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Discrete Event Simulation for Intelligent Supply Chains: A Data-Driven Systematic and Bibliometric Review

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Abstract. The increasing complexity of supply chains has driven the adoption of computational approaches such as discrete-event simulation (DES) to optimize logistics processes, reduce costs, and enhance decision-making. This paper presents a systematic and bibliometric literature review aimed at analyzing the most relevant scientific contributions regarding the application of DES in supply chain management. A rigorous methodology was employed, based on the PRISMA 2020 flow and Kitchenham's approach, selecting 64 papers published between 2018 and 2024 from databases including Scopus, IEEE Xplore, ACM, ARDI, and ScienceDirect. The findings were organized around five research questions. Key criteria such as flexibility, accuracy, and adaptability were identified to assess the effectiveness of simulation models (RQ1). Regarding supply chain management, the most commonly used indicators were demand, costs, and inventory (RQ2). Additionally, a significant proportion of the papers were published in Q1 and non-quartile journals, indicating both thematic consolidation and expansion (RQ3). Co-occurrence networks reflected the leadership of countries like the United States and China (RQ4). Finally, the most frequently addressed topics were risk management, integrated logistics, and data modeling (RQ5), revealing both mature areas and others still under development.

Keywords. Discrete-event simulation, supply chain management, supply chain, supply network, systematic and bibliometric review.

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1 Introduction

Supply chain management has become a strategic cornerstone for organizations seeking to maintain their competitiveness in an increasingly complex global environment. In this context, discrete-event simulation (DES) emerges as a fundamental tool for modeling and optimizing critical logistics processes, such as inventory management, production planning, and distribution operations. Although its application has yielded remarkable advances, the literature review reveals heterogeneous development and disparities in the methodological quality of published studies, highlighting the need for a more rigorous systematic evaluation. For example, one study employed DES to compare two inventory systems within a forest biomass supply chain in Canada, finding that the fixed-quantity system covered greater demand, albeit with higher costs and emissions [1]. Another work proposed a buffer optimization framework in finite queue networks, using the Generalized Expansion Method (GEM) in conjunction with DES, achieving significant improvements in operational efficiency by reducing waiting times and manufacturing bottlenecks [2]. In the energy sector, the use of liquefied natural gas (LNG) in Italian ports was explored as a means of reducing emissions, using simulation to evaluate various fueling station configurations, emphasizing their impact on operational efficiency, cost reduction, and the need for appropriate infrastructure for a green transition [3]. In Vietnam, the application of DES to a pellet supply chain yielded economic benefits totaling USD 15,426,661 and CO_2 emissions of 36,307.6 tons, demonstrating that maintaining a small-scale BOM favors both economic and environmental efficiency [4]. During the COVID-19 pandemic, DES was used to analyze food supply chains in Germany, revealing that resilience was affected by outbreak severity, government measures, demand dynamics, and consumer behavior [5]. During the same period, simulation was used to assess the deployment of dry ports to minimize empty container repositioning (ECR), finding that the combination of street turns and extended temporary storage reduced land-based ECR emissions by up to 32% [6]. Additionally, the L-leap method, based on the Multilevel Monte Carlo (MLMC) approach, was proposed to accelerate DES in supply chains, achieving more efficient uncertainty propagation and greater accuracy compared to the standard Monte Carlo method [7]. From a multi-method perspective, the impact of quality-based segregation in the South African sunflower industry was quantified through agent-based simulations, DES, and Bayesian networks, revealing negative effects on costs and service levels in specific silos [8]. In the technological domain, the BSELA simulator, grounded in an Event-Layered Architecture, was presented as a solution to enhance efficiency and accuracy in blockchain simulations applied to supply chains, validated with Bitcoin data [9]. Other studies evaluated the influence of interconnectivity and circularity on sourcing and recovery strategies, showing that resilience is strengthened through collaborative practices, coordinated planning, and shared reverse flows [10]. In the healthcare sector, a DES-based decision support tool was developed to optimize bed-cleaning logistics in Danish hospitals, accounting for sterile bed availability, cleaning staff stress, and resource utilization [12]. Additionally, order behavior under disruption conditions in the supply chain was examined, concluding that “disruption queues” cause post-event instability and that “revival” policies smooth the transition, improving system stability and performance [13]. Moreover, using simulation in anyLogistix, proactive adjustments in payment terms were shown to increase supply chain resilience by optimizing cash flow during and after disruptions [14]. In the mining sector, the domino effect during the pandemic in the copper supply chain was simulated, revealing that the lack of safety stock and multi-sourcing strategies were key disruption drivers, and proposing solutions for more resilient management [15]. Furthermore, altitude-based risk forecasting was identified as a tool to prioritize wood logistics, preventing up to 73% of load devaluation, with delivery time being a critical variable [16]. In mountainous areas, a multimodal wood transport model reduced the use of self-loading trucks by over 50% and decreased logistics costs by between 6% and 11% [30]. In urban waste management, a water-based system validated through hybrid simulation and implemented in Stockholm reduced transport needs by up to 55%, improving operational efficiency and recycling [18]. Other studies analyzed how variables such as vehicle type, age, and driving style impact emissions and transport times in road-based supply chains under Lean and Green Manufacturing approaches [19]. In the medical products domain, the design and control phases of a three-tier supply chain for glucose test strips were integrated, optimizing costs and inventories through simulation, and showing that reorder points changed after optimization, while order quantities remained stable [22]. In the prefabricated sector, a model for evaluating multiple disturbances was proposed, concluding that system failures were the most critical and should be prioritized under budget constraints [25]. Additionally, the use of DES and agent-based simulation (ABS) in emergency hospital services was reviewed, underscoring the importance of accounting for process and time variability, as well as involving healthcare professionals in validation [66]. In disaster management, a systematic review identified 56 publications employing Monte Carlo, system dynamics, ABS, and DES, highlighting priority topics by technique [67]. A bibliometric review of the past 15 years also revealed research gaps in studies integrating DES and ABS for the design and improvement of supply chains, suggesting the adoption of multi-method approaches as an effective strategy [68]. Modeling methods for biomass supply systems combining GIS, life cycle analysis, and discrete simulation were analyzed, highlighting the computational challenges of such integration and its value for improving result reliability [69]. In the context of humanitarian logistics, 33 studies applying disaster-related simulation were reviewed, revealing that areas such as evacuation and victim transport require further investigation [70]. A co-occurrence analysis of 238 publications on patient-centered logistics identified 13 key research areas, with DES as the predominant technique, followed by hybrid approaches, system dynamics, ABS, and Monte Carlo [71]. Simulation-optimization approaches in resilient supply network design were also reviewed, classifying studies based on their uncertainty-handling strategies, and identifying opportunities for hybrid methods integrating simulation, metaheuristics, and machine learning [72]. From a circular economy perspective, conceptual frameworks based on reinforcement learning were proposed for circular supply chain management (CSCM), acknowledging their potential to reduce waste and mitigate climate change, and recommending further studies on their dynamic and stochastic nature [73]. Finally, 91 studies on quantitative inventory management methods in green supply chains were systematized, highlighting mixed-integer linear programming and heuristic algorithms focused on minimizing costs and emissions [74], along with 93 studies on lean simulations in production and operations, which pointed to the lack of methodological integration and the need for approaches that also address social and economic impacts [75].

