

Discrete-Event Simulation and Digital Twin in Warehouse Logistics: A Bibliometric Analysis

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ABSTRACT

Digital marketing has undergone significant transformations over the past decade, driving fundamental changes in how companies communicate with consumers. This study employs a descriptive method to analyze the evolution of digital marketing, implementation strategies, and its impact on consumer purchasing decisions in the modern e-commerce era. Data were collected through a comprehensive literature review of 50 reputable academic and practical sources. The findings indicate that multi-channel marketing integration, data-driven content personalization, and user experience optimization have become the key pillars of contemporary digital marketing success. Additionally, the study reveals that social media engagement and influencer marketing have a significant impact on brand awareness and customer loyalty. This research concludes that organizations capable of adapting digital marketing strategies in an agile and data-driven manner will gain a sustainable competitive advantage in a dynamic business environment.

Keywords: discrete-event simulation, digital twin, warehouse logistics, bibliometric analysis, thematic mapping, supply chain, optimization, automation, materials handling, industry 4.0.

Introduction

Warehouse logistics is a critical component of supply chain management, where efficient operations directly impact cost, service level, and competitiveness. In recent years, the adoption of Industry 4.0 technologies has transformed traditional warehouse operations, leading to the integration of advanced simulation and digitalization tools. Among these, discrete-event simulation (DES) and digital twin (DT) have emerged as powerful approaches for modeling, analyzing, and optimizing warehouse systems.

DES allows for the detailed modeling of warehouse processes, including material handling, order picking, and resource allocation, enabling the evaluation of different scenarios and the identification of bottlenecks. DT, on the other hand, creates a virtual replica of the physical warehouse, integrating real-time data to support dynamic decision-making and continuous improvement. The convergence of DES and DT in warehouse logistics has opened new avenues for research and practice, making it essential to understand the current state and evolution of this field.

Bibliometric analysis provides a quantitative and visual overview of scientific literature, enabling the identification of research trends, key contributors, and thematic structures. This study aims to conduct a bibliometric analysis of research on DES and DT in warehouse logistics, using a dataset of 315 documents from 1984 to 2026. The analysis will address the following research questions: (1) How

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has the scientific production in this field evolved over time? (2) Which journals, authors, institutions, and countries are the most productive? (3) What are the main thematic clusters and keywords in this research area? The results will contribute to a better understanding of the current landscape and future directions of DES and DT in warehouse logistics.

Method

The bibliometric analysis is based on a dataset of 315 scientific documents related to discrete-event simulation and digital twin in warehouse logistics, covering the period from 1984 to 2026. The dataset was obtained from a bibliographic database and processed using Biblioshiny, a bibliometric analysis tool that provides descriptive statistics, annual scientific production, citation analysis, and thematic mapping.

The analysis follows a descriptive approach, focusing on the following aspects:

- a. **Annual scientific production:** The number of documents published per year is analyzed to identify trends and growth patterns.
- b. **Sources and journals:** The core sources and journals in which the documents are published are identified to determine the main outlets for this research.
- c. **Authors and institutions:** The productivity of authors and institutions is assessed based on the number of documents they have contributed.
- d. **Countries and collaboration:** The contribution of different countries and the extent of international collaboration are examined.
- e. **Thematic mapping:** A thematic map is generated using co-occurrence analysis of keywords to identify the main clusters and themes in the literature.

The results are presented in tables and figures, including a thematic map that visualizes the relationships between keywords and clusters. The analysis is conducted in English, and the findings are discussed in the context of the current state of research on DES and DT in warehouse logistics.

Result and Discussion

3.1. General characteristics of the dataset

The dataset consists of 315 documents, including 137 articles, 161 conference papers, 9 conference reviews, 6 book chapters, 1 book, and 1 erratum. The documents are published in 125 different sources, with an average of 11.46 citations per document and an average document age of 7.85 years.

The majority of the documents are conference papers (51.1%), followed by articles (43.5%), indicating that this field is highly active in conference venues, which is typical for engineering and logistics research. The high average citation rate suggests that the research in this area is influential and widely referenced in the scientific community.

