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A Review of Research in the Field of Low Carbon Logistics based on the Cite-Space Tool

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Abstract: In order to gain a deeper understanding of the research dynamics and future trends in the field of low carbon logistics at home and abroad, Cite-Space visual analysis tool is used to construct a knowledge map to reveal the key information on the current research status, hot topic research, and development frontiers in the field of low carbon logistics.Through co-author mapping, keyword co-occurrence mapping and keyword clustering mapping, low-carbon logistics can be analyzed in multiple dimensions, and the literature can be classified into macro, meso and micro to sort out and summarize the policies, regionalization and technologies in the field of low-carbon logistics, so as to provide a basis for future research.

Keywords: Low-carbon Logistics; Cite-Space; Knowledge Graph.

1. Introductory

According to the Sixth Integrated Assessment Report issued by the United Nations Intergovernmental Panel on Climate Change (IPCC), in order to realize the goal of global warming well below 2°C and to make every effort to limit it to 1.5°C, there is an urgent need to significantly reduce carbon emissions in various fields. In order to achieve net-zero carbon dioxide emissions by the middle of the twenty-first century, China is in a phase of high-quality economic transformation, and the "dual-carbon" goal of carbon peaking and carbon neutrality has become a key driving factor in promoting low-carbon and green development of the economy, which contributes to the structural transformation of the country's economy and innovative development.

The concept of "low carbon" consists of three core terms: low carbon economy, carbon productivity and carbon tariffs. Low-carbon logistics is a sub-concept derived from it. It is a development model that reduces high-carbon energy consumption with the goal of sustainable development. Low-carbon logistics is mainly studied in several aspects of low-carbon logistics definition and concept, implementation mechanism countermeasures performance and effectiveness evaluation system. In China, we strive to achieve carbon peak in 2030 and carbon neutrality in 2060.

In the definition and concept of low carbon logistics: J. Tao [1] believes that low carbon logistics is based on the theory of low carbon economy and green logistics, the concept of "sustainable development" and carbon emission reduction into the logistics activities, while introducing modern technology and management to achieve the highest efficiency, minimal environmental impact and optimization of the benefits of the system; X. Xu [2] believes that low-carbon logistics refers to the logistics process to low energy consumption, low pollution, low emissions as the goal of using a variety of emission reduction techniques to inhibit the logistics of environmental hazards, while realizing environmental purification.

In terms of implementation mechanism countermeasures: Q.L. Dong et al.[3] analyzed the theoretical basis of low-carbon logistics operation and its mode points by using logistics integration ideas, argued that cargo logistics is an important way to realize low-carbon logistics operation, and put forward the idea of designing low-carbon logistics and operation strategies from the aspect of logistics integration program planning and operation monitoring; Sbihi A [4] pointed out that green logistics refers to the production of goods in a sustainable way under the premise of considering environmental and social factors. Sbihi A pointed out that green logistics refers to the production and distribution of materials in a sustainable way under the consideration of environmental and social factors, and combines and optimizes the carbon emission reduction methods of reverse logistics, waste flow and other issues.

In the evaluation system research: Y.M. Li, X. Mei [5] to build the evaluation system model of low-carbon efficiency of logistics enterprises to promote the low-carbon and energy-saving transformation of enterprises; Y.H. Hu et al.[6] around the carbon footprint of the professional logistics transportation of electric power supplies digital application to form a small-scale low-carbon logistics system.

In the research of low-carbon logistics tools: J. Wang [7] and others use Power Map and Tableau map visualization tools to conduct in-depth analysis of distribution center location data, and use K-means clustering algorithm for sorting center site selection. Y.C. Zhang [8] et al. visualize and analyze the cold chain logistics of fresh agricultural products through VOS viewer.

Although scholars at home and abroad have conducted extensive research on low-carbon logistics, relatively few studies have been conducted to systematically summarize and compare its status and focus using visual analysis tools. There is a lack of systematic literature review, as well as in-depth analysis of the evolution of research frontiers and knowledge extraction of emerging trends. Therefore, this paper forms an objective and systematic review to analyze the research development in this field.

2. Research Methodology and Data Sources

2.1. Research Methodology

2.1.1. Sub-section Headings

This paper analyzes the current status and development trend of low carbon logistics with the help of visualization software Cite-Space. To determine the research theme of low carbon logistics, collect relevant literature on low carbon logistics and conduct visual analysis of sample data such as co-occurrence, clustering, etc., to explore the patterns and characteristics within the literature and draw a visual map, and analyze the visual map to draw relevant conclusions.

2.2. Data Sources

This paper analyzes the current status and development trend of domestic and foreign research on low-carbon logistics, mainly based on the China Knowledge Network (CNKI) database and WOS database as the data source, and academic journals as the main type of literature. The Chinese literature search expression is "SU=(logistics) AND (carbon emission + low carbon efficiency)", the source category is "Beida core + CSSCI", and the time range is "2010-2024". "A total of 303 relevant documents were retrieved through manual screening, excluding news interviews, reports, newsletters, etc., which are not closely related to the theme. The core citations were selected through WOS search, Science Citation Index Expanded, and the theme search terms were "(low-carbon logistics OR green logistics) * (Carbon emissions OR Low carbon efficiency)", the source category is mainly "Article, Review", and the time range is "2010-2024". 466 articles were retrieved after manual screening and exclusion. A total of 466 articles were retrieved after manual screening and exclusion.

