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TOPICAL REVIEW

Digital Twin-Enabled Smart Maritime Logistics Management in the Context of Industry 5.0

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ABSTRACT Driven by the IoT technology and smart sensors development in Industry 5.0, the digital twin as an innovative information technology brings new opportunities and challenges for intelligent maritime logistics management. This paper tries to present a systematic review on digital twin-empowered smart maritime logistics management by employing a bibliometric analysis framework under the Industry 5.0 era. The 3372 related publications from the Web of Science database are collected as research samples from 2003 to 2023. Besides, the VosViewer is adopted to perform the co-word and network analysis by visualizing interactive collaborations of published literature. Specifically, more than 3,000 articles on maritime logistics were reviewed to determine the research trajectories and main themes through same-word study and co-citation analysis. Results show that most publications on maritime logistics management are concentrated in China and the United States, where maritime logistics is developing towards digitization and informatization. In particular, Sustainability, Maritime Policy & Management, and Journal of Marine Science and Engineering are the most important journals focusing on maritime logistics management. Moreover, we hope this review study serves as a future direction on digital twin-empowered smart maritime logistics management practices for both researchers and practitioners.

INDEX TERMS Industry 5.0, digital twin, smart maritime logistics, bibliometrics analysis.

I. INTRODUCTION

In the era of Industry 5.0, digital technology is regarded as one of crucial drivers to promote the transformation of the manufacturing industry. Digital twin technology is gaining attention as an innovative solution, not just in manufacturing but also in the maritime transportation management field [1]. Therefore, its empowering role in this sector is noteworthy.

Against the backdrop of deepening global economic integration, maritime transportation accounts for 90% of foreign trade cargo transportation, which plays a critical role in international trade [2]. Recently, the new industrial and technological revolutions have brought increasingly diverse challenges to maritime transportation management. The maritime transport sector requires innovative solutions to cope with challenges such as supply chain congestion, efficient port operations, and decarbonization achievement of the shipping industry [3]. Smart Maritime Transportation Management is devoted to enhancing the operational efficiency,

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safety, and sustainability of the maritime transportation sector through the integration of advanced technologies such as digital technology, data intelligence [4], and the Internet of Things (IoT) [5] under industry 5.0. Digital twin technology, with its exclusive simulation and emulation capabilities, brings new vigor and opportunities to the innovative practices of smart maritime management.

The notion of the digital twin was initially introduced by Michael Grieves in 2002, whose fundamental principle involves the mapping and synchronization of physical entities in real time to attain a virtual representation of said entities by means of digital models [6]. In the context of Industry 5.0, the digital twin has evolved beyond a simple simulation of the manufacturing process and now acts as a bridge that connects reality and virtualization, offering fresh insights and solutions for managing maritime transportation [7]. As underwater communication technology continues to develop, digital twins are positioned to play a significant role in autonomous submarines and other underwater applications [8]. Currently, the international shipping market is greatly impacted by global communication trends. Due to the real-time virtual-physical mapping capability, digital twin technology shows its advantages by providing efficient solutions for ship manufacturers and shipping companies in addressing future challenges.

To promote maritime logistics development, there are vast majority of research topics in maritime logistics including pricing strategies [9], [10], [11], risk analysis [12], [13], [14], emergency management [15], [16], [17], supply chain design [18], [19], [20] and network optimization etc., [21], [22], [23], and [24]. Recently, previous publications have conducted literature reviews from different perspectives, for instance, green ports [25], simulation optimization [26], marine fuels [27], and navigation education [28] in the process of exploring the field of maritime logistics. However, the research topics related to intelligent maritime management still need to be systematically organized and there is little review work on the digital twin technology-empowered maritime logistics area. To help better understand the state-of-the-art knowledge of maritime logistics, we aim to contribute to propelling the entire maritime transportation industry towards a smarter, more efficient, and sustainable direction through in-depth research on the application of digital twin technology in smart maritime transportation management. The research objectives of this paper are to employ bibliometrics and information visualization and analysis techniques to (1) attain a comprehensive overview of the literature on maritime management, and (2) subsequently conduct a bibliometric study on intelligent maritime management using digital twin technology, aiming to discern research hotspots and cutting-edge trends.

The remainder of the paper is organized as follows: Section II presents the theoretical backgrounds of crucial concepts. The research design for the bibliometric review and the source of the sample data are addressed in Section III. Section IV discloses the research findings, and the related hot themes are also discussed. Finally, we conclude this paper with some key insights.