3.2. Annual scientific production

The annual scientific production shows a steady increase in the number of publications over time, with a significant growth in recent years. The number of documents per year is presented in Table 1.

Table 1. Annual scientific production (1984–2026)

Year	Articles	Conference Papers	Total
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1984	1	0	1
1991	1	0	1
1994	1	0	1
1996	1	0	1
1997	1	0	1
1998	3	0	3
2000	1	0	1
2001	1	0	1
2002	2	0	2
2003	5	0	5
2004	5	0	5
2005	2	0	2
2006	5	0	5
2007	7	0	7
2008	7	0	7
2009	3	0	3
2010	7	0	7
2011	10	0	10
2012	11	0	11
2013	11	0	11
2014	5	0	5
2015	9	0	9
2016	10	0	10
2017	14	0	14
2018	15	0	15
2019	29	0	29
2020	22	0	22
2021	22	0	22
2022	23	0	23
2023	22	0	22
2024	35	0	35
2025	23	0	23
2026	1	0	1
Total	315	0	315

The data reveal that the field has experienced a significant growth in recent years, with 2024 being the peak year with 35 articles. This trend reflects the increasing interest in DES and DT in warehouse logistics, driven by the need for more efficient and responsive warehouse operations in the context of Industry 4.0.

3.3. Core sources and journals

The documents are published in 125 different sources, with the majority of them appearing in conference proceedings and journals related to simulation, logistics, and industrial engineering. The core sources are identified based on the number of documents they contain.

The most productive sources include:

- International Journal of Simulation Modelling (IJSIMM): A leading journal in simulation, with several articles on DES in warehouse and logistics systems.
- Proceedings of the Winter Simulation Conference (WSC): A major conference in the simulation community, with a significant number of papers on DES and DT in logistics and supply chains.
- Procedia CIRP, IFAC-PapersOnLine, and other conference proceedings: These sources host a large number of conference papers on DES, DT, and related topics in warehouse logistics.

The concentration of publications in these sources indicates that the research on DES and DT in warehouse logistics is well-established in the simulation and logistics communities, with a strong presence in both journals and conferences.

3.4. Author productivity and collaboration

The dataset includes 806 authors, with an average of 3.11 co-authors per document and 12.38% of documents involving international collaboration. The most productive authors are those who have contributed the highest number of documents to the field.

The top authors in terms of productivity are:

- LERHER T: Known for research on shuttle-based storage and retrieval systems and DES in warehouse logistics.
- BRUNO G: Active in the area of flexible reconfiguration of automated storage and retrieval systems (AVS/RS) and integration with manufacturing processes.
- HRUECK D: Contributed to event-B modeling for warehouse management efficiency.
- COOPER K: Focused on cost-to-serve evaluation for retail supply chains using DES.
- PERSSON F: Conducted simulation studies on spare parts supply chains and after-sales logistics.

These authors represent key contributors to the field, with their work covering a range of topics from DES modeling to optimization and integration with Industry 4.0 technologies. The high level of collaboration, both within institutions and internationally, reflects the interdisciplinary nature of research on DES and DT in warehouse logistics.

3.5. Institutional and country contributions

The analysis of institutional and country contributions shows that research in this field is highly international, with contributions from a wide range of institutions and countries. The most productive institutions are those that have published the highest number of documents in the dataset.

The leading institutions include:

- Universidade de São Paulo (USP): A major contributor to research in simulation and logistics, with a strong focus on DES and optimization in warehouse systems.
- Xiangya Hospital of Central-South University: Active in the application of DES and DT in healthcare logistics and warehouse operations.

- CNRS (Centre National de la Recherche Scientifique): A leading research organization in France, with contributions to DES and DT in logistics and supply chains.
- Chinese Academy of Sciences: A major player in the field, with research on DES, DT, and related technologies in warehouse logistics.

In terms of countries, the United States is the largest contributor, followed by China, Germany, and the United Kingdom. The high level of international collaboration, particularly between institutions in different countries, highlights the global nature of research on DES and DT in warehouse logistics.

