Scientific Research Publishing

Open Journal of Social Sciences, 2024, 12, 341-363
https://www.scirp.org/journal/jss
ISSN Online: 2327-5960
ISSN Print: 2327-5952

Knowledge Graph Analysis of Multimodal Transport of Maritime Logistics in China

Cuiyin Yao[1], Jinzhao Yang[1*], Jiahui Fu[2,3], Herman Li[4], Jia Xu[4], Dan Feng[5]

[1]School of Economics, Management and Law, University of South China, Hengyang, China
[2]School of Physics and Technology, University of Jinan, Jinan, China
[3]Dong'e No.3 Middle School, Liaocheng, China
[4]PSBC Consumer Finance, Guangzhou, China
[5]School of Law, The Pennsylvania State University, State College, USA
Email: y1632616388@foxmail.com, *1149128871@qq.com

How to cite this paper: Yao, C. Y., Yang, J. Z., Fu, J. H., Li, H. M., Xu, J., & Feng, D. (2024). Knowledge Graph Analysis of Multimodal Transport of Maritime Logistics in China. *Open Journal of Social Sciences, 12,* 341-363.
https://doi.org/10.4236/jss.2024.128022

Received: July 16, 2024
Accepted: August 19, 2024
Published: August 22, 2024

Abstract

This study utilizes CiteSpace visualization technology and bibliometric methods to analyze scientific knowledge graphs based on literature from CNKI regarding China's multimodal transport of maritime logistics from 2003 to 2023. It delves into time distribution, key researchers, popular topics, development trends, research hotspots, and other aspects, offering a comprehensive analysis and trend forecast. Findings indicate frequent researcher activity and the formation of several research teams, albeit limited in size and lacking effective communication and cooperation mechanisms, hindering further expansion and innovation. Structure optimization and system construction of container sea-rail combined transport; the multimodal transport of maritime logistics model and the theoretical practice; strategic development under the background of "the belt and road initiative"; construction and improvement of multimodal transport of maritime logistics systems; and the development of networks and the information technology of multimodal transport of maritime logistics are five major research hotspots in this field. The research in this field has gone through three stages: start-up, development, and expansion with innovation. "The Belt and Road" Initiative and the China-Europe train are still the focus of research at this stage. Especially in today's severe and complicated international situation, how to continue to practice "the Belt and Road" and steadily promote the development of multimodal transport of maritime logistics will become the hot frontier of future research.

Keywords

CiteSpace, Bibliometrics, Maritime Logistics, China, Multimodal Transport, Knowledge Graph

1. Introduction

With the development of China's social economy, international trade acts are becoming more frequent and common. The perfection and development of multimodal transport systems largely determine the transportation and distribution capacity of maritime logistics and then affect the overall operation of international trade. Therefore, multimodal transport of maritime logistics often plays a decisive role in international trade and has always been one of the research hotspots.

As shown in Table 1, when studying this field, the authors all chose "sea-rail combined transport" as the research topic, and the research section involved in multimodal transport of maritime logistics is relatively limited. Among them, Qin Lei analyzed the research status of sea-rail combined transport and systematically sorted out and summarized the related literature on sea-rail combined transport at home and abroad from the perspectives of development countermeasures and evaluation research on sea-rail combined transport (Qin, 2017). Jin Zhihong and others, based on the "soft connection" of the organization's optimization of sea-rail combined transport, commented on the related research on container sea-rail combined transport, provided decision-making references, and proposed the future research direction (Jin et al., 2024).

Table 1. Statistical table of literature in review field of maritime logistics multimodal transport (2 articles).

The author	Time slicing	Article	Data sources
QIN Lei	1995-2016	Review of Countermeasure and Evaluation of Sea-rail Intermodal Transportation	CNKI
JIN Zhihong et al.	2000-2023	Review and Prospect on Transportation Organization Optimization for Sea-Rail Intermodal Transportation	CNKI

Due to the limitation of the number of studies in related fields, this paper analyzes the two themes of "maritime logistics" and "multimodal transport," respectively, in order to expand the scope of research and get to know and understand the research dimensions in different fields in turn. Among them, scholars at home and abroad have done a lot of analysis and summary of the literature in the field of maritime logistics, but most of the research is mainly qualitative analysis, and there are few studies using quantitative methods such as literature measurement (Liu, 2017; Ning, Huang, Yang, Wei, Xie, & Gao, 2023; Zeng, Wei, Yu, Huang, & Xie, 2024).

Table 2. Statistical table of literature in review field of maritime logistics research (14 articles).

The author	Time Slicing	Article	Data sources
LYU Cheng	2012-2016	Current Situation Hot Spots and Future Trends of Logistics Research: Bibliometrics and Theoretical Review	WOS (SCI & SSCI)
ZHU Xiaoling	2001-2020	A Summary of the Research on the Training of Shipping Talents from 2001 to 2020—Visual analysis based on CiteSpace knowledge graph	CNKI
YU Zhen et al.	2001-2021	Construction and analysis of shipping economic knowledge graph based on CiteSpace	CNKI
MA Xiang	2017-2021	Knowledge Graph Analysis of Blockchain Technology Empowering Port Supply Chain Finance	CNKI & WOS
WEI Ran	2000-2021	A Summary of Domestic Port Construction Research Based on Document Visualization	CNKI
MA Ji, SHEN Yan	2000-2022	Analysis of Hotspots and Frontiers of Green Port Researches Based on CiteSpace	WOS
LI Jian	2011-2020	Visual Analysis of Research Hotspots and Evolution of Port Logistics at Home and abroad	CNKI & WOS
TANG Guoping	1994-2022	Literature Analysis of Port Logistics Research Based on CiteSpace	CNKI
WANG Danyuan	2000-2022	Knowledge Graph Analysis of Domestic Port Logistics Research Based on CiteSpace	CNKI
SONG Gang, FENG Ru, LI Zhen-dong	1984-2016	Analysis on Research Status of Port Logistics based on LiteratureMetrology	CNKI
Wang Xingxing, TANG Kexin, DAI Xiyue	2000-2020	Research Status of Port Logistics in China—Based on CiteSpace Knowledge Map Analysis	CNKI
FULI ZHOU et al.	2003-2023	Digital Twin-Enabled Smart Maritime Logistics Management in the Context of Industry 5.0	WOS
Jihong Chen et al.	2001-2023	Knowledge mapping analysis of resilient shipping network using CiteSpace	WOS
Shao-Bu Wang, Xian-Hong Peng	2000-2020	Knowledge mapping of port logistics in the recent 20 Years: a bibliometric analysis via CiteSpace	WOS

When applying bibliometrics to explore the field of maritime logistics, different researchers often choose different data sets, research periods, and specific topics for analysis according to their own preferences and needs, among which the choice of research topics is particularly significant. In Table 2, as far as the research topic is concerned, there is an article whose research direction is domestic

(foreign) logistics, and its research content is only mentioned in the field of maritime logistics (Liu, 2017). The main research directions of the three articles are the training of shipping talents, the shipping economy, and port supply chain finance, which belong to the extension of maritime logistics and involve relatively limited research fields in maritime logistics (Zhu, 2021; Yu et al., 2022; Ma, 2022). The two articles mainly analyze port construction and green ports, providing suggestions and references for port construction and development in China (Wei, 2022; Ma & Shen, 2023). The research of the remaining five articles focuses on domestic (foreign) port logistics, among which Li Jian analyzed the basic situation of port logistics at home and abroad from three aspects: the research author, periodical distribution, and time distribution, and discussed the research hotspots and frontier trends of port logistics at home and abroad from two angles of keyword co-occurrence analysis and cluster analysis (Li, 2022). Tang Guoping's research summarized and analyzed the three development stages of China's port logistics and pointed out that the future research direction of port logistics is smart port (Tang, 2023). Wang Danyuan explored the development, evolution, and emerging trends of port logistics from the perspective of temporal and spatial distribution characteristics, keyword co-occurrence, keyword clustering, and visual analysis of time zone knowledge graphs (Wang, 2022). Song Gang and others combed and analyzed the distribution of relevant literature, research topics, and main published periodicals, aiming at excavating countermeasures and suggestions to promote the development of port logistics (Song et al., 2017). Wang Xingxing and others analyzed future development trends in domestic port logistics by analyzing keywords (Wang et al., 2022). Furthermore, the three English articles respectively summarized the influence of digital twins on maritime logistics, resilient shipping networks, and data on international port logistics research (Zhou, Yu, Xie, Lyu, Zheng, & Zhou, 2024; Chen, Liu, Zhou, & Kang, 2023; Wang & Peng, 2023).