The systematic literature review reveals that, despite substantial progress, the application of DES in supply chain management remains limited and heterogeneous. There is a persistent lack of integration with complementary methodologies such as agent-based simulation (ABS) and system dynamics (SD), which restricts the ability to represent logistics complexity. Additionally, the simultaneous incorporation of economic, social, and environmental criteria remains scarce, limiting the development of a holistic sustainability perspective. The insufficient consideration of uncertainties and disruptions—such as those caused by the COVID-19 pandemic—underscores the need for more robust approaches. This situation justifies a systematic review that synthesizes the existing knowledge, identifies critical gaps, and guides future research toward more resilient and sustainable supply chain models.

Accordingly, this paper is structured as follows: Section II presents the theoretical framework of the study; Section III outlines the methodology employed; Section IV discusses the main findings; and Section V concludes with final remarks and directions for future research.

2 Background

This section aims to synthesize and analyze the conceptual definitions present in the reviewed papers, both theoretical and empirical, that have been selected for this systematic review. The objective is not only to provide a clear understanding of the key variables involved but also to establish a solid theoretical foundation that supports the development of the present study.

2.1 Discrete Simulation

Discrete-event simulation (DES) has established itself as a robust methodology for the analysis, planning, and optimization of processes in production and logistics environments [11]. Its ability to model complex systems through the sequential representation of events makes it a widely applied tool in supply chain management [12]. A notable application of DES is found in the use of Witness® software to simulate a forest chip supply chain, integrating input data from Excel spreadsheets. This study made it possible to analyze the impact of innovative technologies, such as new chippers and vehicles, on operating costs and energy efficiency in the direct supply of biomass for combined heat and power generation (CHP) [20]. In the modular construction sector, DES has been used to evaluate the impact of early design decisions on the logistics performance of the supply chain, providing an anticipatory view of their operational implications [23]. Similarly, its application in the surimi supply chain has proven useful in optimizing system performance and promoting sustainability through improvements in downstream operations [24].

2.2 Supply Chain Management

Discrete-event simulation (DES) has become a key tool for the efficient management of supply chains, enabling the modeling, analysis, and optimization of complex processes that are difficult to evaluate through traditional approaches [25]. In sectors such as modular construction, DES facilitates the assessment of early design decisions on the structure and operation of the logistics chain, contributing to better coordination among stakeholders and the mitigation of potential risks [23]. Likewise, its application in the surimi supply chain in India has enabled the comparison of integration scenarios, demonstrating its effectiveness in simultaneously optimizing operational performance and sustainability indicators [24]. Overall, DES stands out for its ability to anticipate and address logistical challenges, increasing the efficiency and adaptability of operations in an increasingly complex global context [21].

2.3 Discrete Simulation as a Transformative Mechanism in Supply Chain Management

The growing complexity and uncertainty of modern supply chains have exposed the limitations of traditional Supply Chain Management (SCM) approaches based on static and deterministic assumptions. In this context, Discrete-Event Simulation (DES) enables the dynamic representation of supply chain processes, capturing variability, stochastic behavior, and feedback effects that are essential for realistic decision-making. From a technological perspective, DES integrates process logic, operational constraints, and performance metrics within a unified modeling framework, supporting scenario analysis and what-if experimentation. Theoretically grounded in systems theory and operations research, DES allows supply chains to be analyzed as complex adaptive systems, promoting a shift from local optimization toward system-wide coordination. Despite challenges related to data quality, computational complexity, and model validation, DES plays a central role in advancing SCM toward data-driven, resilient, and proactive paradigms, enabling organizations to anticipate disruptions and improve strategic and operational decision-making.

3 Review Method

The methodology employed in this study is based on the approach proposed by Kitchenham [65], adapted to the specific requirements of this research. A key modification was the incorporation of the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [76], aimed at enhancing the transparency and reproducibility of the selection process. Unlike Kitchenham's original model, the inclusion of PRISMA enables a more rigorous and systematic structuring of the identification, screening, and evaluation stages of the scientific literature. This combined methodology supports an in-depth analysis of the impact of discrete simulation in

Table 1. Research questions

Research Question
RQ1: What criteria are employed in the scientific literature to evaluate the effectiveness of discrete-event simulation in management and decision-making contexts?
RQ2: What indicators or criteria are used to evaluate the effectiveness of supply chain management?
RQ3: What quartile rankings are presented by the scientific journals in which research on the impact of discrete-event simulation in supply chain management has been published?
RQ4: Which countries most frequently exhibit co-occurrence in publications related to discrete-event simulation applied to supply chain management?
RQ5: What are the main thematic categories addressed in research on discrete-event simulation in supply chain management?

Table 2. Search descriptors and corresponding synonyms grouped by conceptual categories

Conceptual Group	Descriptor
Discrete Simulation	discrete simulation/ discrete-event simulation/ event-driven simulation / discrete system simulation
Supply Chain Management	supply chain management/ supply network / logistics /supply chain/ supply chain coordination

supply chain management, ensuring the inclusion of relevant and methodologically sound studies. The PRISMA 2020 checklist is provided in the Supplementary Materials.

3.1 Main Research Motivation

In order to gain a deeper understanding of the impact of discrete-event simulation on supply chain management, it is essential to formulate research questions (RQs).

These questions guide the development of the study and direct the systematic analysis of the literature. Table 1 presents the five research questions, which underpin the approach adopted in this review.