II. THEORETICAL BACKGROUNDS

A. DIGITAL TWIN

Digital Twin technology is an advanced and widely applied concept across various industries and domains. The concept was initially proposed by Michael Grieves in 2002 [6], defining Digital Twin as the virtual representation of a physical product, forming the foundation for Product Lifecycle Management. In 2012, Glaessgen and Stargel discussed the application of Digital Twin in a paper for NASA and the U.S. Air Force, where simulation and the vehicle's onboard computer were combined to predict the vehicle's lifespan, enhancing safety and reliability [29]. Chen defined Digital Twin as a computerized model of a physical device or system, representing all functional characteristics and connections with working elements. While various scholars have provided different interpretations of Digital Twin, the core definition remains consistent – Digital Twin effortlessly integrates data bidirectionally between the physical and virtual machine in either direction [30].

Currently, the concept and terminology of digital twins are extensively utilized in academia. To enhance the efficiency of the warehouse service system, Leng et al. [31] integrates real-time warehouse data into a digital twin network model for optimal decision-making. This optimization aims to enhance the flexibility and agility of the warehouse system. Simultaneously, the integration of digital twin technology into a company's logistics supply chain improves supply chain visibility, enabling the construction of reliable logistics movement models and the prediction of potential vulnerabilities that might be overlooked [32]. Considering the security challenges in modern marine transportation systems, Liu et al. [33] introduces digital twins (DTs) and IoT technologies to establish a model for maritime transportation DTs. Simultaneously, the integration of digital twin technology into a company's logistics supply chain improves supply chain visibility.

The incorporation of new technologies has spurred the movement toward digitalization, networking, and greater intelligence within the logistics sector. The integration of the digital twin idea within maritime logistics promises to propel the industry into a new dimension.

B. SMART MARITIME LOGISTICS

The enhancement of the shipping route network, combined with its cost-effectiveness and substantial capacity, positions maritime transportation as the primary option for bulk commodity trade [34]. Compared with other logistics, maritime logistics has a longer chain, more links, and more participants, which enhances the uncertainty of maritime logistics.

New cognitive computing methods are driving the development of smart ports by driving technological innovation and changes in the way seaports operate. Hokey Min [35] combines smart ports for the underlying architecture and presents the idea of monitoring smart ports. The digital and integrated end of the smart port increases the utilization of port assets and improves the visibility of maritime logistics. As maritime transport becomes important as countries become more connected, Monzon Baeza V [36] has designed a ship communication system based on IoT connected smart devices to ensure the status of cargo and safety at sea.

In the current era of rapid maritime transportation development, scholars are increasingly expressing concerns regarding its environmental impact. Hanna Dijkstra is actively engaged in research aimed at mitigating marine plastic pollution while concurrently fostering economic growth and environmental benefits to contribute to the Blue Economy [37]. Additionally, Wei Yao has conducted empirical investigations into the effects of the Digital Economy (DE) on the efficiency of marine carbon emissions [38]. Employing both a mediated effects model and a spatial Durbin model in the research, Yao suggests the need to reinforce regional carbon emission reduction exchanges. The emergence of new technologies catalyzes digital transformation, and a fuzzy Technological Innovation System Management (TISM) approach is employed to address the challenges associated with digitization [39].

The logistics industry is facing a severe test under the fierce market competition [40]. The new technological revolution has been the driving force for the development of maritime logistics in the direction of intelligence.

C. INDUSTRY 5.0

Industry 5.0 aims to improve industrial sustainability, human-centricity, and resilience. While Industry 4.0 emphasizes technology-driven industrial paradigm shifts through the integration of advanced digital technologies (e.g., automation, big data, and artificial intelligence) to enhance manufacturing process efficiency and profitability, Industry 5.0 places a stronger emphasis on human involvement and creativity [41], [42]. Industry 5.0 emphasizes human involvement through enhancements in human-machine interaction, digital twins and simulation, big data analytics, and renewable energy technologies [43]. This approach intends to synergize human wisdom with machine intelligence to achieve a more balanced and sustainable manufacturing model, as compared to Industry 4.0. The primary goal of Industry 5.0 is to establish a manufacturing paradigm that not only ensures profitability but also prioritizes environmental impact and the well-being of workers. In contrast to Industry 4.0, Industry 5.0 places greater emphasis on the promotion of human-machine collaboration and prioritizes sustainability in its core principles [44].