Although the above-mentioned literature deeply analyzes the research trends and key areas of maritime logistics from multiple angles and time periods and contributes valuable reference data to the overall progress in this field, it still needs to be further strengthened and improved in terms of comprehensiveness, systematicness, and in-depth generalization. In addition, Ahmed Karam and others analyzed the obstacles to the development of multimodal transport and put forward corresponding solutions, which provided unique insights for the development of multimodal transport (Karam, Jensen, & Hussein, 2023). However, in the field of multimodal transport, there are few studies that use quantitative methods such as bibliometrics to analyze, and there is a large research space. In view of this, this study uses CiteSpace6.1 R6 software as a visualization tool, combined with bibliometrics, to deeply explore the research literature on multimodal transport of maritime logistics in China from 2003 to 2023, aiming at comprehensively analyzing its research history, core topics, hot topics, and future trends, with a view to opening up new horizons and exploring paths for researchers in this field.

2. Data Sources and Research Methods

2.1. Data Sources

The data used in this study are from CNKI, China. Through the comprehensive retrieval of the two keywords "maritime logistics" and "multimodal transport," the accuracy of the research object is ensured, and the interference of unrelated disciplines is excluded. The retrieval time spans from 2003 to 2023, and a total of 851 literature records were obtained and downloaded as text files. After a rigorous screening process, invalid or irrelevant samples, such as non-academic newspaper articles without author information, were eliminated, and finally, 696 documents were selected as the data for this study.

2.2. Research Methods

In this study, the bibliometrics method is adopted. With the help of the CiteSpace6.1.R6 tool and the visual analysis of the scientific knowledge graph (Xie, Wu, Chen, Wei, & Chen, 2023), the research in the field of multimodal transport of maritime logistics in China is comprehensively sorted out: 1) The co-occurrence network of different elements, such as authors, affiliated institutions, and keywords in the literature, is constructed and analyzed, and different effective information is extracted for different nodes based on the visual scientific knowledge graph, so as to explore the relationship between information contents and reveal the correlation between various elements. 2) Through the cluster analysis of the key words in the literature, we can not only identify the terms with high frequency but also pay attention to those words with high frequency. On this basis, we deeply analyze the core concepts and research focuses of this discipline, grasp the current research trends and hot issues, and then accurately summarize the research trends in the whole field (You & Gao, 2023). 3) Time-zone analysis and mutation analysis of literature keywords, focusing on the changes of keywords with time, and at the same time, this study will also predict the future research trends in this field in combination with the latest development trends of China's logistics industry, aiming at providing valuable reference and enlightenment for subsequent scholars.

3. Research Results and Analysis

3.1. Annual Publication Analysis

The academic progress and the active degree of research in a certain period of time depend largely on the changing trend of the number of papers published in this subject area during that period (Ning, Huang, Yang, Wei, Xie, & Gao, 2023). In this study, the sample data obtained from the screening will be preliminary analyzed, and a trend chart of the annual number of articles published and the cumulative number of articles published in the field of multimodal transport of maritime logistics from 2003 to 2023 will be made, as shown in **Figure 1**.

From the point of view of the annual number of papers published and its cumulative number, we can find that the research activities in the field of multimodal

transport of maritime logistics in China showed a stable trend from 2003 to 2023. Although the output of papers fluctuates slightly every year, it remains at a relatively balanced level, which has roughly gone through two stages: 2003-2010 is a period of rising development, and the annual number of papers shows a slow growth trend, with a total of more than 100 papers. From 2011 to 2023, the development entered a moderate stage, and the number of articles published each year remained at about 40, with no obvious increase or decrease. At this stage, the total number of articles published was more than 500. Especially after 2005, the growth accelerated significantly, which indicated that 2005 was a key turning point in this field, which attracted more scholars to join in and significantly improved their research enthusiasm. Although the number of articles published in a year tends to be stable and the cumulative number of articles published increases steadily year by year, it can be seen from the data that the number of articles published in a year is not much, which also shows that there are not many scholars involved in the related research in this field, and there is still a lot of room for development in the field of multimodal transport of maritime logistics. It also shows that there are still many unsolved problems in this field to be explored.

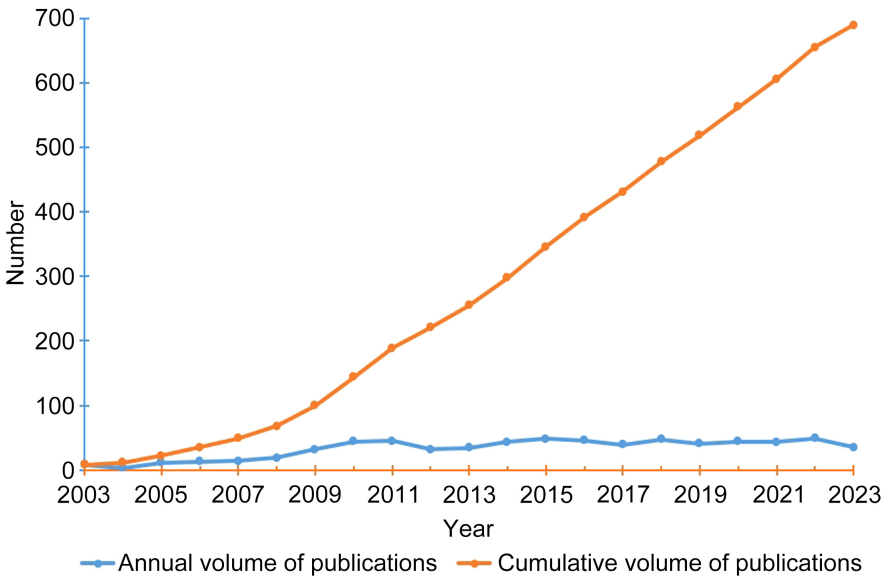

Figure 1. Trend diagram of annual volume and cumulative volume of articles issued by multimodal transport of maritime logistics.

3.2. Co-Occurrence Analysis of Core Authors

When using CiteSpace6.1 R6 software for visual analysis, the node type is set to "Author," while other parameters are kept as default values. Based on this, the knowledge graph is generated, and the results are shown in **Figure 2**.

From **Figure 2** and the actual data, it can be seen that the number of articles published by most authors in this field is not high, and the number of articles published by most authors is one or two. In related fields, scholars such as Zhong Qizhuang, Yang Kailin, and Shi Fenghua have published a lot of articles, among

which Zhong Qizhuang's scholars have published 12 articles in this field, almost twice or more than other authors in the same field, while other authors have published more than 5 articles. These scholars play a leading role in the research in this field and are important promoters of the research on multimodal transport of maritime logistics in China. From the perspective of cooperation, there is close cooperation among these authors, and a number of active research teams have been formed. However, except for a few scholars who have published a large number of articles, most of the research teams are small in scale, showing a small but numerous situation on the whole. It can be observed that the authors' research cooperation is mainly confined to their own teams, lacking cross-team interaction and cooperation. This phenomenon may limit the scale expansion of the research team, broaden the research horizon, and then have a certain impact on the innovation and overall development of this research field.