3.2 Information Sources and Search Strategies

The databases selected for this research were: Scopus, IEEE Xplore, ACM Digital Library, ARDI, and ScienceDirect, due to their relevance in the fields of engineering, logistics, and applied technologies. The search strategy was based on the use of keywords and their respective synonyms, carefully defined to maximize both coverage and accuracy of the results. The search timeframe was extended through 11 May 2024 (with the search conducted on that date) to capture the most recent research developments in this rapidly evolving field. Table 2 presents the set of terms used in the searches, which enabled the identification of scientific literature pertinent to the objective of this review.

The search method was based on the formulation of structured search equations, designed to facilitate the systematic exploration of keywords and their synonyms in each selected database. These equations were adapted to the syntax and query format of each source, ensuring efficient retrieval of relevant literature. Table 3 presents the equations applied in each repository, as well as the number of initial results obtained in each case.

3.3 Initial Studies

Once the searches in each of the selected databases were completed, the initial set of documents potentially relevant to the research was compiled. These results represent the first quantitative filter of the systematic review process. Figure 1 shows the distribution of identified studies by information source, forming the preliminary basis for the screening and selection process.

3.4 Selection Criteria

In order to ensure the relevance and quality of the studies included in this systematic review, exclusion criteria (EC) were defined to accurately filter out documents that did not align with the research objective. These criteria were designed to eliminate irrelevant, redundant, or methodologically weak studies. A total of seven exclusion criteria were applied, as detailed below:

Table 3. Information Sources and Search Equations

Source	Search Equation
Scopus	TITLE-ABS-KEY ((“discrete simulation” OR “discrete-event simulation” OR “event-driven simulation” OR "discrete systems simulation”) AND (“supply chain management” OR “supply network” OR logistics OR “supply chain” OR “supply chain coordination”))
IEEE Xplore	(("All Metadata": "discrete simulation" OR "All Metadata": "discrete-event simulation" OR "All Metadata": "event-driven simulation" OR "All Metadata": "discrete systems simulation") AND ("All Metadata": "supply chain management" OR "All Metadata": "supply network" OR "All Metadata": logistics OR "All Metadata": "supply chain" OR "All Metadata": "supply chain coordination"))
ACM Digital Library	[[All: "discrete simulation"] OR [All: "discrete-event simulation"] OR [All: "event-driven simulation"] OR [All: "discrete systems simulation"]] AND [[All: "supply chain management"] OR [All: "supply network"] OR [All: logistics] OR [All: "supply chain"] OR [All: "supply chain coordination"]]
ARDI	(“discrete simulation” OR “discrete-event simulation” OR “event-driven simulation” OR “discrete system simulation”) AND (“supply chain management” OR “supply network” OR logistics OR “supply chain” OR “supply chain coordination”)
Science Direct	Title, abstract, keywords: (“discrete simulation” OR “discrete-event simulation” OR “event-driven simulation” OR “discrete system simulation”) AND (“supply chain management” OR “supply network” OR logistics OR “supply chain” OR “supply chain coordination”)

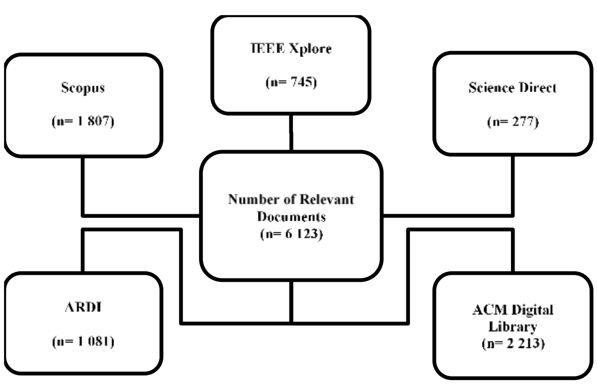

Fig. 1. Number of relevant documents identified

EC1: The paper was published more than seven years ago.

EC2: The paper is not written in English.

EC3: The paper was not published in peer-reviewed journals or conferences.

EC4: The paper is a systematic or bibliometric review.

EC5: The title and keywords do not adequately align with the research objective.

EC6: The full text of the paper is not available for analysis.

EC7: The paper is a duplicate within the selected study set.

3.5 Selection of Studies

As a result of the initial search process, a total of 6123 potentially relevant documents were identified. Subsequently, through the systematic application of the established exclusion criteria and the use of the PRISMA approach, this number was reduced to 64 studies that met the quality and relevance standards defined for this research. Figure 2 graphically illustrates the filtering and selection process of the documents included in the final analysis.

3.6 Quality Assessment

In this phase, the selected studies underwent a rigorous evaluation process through the application of seven quality assessment criteria (QA), designed to ensure the methodological soundness and scientific relevance of the included documents. These criteria allowed the assessment of aspects such as the clarity of objectives, the adequacy of the methodological approach, and the validity of the results. Table 4 provides a detailed presentation of each criterion applied during this stage.

The evaluation of the 64 papers was carried out independently, applying the seven predefined quality assessment criteria (QA). Only those studies that received a "Yes" for all criteria were considered valid for the final analysis. Following this rigorous assessment, no paper was excluded, which allowed the complete set of 64 selected studies to be retained for the development of this study.