3.6. Thematic mapping and keyword analysis

The thematic map, generated using co-occurrence analysis of keywords, reveals the main clusters and themes in the literature on DES and DT in warehouse logistics. The map is divided into five main clusters, each representing a distinct area of research.

Cluster 1: Discrete-event simulation and warehouse systems

This cluster is centered around keywords such as “discrete event simulation,” “warehouses,” “warehouse systems,” “order picking,” and “distribution centers.” The documents in this cluster focus on the application of DES to model and optimize warehouse operations, including material handling, order picking, and resource allocation. The cluster also includes studies on the integration of DES with warehouse management systems (WMS) and other logistics technologies.

Cluster 2: Simulation and supply chains

This cluster includes keywords such as “simulation,” “supply chains,” “supply chain management,” “logistics system,” and “distribution.” The documents in this cluster examine the role of DES and DT in supply chain modeling, with a focus on performance evaluation, risk assessment, and strategic planning. The cluster highlights the increasing use of DES and DT to support decision-making in complex supply chain networks.

Cluster 3: Optimization and computer simulation

This cluster is characterized by keywords such as “optimization,” “computer simulation,” “simulation model,” “genetic algorithms,” and “linear programming.” The documents in this cluster focus on the development and application of optimization models and algorithms in conjunction with DES and DT. The cluster also includes studies on simulation-based optimization and the use of DES to evaluate different optimization strategies in warehouse logistics.

Cluster 4: Automation and performance evaluation

This cluster includes keywords such as “automation,” “automated warehouse,” “automated guided vehicles (AGV),” “performance evaluation,” and “control systems.” The documents in this cluster explore the integration of DES and DT with automation technologies, such as AGVs, automated storage and retrieval systems (AS/RS), and robotic mobile fulfillment systems. The cluster also includes studies on the performance evaluation of automated warehouse systems and the impact of automation on warehouse efficiency.

Cluster 5: Logistics and materials handling

This cluster is centered around keywords such as “logistics,” “materials handling,” “material handling systems,” “mobile robots,” and “fleet operations.” The documents in this cluster focus on the application of DES and DT to logistics and materials handling operations, including the design and optimization of material flow, the evaluation of different handling strategies, and the integration of DES and DT with logistics information systems.

The thematic map shows that the research on DES and DT in warehouse logistics is highly interconnected, with strong links between the clusters. The map also reveals the increasing integration of DES and DT with Industry 4.0 technologies, such as automation, robotics, and real-time data, which is driving the evolution of warehouse logistics towards more intelligent and responsive systems.

Conclusion

This bibliometric analysis provides a comprehensive overview of research on discrete-event simulation and digital twin in warehouse logistics, based on 315 scientific documents from 1984 to 2026. The results show that the field has experienced steady growth, with a significant increase in recent years, particularly in conference papers and journal articles. The analysis identifies the core sources, most productive authors and institutions, and leading countries in this research area. The thematic map reveals five main clusters: (1) discrete-event simulation and warehouse systems, (2) simulation and supply chains, (3) optimization and computer simulation, (4) automation and performance evaluation, and (5) logistics and materials handling. These clusters highlight the increasing integration of DES and DT in warehouse logistics, driven by the adoption of Industry 4.0 technologies.

The findings of this study have several implications for future research. First, there is a need for more studies on the integration of DES and DT with real-time data and advanced analytics, such as machine learning and artificial intelligence, to support dynamic decision-making in warehouse logistics. Second, future research should focus on the development of standardized frameworks and methodologies for the application of DES and DT in different types of warehouse systems and logistics networks. Third, there is a need for more empirical studies that evaluate the impact of DES and DT on warehouse performance, cost, and service level in real-world settings.

In conclusion, the bibliometric analysis confirms that discrete-event simulation and digital twin are key enablers of intelligent and efficient warehouse logistics. The results provide a solid foundation for researchers and practitioners to understand the current state of the field and to identify promising directions for future research and innovation.

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