Figure 2. Co-occurrence knowledge graph of core authors.

3.3. Co-Occurrence Analysis of Core Research Institutions

Make visual analysis with CiteSpace6.1 R6 software, set the node type to "institution," and keep other parameters in the default configuration. Based on this, the knowledge graph as shown in **Figure 3** is constructed, as shown below.

From **Figure 3**, it can be concluded that the number of posts is directly proportional to the size of nodes and data labels, and the connection between nodes symbolizes the cooperative relationship between different research institutions. Among them, the top research institutions with a large number of papers are the College of Transportation Management (now the College of Transportation Engineering)

of Dalian Maritime University, Shanghai Maritime University, Ningbo Modern Logistics Planning and Research Institute, and other universities or institutions. Most of the research also comes from traditional science and engineering universities with strong logistics disciplines, which are the main positions for scientific research and innovation. In addition to the above-mentioned universities and research institutes, enterprises and government departments also occupy a place in the research field of maritime logistics and multimodal transport, such as the Ministry of Transport of the People's Republic of China, China Railway Container Transport Corp., Ltd., and so on. Fundamentally speaking, their institutional nature is different, and they will provide different research directions and contents for the field of multimodal transport of maritime logistics in China according to different research angles and topics and create different values.

Figure 3. Co-occurrence knowledge graph of core institutions.

Judging from the cooperation of research institutions, the cooperation relationship of most institutions is not obvious, and even some institutions have no experience of cooperation with other institutions. In different universities in the same province or city or between different colleges in the same university, there is a major cooperative relationship, such as the cooperation between colleges at Dalian Maritime University. In addition, neighboring provinces and cities usually have more exchange and cooperation. For example, Ningbo and Shanghai are close, and both cities have a large amount of maritime logistics. It is not surprising that cooperation has been reached. However, it is worth noting that enterprises and

government departments that study the field of multimodal transport of maritime logistics rarely reach more cooperation and exchanges with each other or with other institutions. This will lead to a lack of academic communication and exchange between government and enterprises, between schools and enterprises, and between political schools, which will easily lead to news occlusion, which is not conducive to the formation of an academic community in the field of multimodal transport of maritime logistics, thus limiting the comprehensiveness and innovation of research and development in this field. Therefore, universities, research institutes, government departments, and enterprises should cooperate with each other, carry out various forms of activities, such as academic seminars, and strengthen academic exchanges and mutual learning to ensure forward-looking research in this field and promote its innovative development.

3.4. Research Hotspots Analysis

3.4.1. Co-Occurrence Analysis of Keywords

When using CiteSpace6.1 R6 software for visual analysis, the node type is set as "keyword," while other parameters are kept as default values. After the production and generation of the graph, through operation optimization such as merging synonyms or similar words, such as "land-sea combined transport" and "sea-land combined transport," the keyword co-occurrence knowledge graph shown in Figure 4 is finally drawn, and the top 20 keywords in frequency and intermediary centrality are listed, respectively, after induction. See Table 3 and Table 4 for details.

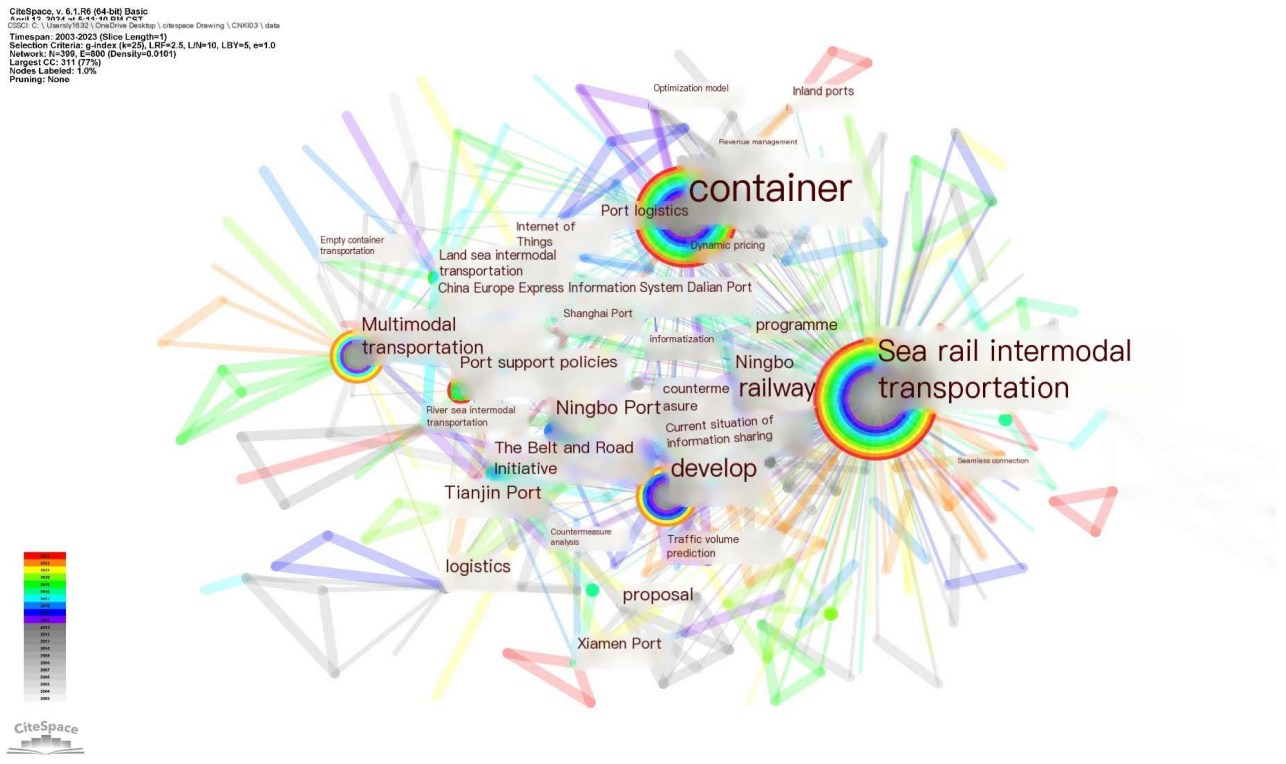

Figure 4. Keywords clustering knowledge graph.

Table 3. High-frequency keywords of multimodal transport of maritime logistics (TOP 20).

Ranking	Keywords	Frequency	Ranking	Keywords	Frequency
1	Sea-rail combined transport	258	11	Railway	8
2	Container	87	12	Dalian port	8
3	Multimodal transport	27	13	Production plan	8
4	Port	20	14	Port of Tianjin	8
5	Water-rail combined transport	17	15	Internet of things	7
6	Develop	14	16	Xiamen port	7
7	The Belt and Road	13	17	Traffic volume forecast	6
8	Port of Ningbo	13	18	Port of Shanghai	5
9	Joint sea-and-rail Transportation	10	19	China-Europe freight train	5
10	Logistics	10	20	Swap trailer transport	5

Table 4. High-centrality keywords of multimodal transport of maritime logistics (TOP 20).