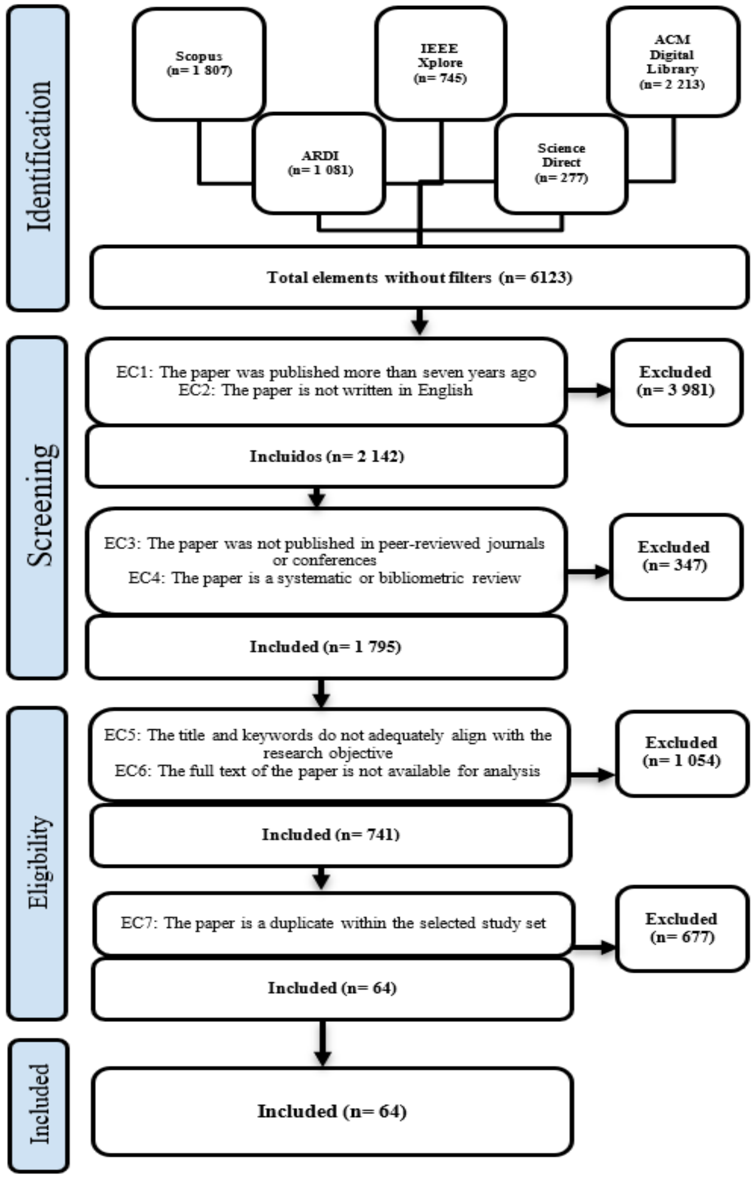

Fig. 2. PRISMA flow diagram

3.7 Data Extraction Strategy

From the final set of 64 selected papers, systematic extraction of relevant information was conducted to meet the objectives of this review.

The extracted data included methodological, contextual, and analytical details of each study. To facilitate organization and traceability, Mendeley Desktop was used.

3.8 Data Synthesis

The analysis of the 64 selected papers enabled the systematic collection of information required to address research questions RQ1 through RQ5,

Table 4. Quality assessment criteria

Quality Assessment (QA)	Score
QA1: Are the study objectives clearly and explicitly stated?	Yes / No
QA2: Are the applied techniques well described and justified?	Yes / No
QA3: Are the data collection methods clearly described?	Yes / No
QA4: Are the obtained data adequately explained in the study?	Yes / No
QA5: Does the data analysis have a clearly defined purpose?	Yes / No
QA6: Are the research questions answered appropriately?	Yes / No
QA7: Is there a clear relationship between the data, its interpretation, and the conclusions?	Yes / No

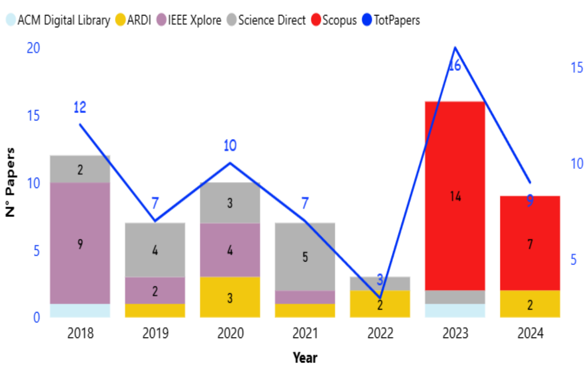

Fig. 3. Papers by year and source

structuring the key findings that support the study's conclusions. This synthesis facilitated the identification of research patterns, methodological trends, and application domains across the selected literature.

Bibliographic records were first imported into Mendeley Desktop to organize and standardize references and to remove duplicate entries, ensuring dataset consistency.

The curated data were then analyzed using RAj Research Assistant, a specialized platform developed by Dr. Javier Gamboa-Cruzado, which was employed to compute descriptive indicators such as publication trends, country distribution, journal quartiles, and research topics.

4 Results and Discussion

This section presents and analyzes the main findings obtained from the final set of selected papers. The results are organized according to the research questions (RQ1–RQ5), providing a structured and critical analysis of the available evidence. This analysis allows the collected data to be linked with the motivations of the study, offering a solid basis for the discussion on the impact of discrete-event simulation on supply chain management.

4.1 General Description of the Studies

Figure 3 displays the number of articles collected by year and by source in this study.

The results show that the number of annual publications on discrete-event simulation in supply chain management has evolved unevenly between 2018 and 2024, with a significant peak in 2023 (16 articles) and a decline in 2022 (3 articles). The most frequent sources are Scopus and IEEE Xplore, although in 2023 Scopus stands out as the predominant source (14 articles). A greater diversity of sources was observed in earlier years, while more recent years show a consolidation toward higher-impact indexed databases. This trend suggests a growing formalization and visibility of scientific output in the field.

Between 2018 and 2024, studies on Discrete-Event Simulation (DES) and supply chain modeling experienced a notable increase in publications. According to Eman Ouda, Andrei Sleptchenko, and Mecit Can Emre Simsekler [66], 62 articles were collected for their systematic review, using sources such as EBSCO, Scopus, and Web of Science. In contrast, Abideen, A. Z., and Mohamad, F. B. [68] conducted a broader document collection covering the years 2005–2019, retrieving 120 relevant papers, 58% of which were collected over the last six years. Similarly, the results of Mika Aalto, Raghu KC, Olli-Jussi Korpinen, Kalle Karttunen, and Tapio Ranta [69] included 498 initial results from Scopus and Web of Science, from which 34 relevant papers were selected. In the same vein, Berrone, P., Mula, J., and Sanchis, R. [74] reported that they selected 91 studies from WOS and Scopus. Finally, Camila Laura Pareja Yale, Marcia Lorena da Silva Frazão, Marco Aurelio de

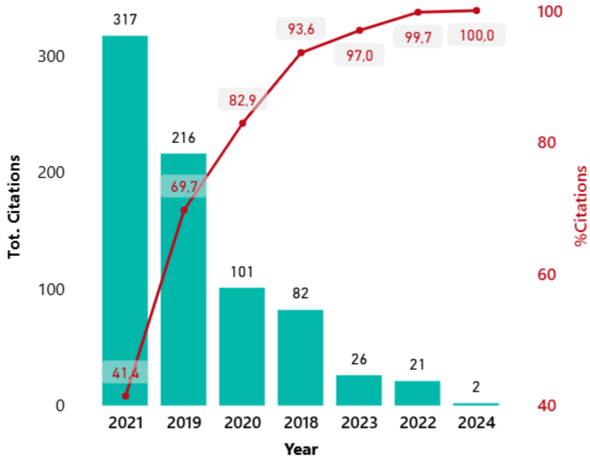

Fig. 4. Pareto Diagram of Citations by Year

Mesquita, and Hugo Tsugunobu Yoshida Yoshizaki [70] highlighted the years 2014 and 2019 in their review, selecting 33 relevant papers.