One of the key features of Industry 5.0 is the utilization of digital twin technology to facilitate seamless collaboration between humans and machines [45]. This technology plays a pivotal role in encouraging increased human involvement in decision-making and innovation. Furthermore, Industry 5.0 promotes adaptable manufacturing processes and advocates for personalized production to minimize resource wastage.

Industry 5.0 adopts a more holistic approach by comprehensively addressing ecological, social, and economic sustainability considerations. This is achieved through meticulous management of product life cycles, the promotion of a sharing economy model, and the encouragement of corporate social collaboration. The manufacturing industry is thus transitioning into a more balanced and sustainable era through these initiatives.

D. RECENT TRENDS

Deep integration of the digital twin and the Internet of Things has received a lot of attention in recent years [46]. By connecting sensors and physical systems to the digital twin platform, real-time data collection, monitoring, and simulation are achieved [47]. This convergence provides more accurate data and real-time operational decision support for smart maritime logistics management [48].

With the continuous development of Industry 5.0 technology, its application in intelligent maritime logistics is becoming more widespread [49], [50]. The integration of digital twins and smart sensors in the maritime logistics sector within the Industry 5.0 framework is propelled by key drivers focused on anticipating maintenance needs, elevating data-driven decision-making, ensuring comprehensive supply chain visibility, advancing environmental sustainability, and fostering human-machine collaborations. This integration serves as a catalyst for a more intelligent, adaptive, and environmentally conscious maritime logistics ecosystem.

In the research of digital twins [51], Industry 5.0 [52], and smart maritime logistics [53], data analytics and artificial intelligence play an important role. How to mine useful information from maritime logistics data using methods such as big data analytics, machine learning, as well as deep learning to achieve optimization of maritime logistics systems, effective use of resources, and early warning of possible risks is currently a hot topic in the field of maritime logistics [54], [55].

Sustainable development and environmental protection are key issues in the intelligent development of modern maritime logistics [56], [57], [58]. How to use intelligent technology to save energy, reduce emissions, improve resource utilization, and promote the development of green maritime logistics is the focus of current research at home and abroad.

III. DATA AND METHODS

A. A DATA COLLECTION

The WOS Core Database [59] contains more than 13,000 of the world's top-ranked academic journals, covering a wide range of natural sciences, engineering, biomedical sciences,

social sciences, arts and humanities. We can search relevant papers by keywords, authors, titles, DOI, etc., learn about the research of relevant papers, and easily trace the origin and history of research papers. At the same time, it has powerful analysis functions that can quickly target high-impact papers, discover the research directions focused on by domestic and foreign authorities, and reveal the development trend of the topic [60]. The unique citation search allows you to use the name of an article, a patent number, a conference paper, or a book as search terms to retrieve citations to the papers cited to track its latest developments. Therefore, the WOS core database was chosen as the source of the literature data. In the WOS core database, ''smart maritime logistics'', ''multimodal transport'', ''maritime transportation'', ''maritime management'', ''port management'', ''port logistics'', ''shipping management'' and ''container logistics'' were used as keywords for the search. To ensure the comprehensiveness and accuracy of the research, non-research literature such as conference proceedings, book reviews, dissertations, and news reports was excluded, and a total of 3372 English-language documents were retrieved.

B. ANALYSIS METHOD

The majority of publications use software applications to analyze information, along with certain visualization software for charting scientific analysis. VOSviewer offers a user-friendly interface and robust computing engine that facilitates co-word analysis, social network analysis, topic analysis, and other features, allowing researchers to analyze research field development more comprehensively [61]. Therefore, this article utilizes VOSviewer to visualize the knowledge graph of literature in maritime logistics. The automatic clustering function of VOSviewer is used to map scientific knowledge. Ultimately, analyzing the generated images reveals trends in research clusters and predicts future issues that require attention.

IV. RESULTS

A. BIBLIOMETRIC ANALYSIS

1) CO-WORD ANALYSIS

As a content analysis technique, co-occurrence analysis can effectively map the strength of association between information items in textual data [62]. To reflect the strength of association between keywords and to determine the research focus, composition, as well as paradigm of the discipline or field represented by these words, the co-occurrence of document words is counted.