Ranking	Keywords	Centrality	Ranking	Keywords	Centrality
1	Sea-rail combined transport	0.92	11	River-sea combined transport	0.02
2	Container	0.21	12	Land port	0.02
3	Multimodal transport	0.10	13	Sea-river combined transport	0.02
4	Water-rail combined Transport	0.09	14	Joint sea-and-rail transportation	0.02
5	Logistics	0.06	15	Work flow	0.02
6	Port	0.06	16	Port of Ningbo	0.01
7	Yangkou Port	0.05	17	the Belt and Road	0.01
8	Railway	0.04	18	China-Europe freight train	0.01
9	Port of Tianjin	0.02	19	Empty container transportation	0.01
10	Xiamen port	0.02	20	Counter-measure	0.01

Frequency refers to the number of times that the keywords in the paper have been detected in the sample documents in this field. The size of nodes and data labels represents the frequency of keywords, and the connecting lines between nodes represent the symbiotic intensity of keywords (Jin & Liu, 2020). According to the knowledge graph obtained from the analysis, we can see that there are 399 nodes, 800 links, and 0.0101 network density. The analysis results show that the research topics in the field of multimodal transport of maritime logistics have a certain concentration, and some keywords are closely related. According to

Figure 4 and Table 3, it can be clearly seen that the frequency of the keyword "sea-rail combined transport" ranks first, followed by containers, multimodal transport, and ports, and there are 10 keywords with a frequency of not less than 10. The research mainly focuses on these keywords, which together constitute the research hotspot in this field. In these 20 high-frequency words, most of them are related to railways and ports, and then the most high-frequency word is sea-rail combined transport. It is not difficult to conclude that the research subject in the field of multimodal transport in maritime logistics is sea-rail combined transport, but sea-river combined transport and other sub-fields are relatively few.

Combined with Figure 4 and Table 4, it can be concluded that, like high-frequency keywords, the keyword with the highest centrality is sea-rail combined transport, followed by high-centrality keywords such as container and multimodal transport. Among them, the centrality of sea-rail combined transport, container, and multimodal transport is greater than 0.1, and the centrality of sea-rail combined transport is far higher than other keywords, reaching 0.92, which shows its high importance. Other keywords are that the centrality of water-rail combined transport, logistics, port, and Yangkou port is not less than 0.05, which should also be the key to the research in the field of multimodal transport of maritime logistics and also need to be paid attention to. In the research direction, it mainly focuses on sea-rail transport, container transport, water-rail transport, sea-land transport, and sea-river transport. The research contents mainly include major ports, trains in the Belt and Road Initiative and Central Europe, and empty container transportation. However, there is no research method in the keywords of high centrality, which shows that scholars in this field have different research systems and methods but mainly focus on port construction and operation optimization.

3.4.2. Cluster Analysis of Keywords

Based on the co-occurrence network analysis of keywords, this study uses the LLR (log-likelihood ratio) algorithm (Feng et al., 2014) in the CiteSpace clustering function to cluster the co-occurrence graph of the above keywords, and the results are shown in Figure 5. Among them, Modularity Q (clustering module value) is used to measure the clustering effect, and the value is between 0 and 1. The larger the value, the better the clustering effect. Generally, when the Q value is greater than 0.3, the clustering structure is significant. Weighted Mean Silhouette S is used to measure whether clustering is reasonable, and the value is between −1 and 1. The larger the value, the more reasonable the clustering result is. Generally, when the S value is greater than 0.5, we think that clustering is reasonable and convincing (Wang et al., 2022). As can be seen from Figure 5, Modularity Q (clustering module value) reaches 0.5937, which is higher than the threshold of 0.3, indicating that the clustering structure is obvious. At the same time, the Weighted Mean Silhouette S (clustering weighted average contour value) is 0.89, which exceeds the standard of 0.5, which verifies the rationality of the clustering results. Therefore, in this study, the first five large-scale and most representative clusters are selected for in-depth analysis, and five clustering labels are derived. These five research

topics represent the research hotspots from 2003 to 2023 to some extent. The order of the five clustering labels is from #0 to #4, which are container, revenue management, the belt and road initiative, multimodal transport, and the Internet of Things. The smaller the number, the more keywords are included in the clustering, as shown in Table 5.

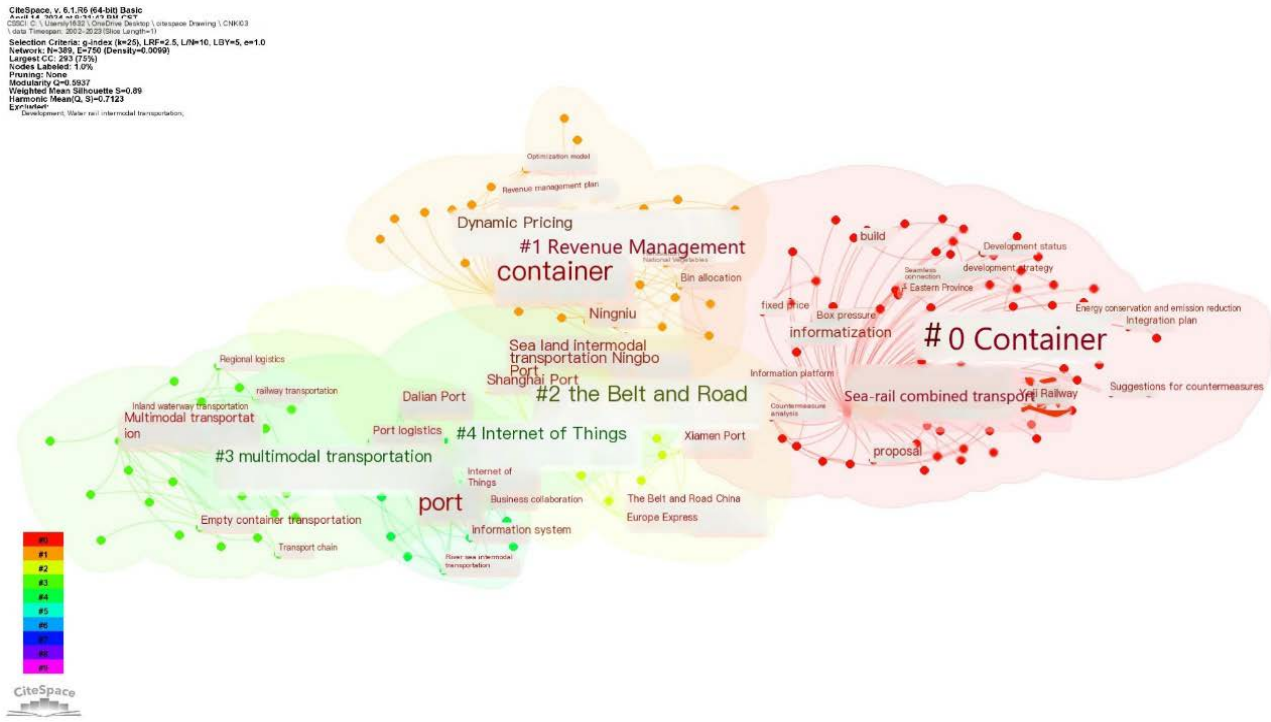

Figure 5. Keywords clustering knowledge graph.

Table 5. Main cluster of multimodal transport of maritime logistics research (TOP 5).

Cluster ID	Cluster labels	The main keywords contained
#0	Container	Sea-rail combined transport, informatization, countermeasure analysis, seamless connection, Guangdong Province, countermeasures and suggestions, information platform, energy saving and emission reduction, pricing, development status, logistics mode, development strategy, container capacity, Yaji Railway, connection scheme, construction, regional economy, Lianyungang, train operation, train arrival, bridge movement, slot assignment, port area, external factors, industrial development.
#1	Revenue management	Container, optimization model, Ningbo, dynamic pricing, revenue management, reloading operation, Shanghai, influencing factors, slot allocation, hub, threat, advantages, disadvantages, opportunities, transportation, basic ideas, accelerated development, policy suggestions, bulk logistics, reloading cost, seamless transportation.
#2	The Belt and Road	The belt and road initiative, Ningbo Port, sea-land combined transport, Xiamen Port, China-Europe train, supporting policies, effectiveness, Shanghai Port, development research, balance check, planning research, sustainable development, coil steel.