The upward trend in 2023 indicates renewed interest that could be replicated in other sectors such as healthcare, transportation, or agriculture. This dynamic also reflects opportunities to strengthen dissemination in underrepresented regions by promoting research from other logistical contexts. In the future, comparing these patterns in other periods of crisis or technological advancement will allow for the identification of cycles in scientific productivity. Furthermore, the concentration in Scopus may be leveraged to guide publication strategies toward greater global impact.

Figure 4 presents a Pareto diagram illustrating the temporal distribution of citations, integrating absolute values and cumulative percentages to identify the years with the greatest scientific impact. This representation enables a clear distinction between periods with dominant contributions and those with marginal participation in the total number of citations.

As shown in the results, the year 2021 accounts for the largest share of citations (≈41.4%), which can be attributed to the maturity of the published studies and their methodological or foundational nature. The inclusion of 2019 raises the cumulative percentage to approximately 69.7%, reflecting a phase of thematic consolidation and high academic reuse. According to the observed distribution, the years 2018–2020 together account for more than 90% of total citations, forming a temporal core of scientific production with high visibility. The decline observed in 2022 and 2023 is consistent with the natural citation lag and the lower maturity of emerging research lines. Finally, the minimal value recorded in 2024 is mainly associated with recency effects and database update cycles rather than a loss of scientific relevance.

The results suggest prioritizing the 2018–2021 period for theoretical and comparative analyses, complemented by longitudinal follow-up studies. This pattern is transferable to other business sectors and fields such as healthcare, finance, and logistics, where scientific impact tends to be temporally concentrated. Moreover, applying this approach across different geographical regions and future time horizons will enable the assessment of the evolution and shifts in cycles of academic influence.

Figure 5, including a georeferenced map and bar chart, shows the distribution of the analyzed scientific papers by continent of origin. These visualizations help identify the level of regional participation in research on discrete-event simulation and supply chain management.

Europe clearly leads scientific production with 47 articles, followed by Asia (14) and the Americas (13), while Africa (7) and Oceania (2) show significantly lower participation. This distribution reflects a geographic concentration of knowledge in regions with greater institutional resources and research traditions. The presence of Africa and Oceania, although limited, indicates emerging interest. The disparity among continents suggests gaps in research capacity, access to technologies, or academic priorities.

From 2018 to 2024, notable regional variability was observed in publications on DES and supply chain modeling. Eman Ouda, Andrei Sleptchenko, and Mecit Can Emre Simsekler [66] report that North America, led by the United States and Canada, has historically dominated the number of publications. Similarly, Sumanta Roy, Shanmugam Prasanna Venkatesan, and Mark Goh [71] highlight the dominance of the United States with 75 articles collected for their research. Likewise, Ahmed Zainul Abideen, Fazeeda Binti Mohamad, and Yudi Fernando [75] emphasize that the United

Fig. 5. Papers by continent

Table 5. Criteria for Evaluating the Effectiveness of Discrete Simulation

Criterion	Reference	Qty. (%)
Execution Time	[11][19][42]	3 (6)
Resource Utilization	[30][32]	2 (4)
Accuracy	[4][7][8][9][10][15][16][[17][18][22][24][25][28][38][51][60]	16 (30)
Flexibility	[2][3][5][6][9][13][14][17][19][21][22][26][27][31][32][33][38][43][44][46][48][52][59][63]	26 (49)
Adaptability	[2][5][10][34][52][54]	6 (11)

States provided 23 articles for their study, followed by the United Kingdom with 11 and India with 9. In contrast, the present research indicates that Europe has gained preeminence between 2018 and 2024.

This shift suggests that, in the most recent period, Europe has become the leading academic hub in this field, in contrast with North America's dominance in previous years. This change in academic leadership reflects a significant shift in the global focus of research and publication in these areas.

These results highlight the need to foster international networks to boost scientific production in underrepresented regions. Sectors such as transportation, healthcare, and mining could particularly benefit in Latin American and African contexts. Replicating such research in new environments will enable validation of models across diverse logistical realities. In addition, temporal analysis by continent may reveal how research evolves based on public policy and access to academic infrastructure.

4.2 Responses to the Research Questions

This section presents the responses to the research questions, based on the rigorous analysis of the 64 selected papers. It is worth noting that the reported results are faithfully presented, relying exclusively on the empirical evidence extracted from the reviewed studies. All included papers passed a thorough quality assessment process, ensuring the validity and reliability of the data considered.

Each research question (RQ) is addressed in detail, presenting the corresponding answer along with the tables or figures that clearly, accurately, and reliably illustrate the findings.

4.2.1 RQ1: What Criteria are Employed in the Scientific Literature to Evaluate the Effectiveness of Discrete-Event Simulation in Management and Decision-Making Contexts?

Table 5 and Figure 6 summarize the most frequently used criteria in the scientific literature to assess the effectiveness of discrete-event simulation (DES) in management and decision-making contexts.

The results show that the most frequently cited criterion is flexibility (49%), reflecting the need for DES models to adapt to various operational scenarios. Accuracy (30%) ranks second as a critical measure for validating simulation outcomes

Table 6. Criteria for evaluating the effectiveness of supply chain management

Criterion	Reference	Qty. (%)
Demand	[1][2][3][4][5][6][9][10][15][16][17] [19][20][22][23][24][25][26][27] [29] [31] [32][33][34][35][36][37][39][40][41][42][43][47][48][49] [51][52][53] [55] [56][58][59][60][62][63][64]	50 (44)
Customer Service	[22][27][35]	3 (3)
Costs	[1][2][4][7][9][10][12][13][14][15][16][17][19][22][23][25][26][27][28][30][31] [32][33][34][35][36][38][39][44][50][54][55][57][58][59][60][61][62][63][64]	41 (36)
Inventory Management	[1][4][7][16][19][20][22] [27][36][44][51][52][54] [63]	14 (12)
Visibility	[2][5][10][14] [31] [37]	6 (5)

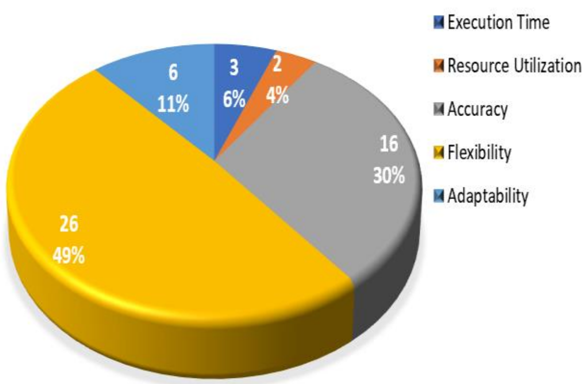

Fig. 6. Summary of criteria for evaluating the effectiveness of simulation

against real-world results. Other criteria such as adaptability (11%), execution time (6%), and resource usage (4%) are also considered, though less frequently. This suggests that studies prioritize a model's capacity to adapt over its computational efficiency. The concentration on a few criteria reveals the absence of a standardized evaluation framework in the field.