The visual analysis of keywords in the literature can reflect the elements and themes contained therein. Based on the revealed high-frequency keywords, it is possible to find the research hotspots in the field and identify the most researched directions related to the field [63]. To visualize the co-occurrence of keywords with a co-occurrence frequency of more than 20, use the VOSviewer software. Visual keyword analysis is shown in Figure 1 below, where each node

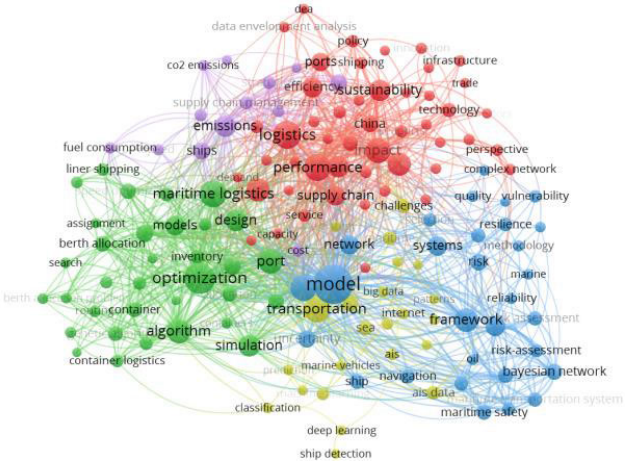

FIGURE 1. Keyword visualization analysis.

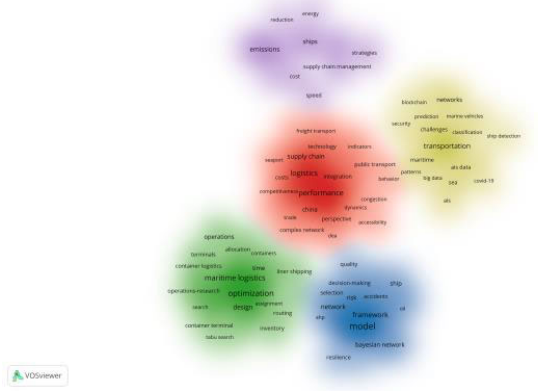

FIGURE 2. Keyword clustering.

represents a keyword, its size is the frequency of occurrence, and the line between nodes indicates keyword co-occurrence.

Through visual analysis of Figure 1 above, we can find that the research on maritime logistics is divided into 5 main research topic clusters, including emissions, transportation, model, performance, and maritime logistics. In Figure 1, the keywords in the different groupings are mingled together. In order to make the groupings clearer, we adjusted the nodes in the above figure to obtain Figure. 2, from which, we found the following research hotspots in the field of maritime logistics:

① Maritime logistics

The realm of marine logistics research entails the investigation of maritime transport, port operations, and marine logistics infrastructure, including container terminals and tanker terminals. This constitutes a comprehensive interdisciplinary study, encompassing the entirety of the transportation process from the point of origin of goods to their ultimate destination. In response to the continual evolution of technology and dynamic shifts in demand, there exists a perpetual necessity to refine the prevailing marine logistics system,

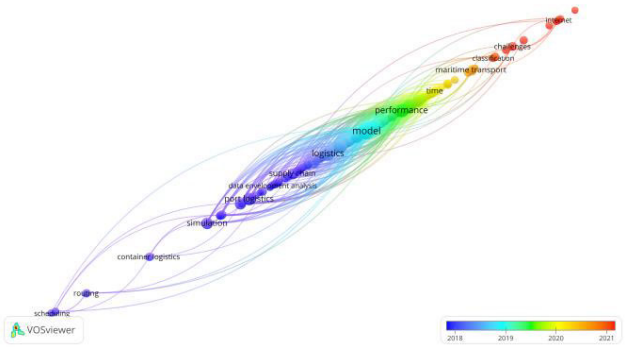

FIGURE 3. Keyword evolution.

thereby realizing heightened efficiency, reliability, and safety within the domain of logistics services.

② Modelling methods

Modeling research encompasses diverse models and methodologies aimed at enhancing our comprehension and optimization of logistics processes. Specifically, the Bayesian networks and the Analytic Hierarchy Process (AHP) are extensively applied in the realms of quality assessment, decision support, risk prediction, and the optimization of logistics networks. Their widespread utilization underscores their significance in contributing to the continual improvement of logistics systems, ultimately fostering greater efficiency, reliability, and resilience in the context of global trade.

③ Transportation challenges

The transportation aspect of marine logistics encounters various challenges and complexities. To ensure safety and stability, advanced information technologies such as blockchain, AIS data, big data, and artificial intelligence are embedded into maritime transport process for risk assessment. The continuous progression of transportation research holds substantial promise in furnishing indispensable support for the sustainable development and advancement of the maritime logistics sector.

