. Prod Plan Control. 2021 Jan 2;32(1):63-81.

43. Bakhshi S, Ghaffarianhoseini A, Ghaffarianhoseini A, Najafi M, Rahimian F, Park C, et al. Digital twin applications for overcoming construction supply chain challenges. Auto Const. Nov 2024;167:105679.

44. Holopainen M, Saunila M, Ukko J. Enhancing the order-to-delivery process with real-time performance measurement based on digital visualization. Prod Manuf Res. Dec 31, 2023;11(1):2217237.

45. Ivanov D, Dolgui A. A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. Prod Plan Control. 2021;32(9):775-88.

46. Hahn GJ. Industry 4.0: a supply chain innovation perspective. Int J Prod Res 2020;58(5):1425-41.

47. Ghobakhloo M, Mahdiraji HA, Iranmanesh M, Jafari-Sadeghi V. From Industry 4.0 digital manufacturing to Industry 5.0 digital society: a roadmap toward human-centric, sustainable, and resilient production. Inf Syst Front. 2024;1-33.

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