According to Eman Ouda, Andrei Sleptchenko, and Mecit Can Emre Simsekler [66], key performance indicators (KPIs) play a crucial role in the modeling, analysis, and optimization of complex systems, highlighting waiting time as a fundamental criterion in DES for assessing system effectiveness. Similarly, Haitham A. Mahmoud, Sarah Essam, Mohammed H. Hassan, and Arafa S. Sobh [73] emphasize the importance of criteria such as forecasting techniques, used to predict waste generation—including batteries, red meat, and post-demolition autoclaved concrete—making them essential for supply chain planning. In this paper, criteria such as execution time, flexibility, adaptability, resource use, and accuracy are also defined to directly measure DES-based systems.

The results highlight the need to develop more comprehensive evaluation frameworks that incorporate both technical and strategic criteria. The prioritization of flexibility suggests its potential applicability in sectors with high variability, such as healthcare, construction, and services. Furthermore, these criteria may be adapted to assess DES models implemented in different geographic contexts, including emerging regions with unstable logistics chains. Finally, applying them in retrospective or prospective studies would enable assessment of simulation effectiveness during various periods of crisis or economic expansion.

4.2.2 RQ2: What Indicators or Criteria are Used to Evaluate the Effectiveness of Supply Chain Management?

Table 6 and Figure 7 summarize the main indicators used to evaluate effectiveness in supply chain management.

These criteria were identified through the analysis of the 64 selected papers, enabling the establishment of common evaluation patterns across various studies.

The most frequently used indicator is demand management (44%), highlighting its central role in the efficient planning of operations. This is followed by total cost (36%), reflecting the ongoing concern with resource optimization.

Although less frequently addressed, inventory management (12%) is also emphasized as essential for balancing availability and efficiency. Visibility (5%) and customer service (3%) appear as less explored criteria, despite their strategic relevance. The dispersion of approaches suggests

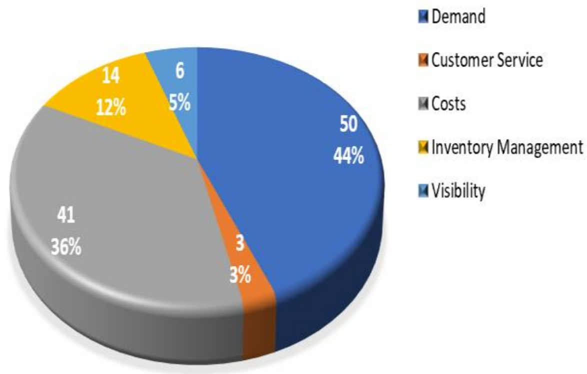

Fig. 7. Summary of criteria for evaluating the effectiveness of supply chain management

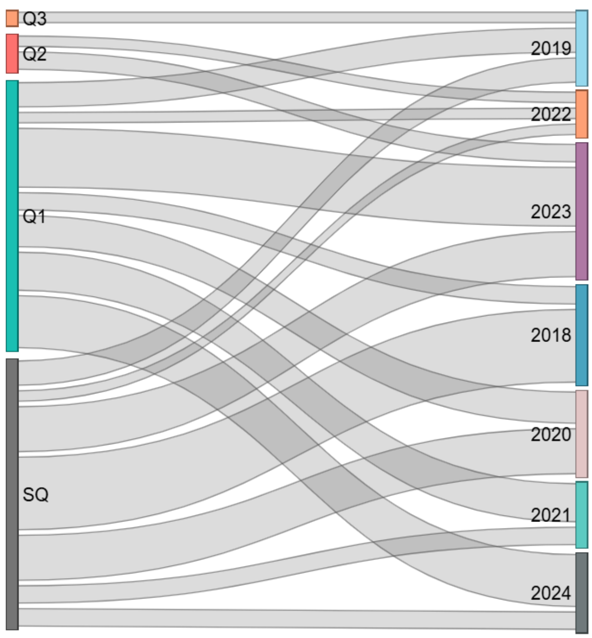

Fig. 8. Quartile rankings by year

that there is still no standardized consensus on how to measure effectiveness in this area.

According to Eman Ouda, Andrei Sleptchenko, and Mecit Can Emre Simsekler [66], their approach focuses on improvement through the reduction of cycle times, inventory minimization, and cost reduction. On the other hand, Pablo Becerra, Josefa Mula, and Raquel Sanchis [74] highlight resource efficiency, disposal costs, and inventory management as key aspects. In contrast, Haitham A. Mahmoud, Sarah Essam, Mohammed H. Hassan, and Arafa S. Sobh [73] mention efficiency, sustainability, and waste reduction within a circular context, although they do not define specific criteria. Likewise, Mika Aalto, Raghu KC, Olli-Jussi Korpinen, Kalle Karttunen, and Tapio Ranta [69] emphasize the importance of Life Cycle Assessment (LCA) in addressing the environmental impact of biomass supply chain management (SCM).

These findings may be extrapolated to sectors such as healthcare, agribusiness, and advanced manufacturing, where demand and inventory control are critical. Moreover, their application in regions with limited logistical infrastructure could enhance operational efficiency. The limited attention to criteria such as visibility and customer service opens opportunities for future research in emerging markets. Finally, these indicators may prove useful in longitudinal studies analyzing the evolution of supply chain management under scenarios of disruption or sustained growth.

4.2.3 RQ3: What Quartile Rankings are Presented by the Scientific Journals in Which Research on the Impact of Discrete-Event Simulation in Supply Chain Management Has Been Published?

Figure 8 (Sankey diagram) and Table 7 illustrate the distribution of the analyzed papers according to the quartile ranking of the journal and year of publication. This visualization helps identify trends in the quality and visibility of the publications.