Continued

#3	Multimodal transport	Multimodal transport, empty container transportation, inland river transportation, transportation chain, railway transportation, regional logistics, information coordination, service platform, waterway transportation, obstacles, service process, foreign trade goods, whole-course logistics, railway ferry, Nantong, system construction.
#4	Internet of things	Port, Dalian Port, Internet of Things, River-sea combined transport, port logistics, information system, business collaboration, logistics industry, low-carbon economy, station, real-time monitoring, job dispatch, operation mode, mobile terminal.

According to the different labels and clustering contents of the five clusters, after studying the literature, they are summarized into the following five research topics:

1) Structure optimization and system construction of container sea-rail combined transport.

System structure determines system function (Xie, Li, Wei, Jiang, & Xie, 2016; Xie, Ni, Zhang, & Wei, 2019; Li, Xie, & Yang, 2014; Wei, Chen, Xie, & Peng, 2022). In the initial stage of multimodal transport of maritime logistics in China, container transport was the main mode, and the mode of transport was mainly sea-rail combined transport. The transportation structure of many ports is chaotic. Although there are a large number of imports and exports, the overall transportation efficiency is low, and the cost of intermodal transportation is high. Perfecting the information system of maritime logistics multimodal transportation and accelerating the construction of container sea-rail intermodal transportation systems is one of the keys to promoting their rapid development (Mu & Li, 2010). system dynamics is a method commonly used for structural analysis of systems (Xie, Wei, Chen, & Huang, 2020; Bao, Xie, & Huang, 2021; Huang, Chen, Xie, Wei, Feng, & Wu, 2021). In the study of the container sea-rail combined transport system, Wu Huirong and others applied the method of system dynamics to analyze the causal feedback relationship between the container sea-rail combined transport system and internal and external influencing factors and put forward countermeasures and suggestions to establish and improve the system mechanism and system and optimize the collection and distribution structure (Wu et al., 2013). Under the overall layout of China's optimized transportation development environment, it is the most important thing to build a collection and distribution system structure and establish an open system of container sea-rail combined transport so as to improve the overall transportation quality and promote the benign development of multimodal transport in maritime logistics (Ye, 2014; Wang & Chen, 2023).

2) The multimodal transport of maritime logistics model and the theoretical practice.

At the present stage, the development of China's maritime logistics and multimodal transport is influenced by many factors, such as economic development and infrastructure construction. It is beneficial to target the problems that restrict

the development of maritime logistics multimodal transport and promote its construction and development (Zong et al., 2015) by clarifying the internal logical relationship between various factors and grasping the degree of influence of each factor. In view of the challenges faced by container sea-rail combined transport and its unique operational characteristics, it is particularly important and feasible to adopt a revenue management system. On this basis, Darren Liu and Yang Hualong established a conceptual model of the revenue management system of container sea-rail combined transport and analyzed it, which provided a framework for the practical application of revenue management theory (Liu & Yang, 2012). In addition, Ji Mingjun and others used the customer value theory to analyze the relationship between the customer's railway transportation demand and price for sea-rail combined transport, and designed an operation optimization model with the goal of maximizing profits in order to explore the maximum profit in practical application (Ji et al., 2018).

3) Strategic development under the background of "the belt and road initiative".

The "belt and road initiative" strategy covers the "Silk Road Economic Belt" and the "21st Century Maritime Silk Road" and is an important national development strategy. Under the background of "the belt and road initiative," it will undoubtedly become an important part of this strategy to build and develop the multimodal transport system of maritime logistics. However, in response to the call for national strategy, there are still many problems in the construction and development of China's maritime logistics multimodal transport. Measures such as actively developing modern port logistics, standardizing multimodal transport markets, improving land and water transportation networks, and accelerating the development of information technology are important guarantees for the full implementation of the "belt and road initiative" strategy (Zhang et al., 2015). Chen Xiangming analyzed and combed the influence of border cities under the strategy of "the belt and road initiative" from the perspective of China-Europe trains and proposed to promote the sustainable development of China-Europe trains, promote land-sea combined transport and border-sea combined transport, and inject long-term and effective vitality into the strategic development of "the belt and road initiative" (Chen, 2022).

4) Construction and improvement of multimodal transport of maritime logistics systems.

With the proposal of the new western land-sea corridor, the field of multimodal transport of maritime logistics is further informationized, and the construction and improvement of multimodal transport systems has become a necessity of the times (Yu & Li, 2021). Yu Pei's in-depth analysis of the present situation and problems of the development of multimodal transport in Beibu Gulf Port provides countermeasures and suggestions for building a "five-in-one" three-dimensional multimodal transport high-quality development system and promoting a new pattern of opening up multimodal transport in maritime logistics (Pei, 2021). At this stage, China's maritime logistics multimodal transport system is evolving towards

intelligence, informationization, systematization, and modernization, promoting high-quality development.

5) The development of networks and the information technology of multimodal transport of maritime logistics.

With the development of logistics information technology, Internet of Things technology has been widely used in the field of multimodal transport in maritime logistics, providing good benefits for railways and ports (Liu & Zhang, 2014). In order to realize the information interconnection between ports and railways, Sun Qian and others built an information system for sea-rail combined transport based on Dalian Port container sea-rail combined transport, thus improving the coordination level and service efficiency of the sea-rail combined transport business (Sun et al., 2018). The development of Internet of Things technology and the popularization of other information technologies have provided strong support for the rapid development of China's multimodal transport of maritime logistics (Cheng et al., 2011).