④ Performance research

The study endeavors to forecast maritime logistics operations via the use of dynamics, complex networks, and other techniques. Supply chain management bolsters competitiveness and reduces transportation expenses. Application of such methods allows us to gain greater insight into customer requirements and enhance logistics operations.

⑤ Carbon emission reduction

Maritime logistics operations span across the world and have a substantial environmental footprint. This study examines the clustering of carbon dioxide and other greenhouse gas emissions arising from maritime logistics operations and outlines strategies for curbing these emissions.

To help better understand the evolution of research hotspots related to maritime logistics, the average year of keyword occurrences was calculated using VOSviewer illustrated in Figure 3.

Figure 3 shows the average annual evolution of keyword occurrences, through which we can clearly know the shift of research focus on maritime logistics, we found that the focus of maritime logistics research in 2018-2019 was in scheduling, simulation, and supply chain; 2020-2021 research The focus is on model, performance and time, while the latest research is more focused on blockchain, deep learning and the internet of things (IoT). We find that the focus of maritime transport research has gradually shifted to the direction of digitalization and informatization driven by the continuous advancement of technology.

The above research results demonstrate the dynamic evolution of maritime logistics towards digitalization and informatization. This transformation is achieved by the emergence of smart ports and terminals through adopting automated devices and intelligent equipment for cargo handling, as well as intelligent tracking systems. One of the critical drivers to this evolution is the application of digital twin technology, which generates virtual replicas of physical assets for real-time monitoring, predictive maintenance, and operational optimization. Besides, blockchain adoption enhances transparency and security of the whole process and facilitates improving the resilience and robustness of supply chains. Route optimization is achieved by programming modeling and AI solvers, where predictive maintenance and preventive risk analytics are also considered in advance. Furthermore, there is a notable trend towards automating shipping operations and creating self-piloted ships, demonstrating a broad adoption of advanced technologies to improve the sustainability, transparency, and efficiency of marine logistics.

2) RESEARCH MAP ANALYSIS

To understand the degree of cooperation among countries in maritime transportation research, the cooperation of 92 countries was analyzed, and the top 30 countries in terms of cooperation intensity were selected for visualization, shown in Figure 4. Larger nodes in Figure 4 indicate a greater number of co-publications, and thicker connecting lines indicate a greater number of co-publications between each two countries.

Figure 4 shows the cooperation network map of the top 30 countries in terms of cooperation intensity. An analysis of the cooperation intensity graph shows that China is the country with the highest cooperation intensity with other countries with 1171, and the USA, UK, Australia, and Norway, which follow closely behind, form the five countries with the highest cooperation intensity. This indicates that these countries have more research in maritime logistics.

In order to understand which countries are making the most prominent contributions in the field of maritime transportation, this study analyzed the volume of articles issued by the issuing countries, and the results are shown in Figure 5. The larger the circle nodes in Figure 5, the higher the number of publications.

Figure 5 shows the analysis of the number of articles published by country, with China having the highest number

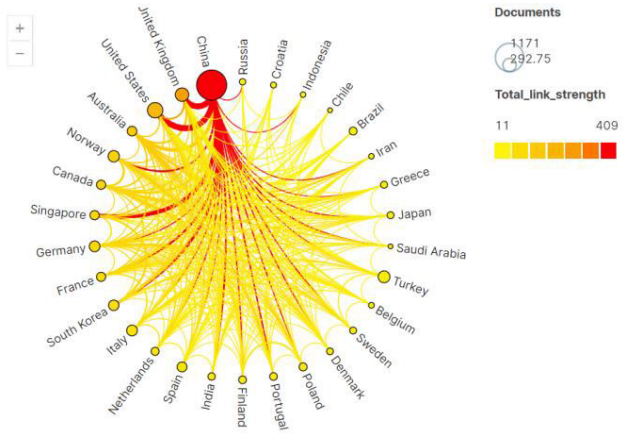

FIGURE 4. Country cooperation intensity.

FIGURE 5. Volume of articles issued by country.

of articles with 1171, followed by the USA with 305 and the UK with 233. The research on maritime transport in China is closely related to national policies. We can see that although European countries are not at the top of the list in terms of number of articles, almost all European countries have researched smart maritime transport, which is inseparable from Europe's unique geographical location.