The papers are primarily concentrated in Q1 journals (47%) and non-quartile (NQ) journals (47%), revealing a duality between high-impact publications and those with lower indexation. The presence of Q1 journals has notably increased since 2020, peaking in 2023 with 8 publications. Only one paper was published in a Q3 journal, and three in Q2, reflecting low representation at these levels. The stability in the total number of publications in recent years indicates sustained interest in the topic. The coexistence of Q1 and NQ papers suggests an expanding field still undergoing editorial consolidation.

According to Eman Ouda, Andrei Sleptchenko, and Mecit Can Emre Simsekler [66], the papers used in their study were sourced from databases such as EBSCO, Scopus, and Web of Science,

Table 7. Quartile rankings by year

Quartile	2018	2019	2020	2021	2022	2023	2024	Total
Q1	2	3	4	5	1	8	7	30
Q2	0	0	0	3	0	1	2	3
Q3	0	1	0	0	0	0	0	1
SQ	10	3	6	2	1	6	2	30
Total	12	7	10	7	3	16	9	64

Table 8. Country-Level Distribution of Scientific Production and Bibliometric Indicators

Country	N° Papers	% Papers	N° Citats.	% Citats.	Citats./ Paper	H-Index
Germany	16	19,3%	426	47,9%	251	1.645
US	8	9,6%	94	10,6%	126	999
United Kingdom	6	7,2%	37	4,2%	94	473
Austria	5	6,0%	28	3,1%	79	427
Sweden	5	6,0%	5	0,6%	79	439
China	3	3,6%	66	7,4%	47	580
India	3	3,6%	37	4,2%	47	485
Italy	3	3,6%	10	1,1%	47	405
Morocco	3	3,6%	4	0,4%	47	286
…	…	…	…	…	…	…
Total	**83**	**100,0%**	**889**	**100,0%**	**1.304**	**8.108**

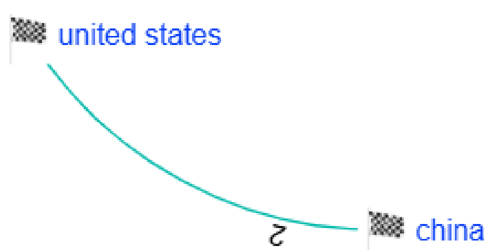

Fig. 9. Bibliometric network by country

which suggests that the reviewed publications were likely ranked in Q1 or Q2. In contrast, Abideen, A. Z., and Mohamad, F. B. [68] used articles from Q1 journals such as the International Journal of Production Research and the International Journal of Production Economics, which results in more reliable findings due to the high quality of these sources. Although these authors do not explicitly mention quartile levels, it is crucial for future research in this field to include the identification of journal quartiles in systematic reviews. This is fundamental, as quartiles are key indicators of the relevance and rigor of scientific research, and their consideration can enhance the evaluation of quality and contribution in studies on Discrete Simulation in Supply Chain Management.

These findings suggest the potential for future publications in Q1 journals from other disciplines such as operations, sustainability, or applied engineering. The publication pattern may be replicated in regions where simulation is still emerging, encouraging high-impact research. The increasing presence in Q1 since 2020 indicates a thematic maturity that may support comparative studies across different temporal contexts. Finally, the proportion of papers in non-quartile journals presents opportunities to raise editorial standards in developing publications.

4.2.4 RQ4: Which Countries Most Frequently Exhibit Co-Occurrence in Publications Related to Discrete-Event Simulation Applied to Supply Chain Management?

Figure 9 of country co-occurrence network, together with the production and citation indicators, provides a dual perspective on (i) structural collaboration patterns and (ii) bibliometric influence in discrete-event simulation (DES) applied to supply chain management. This combined visualization avoids simplistic interpretations based solely on publication counts by linking network centrality with impact metrics.

As evidenced in the results, the most visible co-occurrence pattern is observed between the United States and China, suggesting collaboration driven by complementary industrial capacities, large-scale data availability, and strong research ecosystems focused on logistics optimization and digital transformation. According to the findings shown, Germany's leadership in both publication share (19.3%) and citation proportion (47.9%) indicates that high-impact DES contributions are strongly anchored in engineering-oriented environments with established traditions in

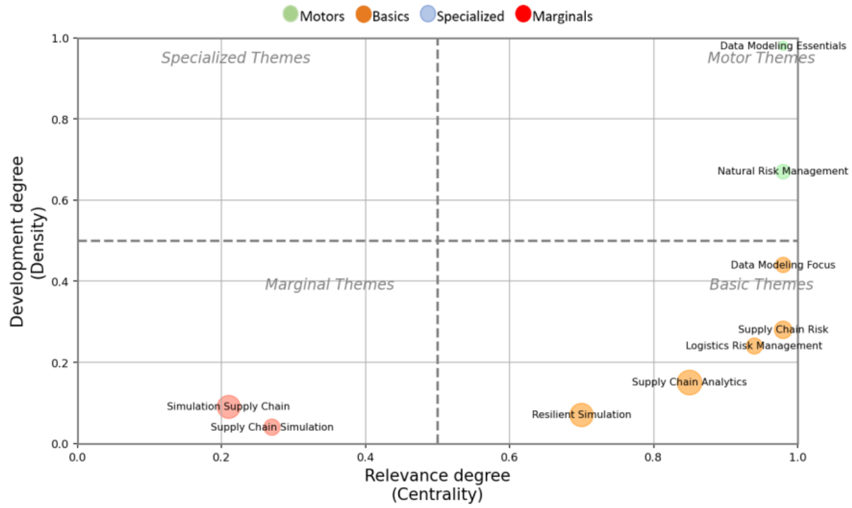

Fig. 10. Thematic map with topic categories

production systems and operational research. In line with the observed distribution, the influence of the United States and China exceeds their relative publication volume, implying that research addressing resilience, disruption management, and global logistics complexity tends to generate broader cross-national citations. Consistent with the bibliometric indicators, European countries such as the United Kingdom, Austria, and Sweden maintain steady contributions, likely facilitated by multinational research consortia and structured funding programs that encourage transnational co-authorship. It is worth emphasizing that co-occurrence patterns may also reflect editorial ecosystems, database coverage, and thematic proximity rather than purely collaborative intensity; therefore, structural prominence should be interpreted alongside contextual publication dynamics.

According to Ahmed Zainul Abideen, Fazeeda Binti Mohamad, and Yudi Fernando [75], co-occurrence is observed between countries such as the United Kingdom and India, as well as Germany and Brazil. Their study highlights the United States, the United Kingdom, Germany, and India as the countries with the highest levels of co-occurrence. I concur with these findings, as my research also identifies the United States as the country with the highest current co-occurrence.