3.5. Trend and Frontier Analysis

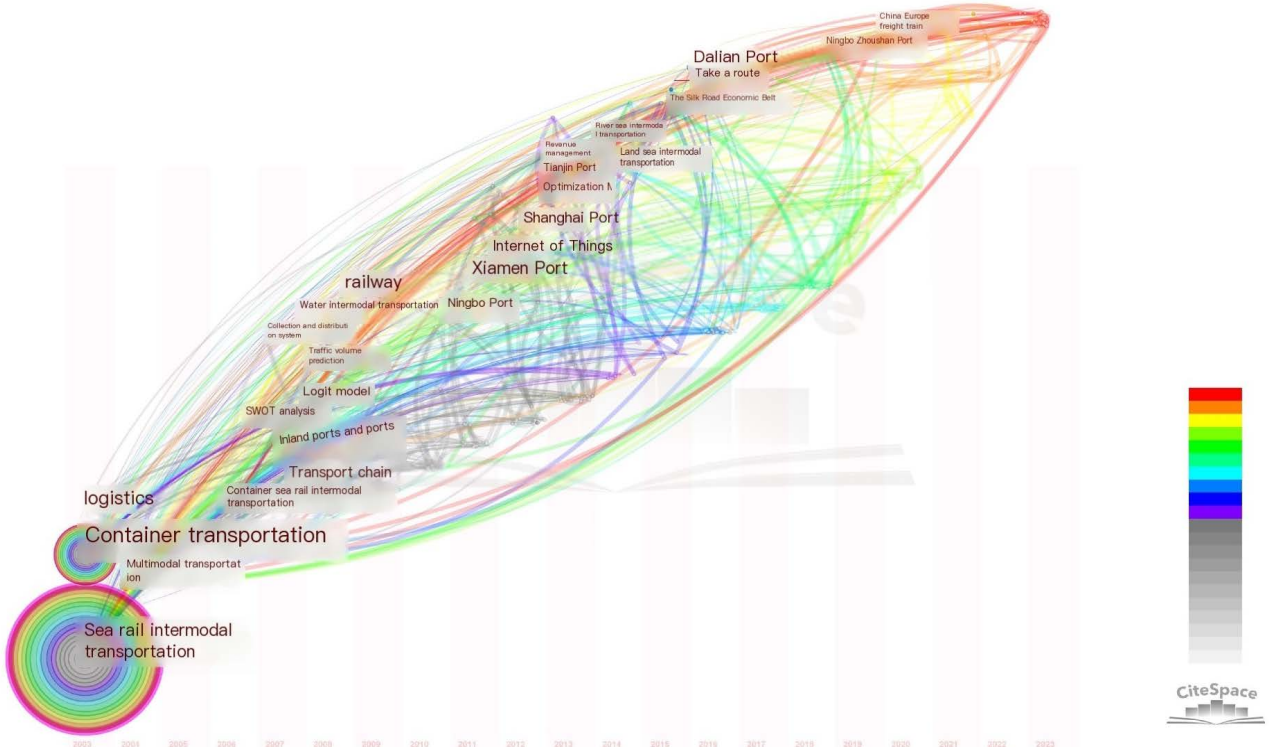

Figure 6. Time-zone view of keyword co-occurrence knowledge graph.

Keywords frontier time zone knowledge graph can clearly show the evolution track of the field of multimodal transport of maritime logistics and can better help predict the future research and development direction of this field (Wang, 2022). On the basis of the parameter setting of keyword co-occurrence spectrum analysis, the visualizations in the layout of the control panel are set to time-zone view, and

the keyword time-zone diagram of multimodal transport of maritime logistics is obtained by running. After the production and generation of the graph, the time-zone view of the keyword co-occurrence knowledge graph shown in **Figure 6** is finally drawn after the operation optimization, useless word screening such as deleting meaningless keywords, "countermeasures," and more.

From **Figure 6**, it can be seen that the research hotspots in the field of multimodal transport of maritime logistics are not static, and the research hotspots will change accordingly with the passage of time and the changes of the times. According to the information in the time zone graph, the development of multimodal transport of maritime logistics can be roughly divided into three stages:

1) Initial stage: 2003-2005. 2003-2005 is the initial development stage of China's maritime logistics multimodal transport since the 21st century, and the contents of "sea-rail intermodal transport," "containers," and "logistics" are the focus of scholars' research at this stage. At this time, because China's maritime logistics multimodal transport is stimulated by external forces, it is still in the traditional logistics state, and the main problems faced at this stage are insufficient modern logistics awareness, weak infrastructure, shortage of professionals, sudden influx of foreign companies, and competition (Fang & Le, 2003). How to quickly improve the hardware level of multimodal transport of maritime logistics and integrate it with the development of international logistics is worth thinking about and exploring for multimodal transport of maritime logistics in the initial development stage. As a result, many scholars began to make suggestions on the construction and development of multimodal transport for maritime logistics. Ye Yuling and others studied and analyzed the container sea-rail combined transport market in East China and put forward effective countermeasures (Ye et al., 2005). Taking Shenzhen as a typical example, Xia Weipeng pointed out the relevant factors affecting the development of sea-rail combined transport during this period and provided feasible thoughts and suggestions for expanding the sea-rail combined transport business (Xia, 2003). It can be seen that during this period, how to develop container sea-rail intermodal transport is the main research content of scholars in multimodal transport of maritime logistics at this stage.

2) Development stage: 2006-2013. From 2006 to 2013, the multimodal transport of maritime logistics was another stage of rapid development after the previous stage. Container sea-rail transport has formed a preliminary and perfect operation mode, and the problems in traditional logistics have become a thing of the past. Scholars' research focus has shifted to the application of research methods such as logit models and traffic volume forecasts, as well as structural construction and system reform such as collection and distribution systems. At this stage, China's port container throughput has been ranked first in the world for many years. However, in sharp contrast, the development of sea-rail combined transport has not reached the expected height, and there is obvious disharmony between them. Therefore, scholars analyze and study the multimodal transport system of maritime logistics and optimize and improve it on an original basis. Wu Tiefeng and

Zhu Xiaoning analyzed the advantages and disadvantages of three operation modes of sea-rail combined transport and their influencing factors from the contradiction between traffic volume and transportation capacity and put forward solutions in terms of system construction and key technologies (Wu & Zhu, 2011). Taking Shaanxi Province as an example, Zhang Rong and Yan Panyu analyzed the factors affecting the sea-rail combined transport volume, established a transport chain selection model by using multiple logit models, predicted the generation of import and export containers in the hinterland and the future market share of each transport chain, and proved the feasibility of this method (Zhang & Yan, 2007). It can be seen that during this period, how to improve the multimodal transport system of maritime logistics to promote the overall development of coastal cities and hinterland cities is the main research content of scholars at this stage.

3) Expanding and innovating stage: 2014-2023 On the basis of the rapid development in the previous stage, the multimodal transport of maritime logistics entered the stage of expansion and innovation from 2014 to 2023. During this period, based on China's national development strategy, "the belt and road initiative" and "Silk Road Economic Belt" became important research backgrounds, and the research focus was not limited to sea-rail combined transport but a wider range of sea-land combined transport came into view more frequently. In addition, the application of digital technology in the field of multimodal transport of maritime logistics is also a hot research topic at present. Zhang Bin and others pointed out the problems in the construction and development of China's land-sea combined transport at this stage and provided effective suggestions for the full implementation of the "belt and road initiative" strategy (Ji et al., 2018). Starting from an overview of land-sea overall planning, Silk Road, and multimodal transport, Cai Wenhua established a multi-objective model with the minimum cost and time under land-sea overall planning, designed an algorithm, and simulated it so as to promote the greatest role of Silk Road transportation (Cai, 2016).

Based on the co-occurrence of keywords, this study counts the top 25 mutant words and lists the detailed data, as shown in **Table 6**. As can be seen from the above table, the keyword mutation graph includes several pieces of information, such as mutation words, year of first appearance, intensity, start and end years of mutation, etc. Among them, the red line represents the start and end times of keyword mutation, and there are differences in strength and span between them. In the field of multimodal transport of maritime logistics, "the belt and road initiative" has the highest mutation intensity, which is 4.6. It is followed by keywords such as railway, Dalian port, rail-sea combined transport, etc., and their mutation intensities all exceeded 2.7. These keywords have played a certain role in the study of multimodal transport in maritime logistics in the corresponding time stages. From the perspective of mutation time, the mutation words with the longest time span are logistics, followed by sea-land transport and other keywords. In recent years, mutation words such as China-Europe train, rail-sea transport, water-rail

transport, multimodal transport, and development strategy have been hot keywords in the field of multimodal transport in maritime logistics. Combining catastrophe time and catastrophe intensity, we can find that logistics, railway, sea-land combined transport, the belt and road initiative, China-Europe train, and other things together constitute the frontier hot spots in the field of multimodal transport of maritime logistics.

Table 6. Keywords mutation of multimodal transport of maritime logistics (TOP 25).