B. NETWORK ANALYSIS AND LITERATURE MAPPING

1) CO-CITATION ANALYSIS

Co-citation analysis is mainly used to measure whether a paper has a certain influence among peers [64]. A paper with a high number of citations and all written by well-known scholars indicates that the paper has a certain influence among peers. The figure below shows the analysis of co-cited references in the field of maritime logistics.

The co-citation network of journals can be seen in Figure 6 consists of 4 clusters, corresponding to the 4 colors in the figure, and the top three journals cited are ⟨⟨ European Journal Of Operational Research ⟩⟩ (2668 citations), ⟨⟨ Transportation Research Part E⟩⟩(2617 citations) and ⟨⟨ Maritime Policy & Management ⟩⟩(2587 citations). The top two journals belong to ScienceDirect Publishing.

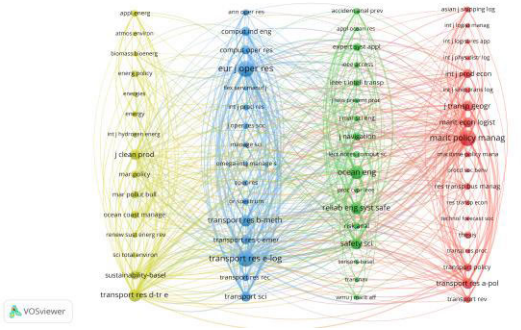

FIGURE 6. Co-citation of cited sources.

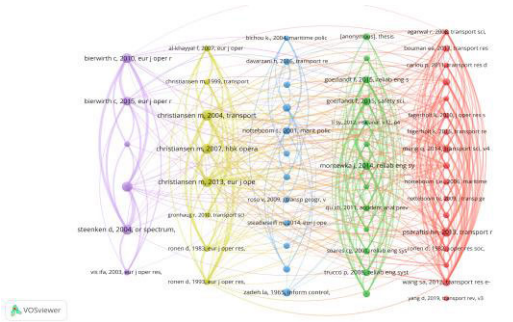

FIGURE 7. Co-citation of cited references.

The co-citations of the literature were further analyzed and the top ten cited articles in the field were analyzed using Vosviewer, as shown in Table 1.

Next, the reference co-citation mapping was drawn and the threshold for the minimum number of literature co-citations was set to 30, leaving 57 articles for the cited literature analysis. The final citation relationship mapping presented is shown in Figure 7.

It is easy to find through the above chart information that most of the highly cited literature was published in 2004-2009, and only 4 of the literature published before 2000 had been cited more than 30 times.

2) SCIENTOMETRICS LAWS

Lotka's Law [65] is an empirical law describing the productivity of science pioneered by the American scholar Lotka in the 1920s, also known as the "law of inverse squares", which is often used to identify the core authors in the field.

$$\sum_{m+1}^{\mathrm{I}} n(x) = \sqrt{N}$$

The minimum number of publications of core authors in the field based on this law is m=0.749$\times\sqrt{n_{max}}$ $\approx$ 5.7(n_{max} = 58), so the authors with 5 or more articles are core authors, and there are 261 core authors with 1596 articles, accounting for about 47.3% of the total. It can be roughly assumed that a more stable author cooperation group has been formed in the field of maritime logistics. Table 2 shows the high-output authors in this field.

TABLE 1. High-output authors.

Author	Documents	Citations	Average Citation
Kjetil Fagerholt	58	2165	37.33
Shualan Wang	41	1032	25.17
Marielle Christiansen	25	1439	57.56
Floris Goerlandt	21	1588	75.62
Jakub Montewka	19	1851	97.42

TABLE 2. Journal partition.

Zone	Number of Journals	Number of Publications
First zone	27	1115
Second zone	190	1028
Third zone	1066	1229

TABLE 3. Core journals.

Sources	Documents	Citations
Sustainability	94	670
Maritime Policy & Management	92	2083
Journal of Marine Science and Engineering	85	412
Ocean Engineering	84	2432
Journal of Coastal Research	67	246

From Table 2, Kjetil Fagerholt has the most articles, followed by Shualan Wang. Although Jakub Montewka doesn't have the highest number of posts, he does boast the highest average citation count.

Bradford's law [66] states that the number of journals in the core and related areas are arranged in descending order by number of papers in a discipline in a $1{:}m{:}m^2\ldots\ldots$ It is often used when studying the distribution pattern of journals in the literature. Table 3 below shows the journal divisions.