These collaboration patterns suggest that DES frameworks validated in dominant research hubs could be extended to other sectors such as healthcare logistics, energy systems, retail operations, and financial risk networks, where uncertainty and coordination remain critical.

Future studies should replicate DES applications in underrepresented regions—including Latin America and Africa—and across different economic cycles to strengthen external validity and contextual adaptability. Methodologically, distinguishing between co-authorship, co-affiliation, and co-citation networks, while normalizing for database bias, is essential to prevent overestimation of national collaboration leadership in longitudinal bibliometric analyses.

4.2.5 RQ5: What Are the Main Thematic Categories Addressed in Research on Discrete-Event Simulation in Supply Chain Management?

Figure 10 and Table 9 present the thematic map constructed from the bibliometric analysis, which classifies the themes according to their centrality (degree of relevance) and density (degree of development). This visualization identifies the main categories covered in the literature on discrete-event simulation applied to supply chain management.

Table 9. Thematic Map details

Theme	Density	Centrality	Total Citations	Total Documents	Category
Data Modeling Essentials	0.98	0.98	32	9	Motor
Natural Risk Management	0.67	0.98	83	14	Motor
Data Modeling Focus	0.44	0.98	92	16	Basic
Supply Chain Risk	0.28	0.98	149	20	Basic
Logistics Risk Management	0.24	0.94	125	16	Basic
Supply Chain Analytics	0.15	0.85	297	17	Basic
Simulation Supply Chain	0.09	0.21	257	9	Marginal
Resilient Simulation	0.07	0.70	265	13	Basic
Supply Chain Simulation	0.04	0.27	127	6	Marginal

Motor themes such as data modeling languages and risk management stand out due to their high centrality and density, indicating that they are well-developed and structurally relevant research cores. On the other hand, themes such as logistics management, integrated logistics, supply logistics, and data modeling are classified as basic themes—fundamental yet still in development. Logistics resilience also appears as a basic theme, reflecting its recent growth in disruption-related scenarios. Topics such as simulation management and supply chain simulation are classified as marginal themes, due to their low density and centrality, indicating underexplored research opportunities.

As evidenced by the results, Data Modeling Essentials (0.98/0.98) emerges as a highly developed and central motor theme, suggesting that modeling quality—encompassing assumptions, parameterization, and verification/validation—functions as a methodological “infrastructure” that enables and standardizes DES studies in SCM. According to the findings, Natural Risk Management also qualifies as a motor theme (0.67/0.98), indicating that the management of exogenous risks attracts sustained attention because disruptive events increase the value of DES for anticipating scenarios and designing robust policies. Based on the observed distribution, the basic themes (Data Modeling Focus, Supply Chain Risk, Logistics Risk Management, Supply Chain Analytics, and Resilient Simulation) exhibit high centrality (0.70–0.98) but moderate-to-low density (0.07–0.44), a pattern consistent with broadly relevant yet methodologically heterogeneous research lines across metrics and application contexts. Considering impact metrics, Supply Chain Analytics (297 citations) and Supply Chain Risk (149 citations) demonstrate strong traction despite limited density, which can be explained by their “bridging” role with data analytics and risk management, attracting cross-disciplinary citations. Finally, Simulation Supply Chain and Supply Chain Simulation remain marginal (centrality 0.21–0.27; density 0.04–0.09) because their keyword formulations are generic and semantically redundant, dispersing co-occurrences and reducing thematic cohesion even when citation counts are inflated by highly visible studies.

According to Sumanta Roy, Shanmugam Prasanna Venkatesan, and Mark Goh [71], the use of a thematic map facilitates the definition of clusters based on their centrality (X-axis) and density (Y-axis). In this map, clusters are categorized into four quadrants: Motor Themes (first quadrant), with high centrality and high density, indicating fundamental importance; Basic Themes (second quadrant), with high centrality but low density, suggesting limited development despite relevance; Niche Themes (third quadrant), with low centrality and high density, indicating specialized focus; and Declining Themes (fourth quadrant), with low centrality and low density, suggesting a decreasing level of importance. This approach helps identify the relevance and development of each cluster based on its scientific impact.

The findings suggest directing the research agenda toward methodological consolidation, particularly in modeling, verification and validation (V&V), and comparability, as well as toward risk and resilience, by integrating DES with analytics (e.g., operational data and forecasting) to increase thematic density and conceptual convergence. This framework is transferable to other sectors such as healthcare, energy, manufacturing, transportation, and finance, as well as to diverse business areas where disruptions and uncertainty necessitate policy evaluation and scenario-based operational capacity assessment. From a geographical and temporal perspective, replicating the thematic mapping across regions and time windows is advisable to detect thematic shifts (e.g., emerging risk sources, regulation, digitalization) and to assess the stability of the keywords that currently dominate centrality.

5 Conclusions and Future Research

This systematic review provides a comprehensive overview of the use of discrete-event simulation (DES) in supply chain management, identifying the main effectiveness criteria, editorial trends, thematic approaches, and performance metrics. Regarding the evaluation of DES models (RQ1), a strong focus on flexibility and accuracy is observed, highlighting the need for adaptive systems in complex logistics environments. With respect to supply chain management (RQ2), demand and cost emerge as the predominant indicators, revealing a functional approach centered on efficiency. The bibliometric analysis reveals that nearly half of the reviewed studies were published in Q1 journals (RQ3), suggesting growing high-impact academic interest, although a substantial proportion of articles still appear in non-quartile journals. In thematic terms (RQ5), data modeling and risk–resilience themes dominate the field, highlighting a strong focus on methodological robustness and uncertainty management. By contrast, “Supply Chain Simulation” remains weakly developed, reflecting limited thematic consolidation. Overall, these findings indicate a field in consolidation that still exhibits conceptual and methodological gaps requiring further research. The limited presence of holistic approaches integrating technical, social, and environmental aspects underscores the need for more integrative models. Additionally, the geographic concentration of scientific production raises challenges related to contextual diversity and global representativeness. Overall, the results not only confirm the current relevance of DES in SCM but also underscore the need to broaden, deepen, and diversify research perspectives to enhance both practical applications and theoretical foundations.

It is recommended to investigate the integration of hybrid and sustainable approaches into DES models, particularly in non-traditional sectors and underrepresented regions. Moreover, longitudinal studies will allow the analysis of its impact across different historical and geographical contexts.

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