Keywords	Year	Strength	Begin	End	2003-2023
Logistics	2003	2.6	2003	2011	
Yangshan Port	2004	1.29	2004	2008	
Counter-measure	2005	1.24	2005	2009	
Traffic volume forecast	2007	1.94	2007	2010	
Transport chain	2007	1.26	2007	2009	
Railway	2008	3.05	2008	2013	
Status	2009	1.35	2009	2012	
Swap trailer Transport	2012	2.22	2012	2015	
Optimization model	2012	1.77	2012	2015	
Revenue management	2012	1.7	2012	2013	
Hot metal combined transport	2012	1.7	2012	2013	
Dynamic pricing	2012	1.53	2012	2014	
Joint sea-and-rail transportation	2014	2.35	2014	2020	
Develop	2005	1.77	2014	2015	
The Belt and Road	2015	4.6	2015	2018	
Dalian port	2015	2.88	2015	2016	
Port of Ningbo	2010	2.77	2015	2016	
Water combined transport	2007	1.24	2015	2017	
Information sharing	2017	1.36	2017	2020	
Port	2008	1.4	2018	2019	
China-Europe freight train	2019	2.01	2019	2023	
Rail-sea combined transport	2008	2.76	2020	2023	
Water-rail combined transport	2010	2.55	2021	2023	
Multimodal transport	2004	2.29	2021	2023	
Development tactics	2010	1.33	2021	2023	

4. Conclusion and Future Work

This study reveals the research's dynamic status, hot topics, and future trends in this field and draws the following conclusions:

1) From the time dimension, the number of articles published in the field of multimodal transport of maritime logistics in China is relatively stable, showing a trend of rapid growth first and then steady improvement. Especially in 2005, thanks to the active guidance and strong support of the government at the policy level, research in this field has achieved remarkable progress. Considering the current international trade tension and frequent friction incidents, it is expected that the number of papers will gradually increase in the future, and the cumulative number of papers will also usher in a more significant increase.

2) Through the analysis of the co-occurrence relationship between core authors and research institutions, there is a group of active researchers, pioneering scholars, and some small research teams in this field. However, the communication and cooperation between these teams are relatively limited, lacking diversified interaction and deep cooperation modes, including school-enterprise cooperation, government-enterprise cooperation, and cooperation between government and schools. In addition, the cooperation between universities and research institutions in different regions or the same region needs to be strengthened, which is not conducive to the formation of an academic community in the field of multimodal transport of maritime logistics and further restricts the expansion and innovation of research on multimodal transport of maritime logistics.

3) After in-depth research on keyword co-occurrence, cluster analysis, and combing related literature, five main research directions in this field are summarized: Structure optimization and system construction of container sea-rail combined transport; The multimodal transport of maritime logistics model and the theoretical practice; Strategic development under the background of "the belt and road initiative"; Construction and improvement of multimodal transport of maritime logistics systems; The development of networks and the information technology of multimodal transport of maritime logistics.

4) Summarize the research trends and frontiers in the field of multimodal transport of maritime logistics in China through the analysis of mutation words and the time zone graph of keywords. From 2003 to 2005, China's maritime logistics multimodal transport field was still in its infancy, influenced by international trade and promoted by domestic policies. From 2006 to 2013, China's maritime logistics multimodal transport field got rid of the traditional logistics problems, moved towards information and intelligent logistics, and entered the development stage. From 2014 to 2023, influenced by the development strategies of the Belt and Road Initiative and other countries, China's maritime logistics multimodal transport field entered a stage of expansion and innovation. "The Belt and Road Initiative" and "China-Europe Train" are still the focus of attention in this field. Especially in today's severe and complicated international situation, how to continue to practice "the belt and road initiative" and steadily promote the development

of multimodal transport of maritime logistics will become the hot frontier of future research.

There are still the following deficiencies to be improved in this study: 1) The sample literature of this study is only limited to the pure text literature data of CNKI, which cannot exceed the technical limitation of analyzing the data from WOS or CNKI comprehensively. 2) There are some differences between the plain text format data in the CNKI database and the WOS database, which makes it impossible to carry out more diversified analysis, such as in-depth research on journal co-citation, literature co-citation, author co-citation, and so on.

Fund

This article was funded by the Special Fund for Student Innovation and Entrepreneurship Training Program (D202305171931069577).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Bao, X., Xie, T., & Huang, H. (2021). Prediction and Control Model of Carbon Emissions from Thermal Power Based on System Dynamics. *Polish Journal of Environmental Studies, 30,* 5465-5477. https://doi.org/10.15244/pjoes/135612

Cai, W. H. (2016). Multimodal Transport Path Optimization on Silk Road of Land and Sea. Master's Thesis, Dalian Maritime University.

Chen, J. H., Liu, X. R., Zhou, S. R., & Kang, J. (2023). Knowledge Mapping Analysis of Resilient Shipping Network Using CiteSpace. *Ocean & Coastal Management, 244,* Article ID: 106775. https://doi.org/10.1016/j.ocecoaman.2023.106775

Chen, X. M. (2022). The Belt and Road Initiative and Border City Development: The Impact of the China-Europe Freight Train on Cross-Border Logistics and Land-Sea In-termodal Shipping. *Journal of Boundary and Ocean Studies, 7,* 67-83.

Cheng, T., Zhou, J. X., & Wang, X. M. (2011). Status and Thinking on Container Ocean-rail Transportation for Internet of Things Application. *Port & Waterway Engineering, No. 9,* 205-208, 219.

Fang, Y., & Le, M. L. (2003). The Current Status and Development Strategies of Harbor Logistics. *Navigation of China, No.2,* 40-43.

Feng, J., Wang, K. F., & Liu, X. (2014). Emerging Trends in Translation Studies (1993-2012): A Scientometric Analysis in CiteSpace. *Technology Enhanced Foreign Language, No. 1,* 11-20.

Huang, H. N., Chen, W. F., Xie, T., Wei, Y. Y., Feng, Z. Q., & Wu, W. J. (2021). The Impact of Individual Behaviors and Governmental Guidance Measures on Pandemic-Triggered Public Sentiment Based on System Dynamics and Cross-validation. *International Journal of Environmental Research and Public Health, 18,* Article 4245. https://doi.org/10.3390/ijerph18084245

Ji, M. J., Yan, Y., & Zhu, H. L. (2018). Railway Pricing and Operation Scheduling in Rail-sea Intermodal Transportation. *Chinese Journal of Management Science, 26,* 159-169.

Jin X. T., & Liu, Y. J. (2020). The Research Process of Cultural and Creative Industry under the Background of Digital Economy at Home and Abroad—Based on the Visual Analysis

of CiteSpace Knowledge Map. *Chongqing Social Sciences, No. 8,* 108-122. https://doi.org/10.19631/j.cnki.css.2020.008.010

Jin, Z. H., Wang, X. H., Yi, T. P., & Zuo, Z. Y. (2024). Review and Prospect on Transportation Organization Optimization for Sea-Rail Intermodal Transportation. *Journal of Dalian Jiaotong University, 45,* 1-12.

Karam, A., Jensen, A. J. K., & Hussein, M. (2023). Analysis of the Barriers to Multimodal Freight Transport and Their Mitigation Strategies. *European Transport Research Review, 15,* Article No. 43. https://doi.org/10.1186/s12544-023-00614-0

Li, C. D., Xie, T., & Tang, Y. L. (2014). GMVN Oriented S-BOX Knowledge Expression and Reasoning Framework. *Journal of Intelligent Manufacturing, 25,* 993-1011. https://doi.org/10.1007/s10845-012-0722-x

Li, J. (2022). Visual Analysis of Research Hotspots and Evolution of Port Logistics at Home and abroad. *Journal of Urumqi Vocational University, 31,* 24-28.

Liu, C. (2017). Current Situation Hot Spots and Future Trends of Logistics Research: Bibliometrics and Theoretical Review. *China Business and Market, 31,* 33-40.

Liu, D. & Yang, L. H. (2012). Study on Application of Revenue Management in Contain-er Sea-Rail Intermodal Transportation. *Logistics Technology, 31,* 10-14.

Liu, M. L., & Zhang, Z. R. (2014). The Existing Problems and Solutions of China Railway Container Sea-Rail Combined Transport. *Shipbuilding Vocational Education, 2,* 28-31.