The literature contained was partitioned in the field of maritime logistics, as shown in Table 3, at which point the number of papers in each region was approximately the same and the ratio was approximately 1:7:39.5 ($1{:}6.5{:}6.5^2$). With this, we can identify the core journals in the field, as shown in Table 4 below.

Table 4 shows the core journals in the field of maritime logistics calculated under Bradford's law, and we have selected only five journals for presentation. It should be noted that although Sustainability has the most published articles, it does not have the highest average citation rate for its articles. Ocean Engineering has the highest average citation rate.

C. RESEARCH THEMES

1) DIGITAL TWIN EMPOWERED MARITIME LOGISTICS MANAGEMENT

The ship plays an important role in the development of maritime transportation as an important carrier of maritime logistics. In the marine industry and shipping industry, the current application of digital twin is mainly reflected in the digital mapping and simulation stage [77]. There are many challenges in the path of smart ships towards digitalization and autonomy. Digital twins are a technology tool for overcoming many challenges as we move toward a digital and autonomous intelligent vessel. The basis for the application of digital twin technology is an accurate digital twin model based on stable and reliable data. At present, there is a mature technology accumulation and industry consensus in ship data collection [78], which strongly supports the application of twin technology.

The application of digital twins on ships is demonstrated by: a ship function simulation test. Simulation of marine environment and ship structure is carried out to establish a real-time prediction system for wave field and ship operation, which is used to predict the occurrence of future waves and ship response, reducing the risk and fuel consumption of the ship in waves [79]. Moreover, the digital twin is an important part of achieving ship automation. In the digital twin application platform, the navigation or speed is adjusted in real-time in response to the change of controller parameters in the simulation environment [80]. As a key step in the shipbuilding process, pipe fabrication and installation are prone to schedule disconnections as well as distribution delays due to complicated parts. Based on this, a digital twin system is constructed for the pipeline processing line to optimize the layout to improve the efficiency of ship pipeline installation through real-time mapping and interaction technology [81].

The digital twin technique has found widespread application in industrial, agricultural, and construction manufacturing [82], [83], [84]. However, it is still in the early stages of getting applied to shipping. With the development of high-speed communication network technology and intelligent technology, as well as the increasing maturity of digital twin technology, the technology that will be widely used in the shipping industry will also become more and more common. Especially, the establishment of a multi-terminal digital twin will make it possible to build an intelligent global shipping world [85].

2) DIGITAL TWIN EMPOWERED SMART PORT CONSTRUCTION

The port, as the hub station and assembly point of water and land transportation, is a vital part of the logistics transportation [86]. As information technology for material operations management and production deployment in ports becomes more accurate, it is a major trend for port infrastructure to be intelligent, digital, and integrated [35], [87], [88], but at present, there are still pain points such as data silos, high human cost and lack of intelligent scheduling scenarios in the actual operation of ports [89], [90]. Thus, the deep integration of cutting-edge information technologies such as digital twin, Internet of Things, cloud computing, and intelligent perception with the port transportation business to create a "digital twin smart port". With the deep computing and extensive interconnection of key information from all the cores of the port supply chain, the achievement of seamless connection and coordination of all the parties in the port supply chain is the development trend of smart ports [91].

TABLE 4. TOP 10 most important publications in the maritime logistics.

	Title	Journal	Source	Citations
1	Ship routing and scheduling in the new millennium	European Journal of Operational Research	[67]	79
2	Ship Routing and Scheduling: Status and Perspectives	Transportation Science	[68]	78
3	Chapter 4 Maritime Transportation	Handbooks in Operations Research and Management Science	[69]	73
4	Speed models for energy-efficient maritime transportation: A taxonomy and survey	Transportation Research Part E	[70]	67
5	A framework for risk assessment for maritime transportation systems—A case study for open sea collisions involving RoPax vessels	Reliability Engineering & System Safety	[71]	60
6	A framework for risk analysis of maritime transportation systems: A case study for oil spill from tankers in a ship–ship collision	Safety Science	[72]	54
7	Sailing speed optimization for container ships in a liner shipping network	Transportation Research Part E	[73]	54
8	Containership Routing and Scheduling in Liner Shipping: Overview and Future Research Directions	Transportation Science	[74]	54
9	The effectiveness and costs of speed reductions on emissions from international shipping	Transportation Research Part D	[75]	45
10	The effect of oil price on containership speed and fleet size	Journal of the Operational Research Society	[76]	32

The construction of the digital twin smart port empowers port business through the detection of comprehensive port posture [92], loading/unloading facilities [47], port logistics, and transportation [93]. In addition, the digital twin empowers management [89], the advanced intelligent search realizes efficient data retrieval and targeted query. Meanwhile, the massive data and rich analysis methods provide a scientific as well as comprehensive basis for management decisions.

Smart port construction on the basis of digital twins will significantly improve the efficiency of port operations and reduce the cost of logistics while providing real-time information feedback for port managers to better monitor and adjust port operations. It can better meet the needs of modern society for efficient, green [94], and intelligent port services [95], which can realize the transformation of port functions, technology, and service upgrading.

V. CONCLUSION

A. CONTRIBUTIONS

Maritime logistics management, as a social science, is extremely sensitive to changes in society and is a discipline that is constantly iterating and updating. This study analyzes relevant research in the field of maritime logistics management by a systematical review study based on VOSviewer and Scimago Graphica software. The keywords, high-producing countries, key journals in the field, the core authors are discussed and analyzed to help readers better understand maritime logistics under the Industry 5.0 era. The findings of the study are summarized as follows:

(1) The collaborative group of authors in the field of maritime logistics management is still in the process of formation, but several well-known scholars have been formed. For example, Kjetil Fagerholt, Shualan Wang, Marielle Christiansen etc.

(2) The core journals that publish papers in this field are Sustainability, Maritime Policy & Management, and Journal of Marine Science and Engineering.

(3) Chinese scholars contributed the most to the field, accounting for 34% of the articles published, but in terms of the average number of citations per article, articles published by Poland scholars are more recognized in the field.

(4) The co-occurrence analysis and cluster analysis of keywords found that several stable research themes have been formed in this research field, such as management optimization and model simulation, and transportation as a key factor at the management level is mentioned many times in the keywords. With the development of technology blockchain, sustainability, and digitalization are starting to be emphasized in this field of research.

(5) The analysis of authors' co-citations reveals that the research hotspots in the field are constantly changing, and a careful analysis of the chronology of the literature of highly cited authors can further understand the dynamics of hotspot change. It is also noted that several authoritative scholars in the field have been formed and have played a great influence on the development of the research field. Future research will center on comprehensive explorations of key areas within maritime logistics, including autonomous shipping, the utilization of digital twin technology for real-time monitoring and predictive maintenance, green shipping strategies, and the adoption of alternative fuels. Digital twin technology facilitates real-time monitoring and optimization of maritime operations, encompassing aspects such as fuel consumption, energy utilization, and the reduction of environmental impact, thereby aligning with sustainability objectives. Additionally, digital twin plays a crucial role in monitoring and improving safety conditions for maritime workers. By offering a comprehensive view of vessel operations, it helps identify and mitigate potential hazards, ensuring the overall well-being of the workforce. In additions, digital twin offers maritime stakeholders valuable data-driven insights, contributing to fostering informed and efficient decision-making. The heightened efficiency not only contributes to

achieve economic sustainability but also aligns with broader ESG goals by minimizing waste and optimizing resource utilization.

B. LIMITATIONS

This study also carries some limitations. First of all, in order to ensure the norms and standards of the data, the research selects only SSCI, SCIE, and SCIE journal papers in the core collection of the Web of Science database. However, the data is incomplete due to the absence of other databases (such as Scopus). In addition, there is inevitably a degree of subjectivity involved in quantitative analysis, which requires analysis and interpretation of the data.

We believe that the research on the combination of maritime logistics and digital twins will continue and be full of vitality, so the research in this paper is a topic worthy of in-depth study. It is necessary to integrate the literature in several databases to make the filtered data more comprehensive and to communicate with scholars in the field of maritime logistics and digital twins to conduct in-depth research on the frontiers of this field.

As an active interdisciplinary subject, maritime logistics management undoubtedly has a lot of room for development, so the research lineage obtained from the perspective of bibliometric and scientometrics is extremely valuable which provides research directions and ideas for researchers in this field. This is reflected in the following aspects:

(1) It will help scholars who intend to conduct research on shipping management to sort out the existing research on shipping management, and understand the development process of shipping management;

(2) The analysis of the evolution law of high-frequency keywords, will help scholars to form a clear understanding of the focus and hot issues in the field of shipping management, and provide a basis for them to select research topics;

(3) This study analyzes the core journals and core authors in the field of maritime transportation management, which can help scholars quickly find the literature they want to refer to when researching, and also provide a certain degree of help for scholars related to this topic when submitting papers.

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