Ma, J., & Shen, Y. (2023). Analysis of Hotspots and Frontiers of Green Port Researches Based on CiteSpace. *Logistics Technology, 42,* 1-4, 11.

Ma, X. (2022). Knowledge Graph Analysis of Blockchain Technology Empowering Port Supply Chain Finance. *Social Sciences in Guangxi, No. 3,* 124-133.

Mu, Z. L. & Li, Z. F. (2010). SWOT Analysis of Developing Container Sea-Rail In-termodal Transport in China. *Port Economy, No. 10,* 47-49.

Ning, T. M., Huang, Y. J., Yang, J. Z., Wei, Y. Y., Xie, T., & Gao, Y. (2023). Knowledge Structure of Emergency Logistics Research in China: An Analysis Based on Bibliometrics. *Open Journal of Social Sciences, 11,* 244-261. https://doi.org/10.4236/jss.2023.112016

Pei, Y. (2021). Study on the Development Countermeasures of Multimodal Transport in Beibu Gulf Port under the Background of the New Land Sea Channel in the West. *Popular Science & Technology, 23,* 146-148.

Qin, L. (2017). Review of Countermeasure and Evaluation of Sea-rail Intermodal Transportation. *Logistics Sci-Tech, 40,* 84-88.

Song, G., Feng, R., & Li, Z. D. (2017). Analysis on Research Status of Port Logistics based on Literature Metrology. *Technology and Innovation Management, 38,* 298-301.

Sun, Q., Yang, H. Y., Yan, X. M., Wang, H. P., & Wu, D. (2018). Construction Practice on Demonstration Project of Container Sea-Rail Intermodal Transportation with Internet of Things in Dalian Port. *Port Science & Technology, No. 3,* 1-5, 49.

Tang, G. P. (2023). Literature Analysis of Port Logistics Research Based on CiteSpace. *China Storage & Transport, No. 3,* 80-81.

Wang, D. Y. (2022). Knowledge Graph Analysis of Domestic Port Logistics Research Based on CiteSpace. *Logistics Sci-Tech, 45,* 22-26.

Wang, P. P., & Chen, J. H. (2023). A Large Group Emergency Decision Making Method Considering Scenarios and Unknown Attribute Weights. *Symmetry, 15,* Article 223. https://doi.org/10.3390/sym15010223

Wang, S. B., & Peng, X. H. (2023). Knowledge Mapping of Port Logistics in the Recent 20

Years: A Bibliometric Analysis via Citespace. *Maritime Policy & Management, 50,* 335-350. https://doi.org/10.1080/03088839.2021.1990429

Wang, X. X., Tang, K. X., & Dai, X. Y. (2022). Research Status of Port Logistics in China—Based on CiteSpace Knowledge Map Analysis. *China Storage & Transport, No. 8,* 63-65.

Wei, R. (2022). A Summary of Domestic Port Construction Research Based on Docu-ment Visualization. *China Water Transport, No. 4,* 78-81.

Wei, Y. Y., Chen, W. F., Xie, T., & Peng, J. J. (2022). Cross-Disciplinary Curriculum Integration Spaces for Emergency Management Engineering Talent Cultivation in Higher Education. *Computer Applications in Engineering Education, 30,* 1175-1189. https://doi.org/10.1002/cae.22513

Wu, H. R., Zhu, X. N., & Qian, J. F. (2013). Study on Analysis and Development of Container Sea-rail Intermodal Transportation System. *Logistics Technology, 32,* 1-4.

Wu, T. F., & Zhu, X. N. (2011). Research on Program of Container Sea-Rail Inter-modal Development. *Journal of Beijing Jiaotong University (Social Sciences Edition), 10,* 27-32.

Xia, W. P. (2003). Thoughts and Exploration on Promoting Sea-Rail Combined Transport. *Railway Economics Research, No. 3,* 16-18.

Xie, T., Li, C., Wei, Y. Y., Jiang, J., & Xie, R. (2016). Cross-Domain Integrating and Reasoning Spaces for Offsite Nuclear Emergency Response. *Safety Science, 85,* 99-116. https://doi.org/10.1016/j.ssci.2016.01.005

Xie, T., Ni, M., Zhang, Z., & Wei, Y. Y. (2019). Parallel Simulation Decision-Making Method for a Response to Unconventional Public Health Emergencies Based on the Scenario-Response Paradigm and Discrete Event System Theory. *Disaster Medicine and Public Health Preparedness, 13,* 1017-1027. https://doi.org/10.1017/dmp.2019.30

Xie, T., Wei, Y. Y., Chen, W., & Huang, H. (2020). Parallel Evolution and Response Decision Method for Public Sentiment Based on System Dynamics. *European Journal of Operational Research, 287,* 1131-1148. https://doi.org/10.1016/j.ejor.2020.05.025

Xie, T., Wu, J., Chen, W., Wei, Y. Y., & Chen, K. (2023). Pandemic and Emergency Manufacturing Innovation: A Scientometric Analysis Using CiteSpace. *Disaster Medicine and Public Health Preparedness, 17,* e502. https://doi.org/10.1017/dmp.2023.162

Ye, G. Q. (2014). Present Situation and Strategy of Container Sea-Rail Combined Transport in China. *Containerization, 25,* 18-21.

Ye, Y. L., Shi, L. M., He, J., & Liu, Z. J. (2005). Research on the Development of Countermeasures for Container Sea-Rail Combined Transport in East China. *Shanghai Railway Science & Technology, No. 5,* 8-10, 18.

You, Y. Y., & Gao, S. (2023). Research Progress and Trends in Organizational Resilience Research: Knowledge Graph Analysis Based on CiteSpace. *Open Journal of Applied Sciences, 13,* 832-846. https://doi.org/10.4236/ojapps.2023.136067

Yu, L. Y., & Li, J. (2021). Research on the Construction of Intelligent Logistics System of Multimodal Transport in the New Land-Sea Passage—From the Perspective of Car-Free Carrier Platform as the Core. *China Market, No. 6,* 167-168, 176.

Yu, Z., Li, Y., Xiao, J. L., & Jiang, Z. L. (2022). Construction and Analysis of Ship-ping Economic Knowledge Graph Based on CiteSpace. *China Water Transport, No. 12,* 17-18.

Zeng, M., Wei, Y., Yu, K., Huang, H., & Xie, T. (2024). Scenario Deduction of Oil Spill from Tankers in a Ship-Ship Collision Based on the Knowledge Element and Dynamic Bayesian Network. *Polish Journal of Environmental Studies, 33,* 4421-4434. https://doi.org/10.15244/pjoes/177436

Zhang, B., Huang, B., & Fan, P. (2015). The Study of Multi-modal Transportation in the Light of "One Belt and One Road". *China Business and Market, 29,* 96-102.

Zhang, R., & Yan, P. Y. (2007). Rail-sea Intermodal Transportation Volume Forecast Method Based on Assignment of Hinterland Container Production. *Journal of the China Railway Society, No. 2,* 14-19.

Zhou, F. L., Yu, K. Z., Xie, W., Lyu, J. Y., Zheng, Z., & Zhou, S. Q. (2024). Digital Twin-Enabled Smart Maritime Logistics Management in the Context of Industry 5.0. *IEEE Access, 12,* 10920-10931. https://doi.org/10.1109/access.2024.3354838

Zhu, X. L. (2021). A Summary of the Research on the Training of Shipping Talents from 2001 to 2020—Visual Analysis Based on CiteSpace Knowledge Graph. *Maritime Education Research, 39,* 15-23.

Zong, G., Fang, L., & Liu, J. J. (2015). Research on Influencing Factors of Sea-rail Intermodal Transport Development Based on ISM. *Modernization of Management, 35,* 108-110.