3. Domestic and International Research Status

3.1. Analysis and study of the volume of domestic and foreign publications

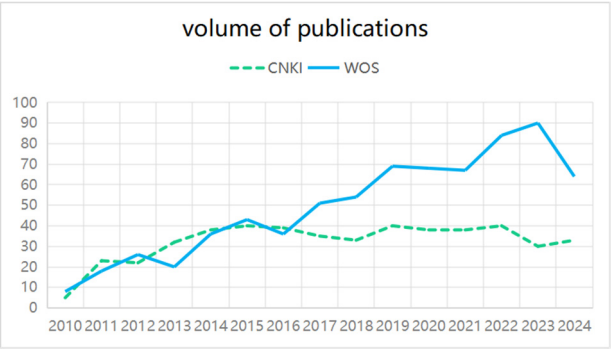


Fig 1. Annual publications statistics

The amount of articles published in the related field of research can get the macro research characteristics of the field, from the point of view of the time distribution of domestic and foreign low-carbon logistics literature, the amount of articles published in CNKI and WOS and the overall distribution of the relevant literature and the annual distribution of the situation is shown in Fig. 1: the annual amount of articles published in CNKI shows a stable trend, and the annual amount of articles published in WOS shows an upward trend. Since the statistics of 2024 is only up to July, the number of publications is not available, but from the trend of half a year, the number of publications for the whole year is in an upward trend.

In CNKI, the individual with the largest number of articles is Y.W. Zhao, who in recent years has mainly studied the carbon emission problem in logistics and distribution, seeking to optimize the site selection to achieve the purpose of low-carbon environmental protection. In the modeling, She proposes three different algorithms to solve the problem of site selection path, namely, adaptive super-postponement algorithm based on sharing mechanism [9], heuristic algorithm based on global edge sorting evaluation index as acceptance strategy[10], and quantum super-postponement algorithm[11]. And at the end, targeted policy and management guidance is proposed through example analysis.

The individual with the largest number of publications in WOS is L.Y. Zhang, whose main research in recent years has been on the optimization of low-carbon cold chain logistics systems, focusing on path optimization and distribution center siting to achieve low-carbon economic development. The RNA-Ant Colony optimization algorithm[12] was used in the algorithm optimization to solve the low carbon cold chain logistics route optimization problem, emphasizing the importance of considering the cost of carbon emission in the optimization process. The artificial fish swarm algorithm and the gray wolf optimization algorithm are used to investigate whether the total cost of the logistics system and carbon emissions are reduced by using the Beijing-Tianjin-Hebei region as the study area in combination with practical cases [13].

3.2. Analysis of Domestic and International Core Authors and Collaborations

Core research authors and inter-authorship collaboration were analyzed. Core authors refer to those with relatively high publication volume, citation rate and influence in the relevant fields, and their research results often express the direction of the time period and future research. According to Price's law [14] to determine the core author candidates for statistical authors of the minimum number of publications

$$M_p = 0.749\sqrt{N_{p\max}} \quad (1)$$

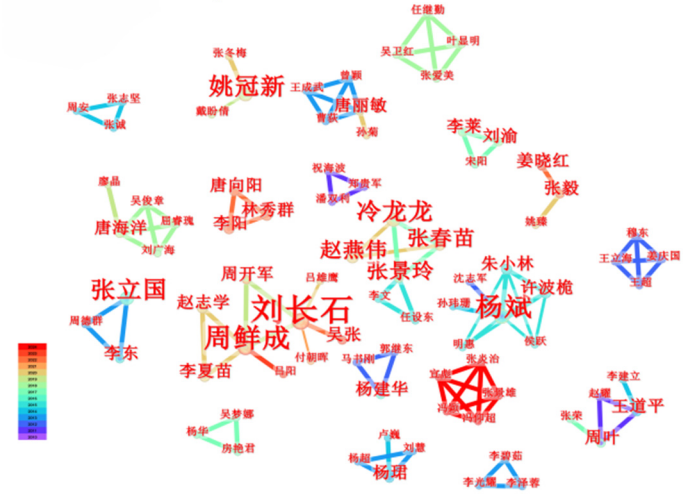
where N_{PMAX} is the maximum number of core authors' publications and MP is the minimum number of authors' publications.

Calculation based on equation (1) yields that the core authors of Chinese literature at least at least the amount of publications MP1 = 2.19, and the core authors of foreign literature at least the amount of publications MP2 = 2.19. The two are rounded upwards to 3 and 3, respectively. The total number of publications stands at 2.6% and 1.7% of the total number of publications in the field, which fails to meet the Price's law requirement, indicating that despite the large number of researchers in the field of low carbon logistics, the overall core authors' research is not strong, and the author group is relatively weak [15]. It is recommended to strengthen the academic communication among scholars in the field of low-carbon logistics to improve the academic level.

Co-author mapping to purple to red as indicating the time distribution of 2010-2024, Fig. 2(a) found that the largest CNKI author cooperation network for C.S. Liu, X.C. Zhou team [16][18], the team mainly designed the green vehicle path problem (GVRP) in logistics and distribution including the optimization of the environmental benefits as the goal of

the reduction of energy consumption and environmental pollution as the main objective, using the hybrid algorithm of NSGA -II and Variable Neighborhood Search as well as other innovations in multi-objective optimization models to solve the GVRP, exploring the possibility and effectiveness of the models and algorithms to be applied in scenarios such as cold chain, just-in-time distribution, and so on, so as to achieve a win-win situation for both the economy and the environment.

Fig. 2(b) finds that the largest collaborative network of WOS authors is F. Tao team [19][20], which in recent years mainly focuses on how to consider the balance between environmental factors and cost-effectiveness in logistics and supply chain management. The total cost is minimized by constructing a fuzzy low carbon emission open location routing problem model considering carbon emissions in emergency logistics. A vehicle route optimization problem considering cost, customer satisfaction and carbon emission is also proposed from the perspective of cold chain logistics, also taking the minimization of the cost per satisfied customer as the objective function, and solving the model by circular evolutionary genetic algorithm. This reflects the dual concern for environmental sustainability and customer service level in logistics optimization research.



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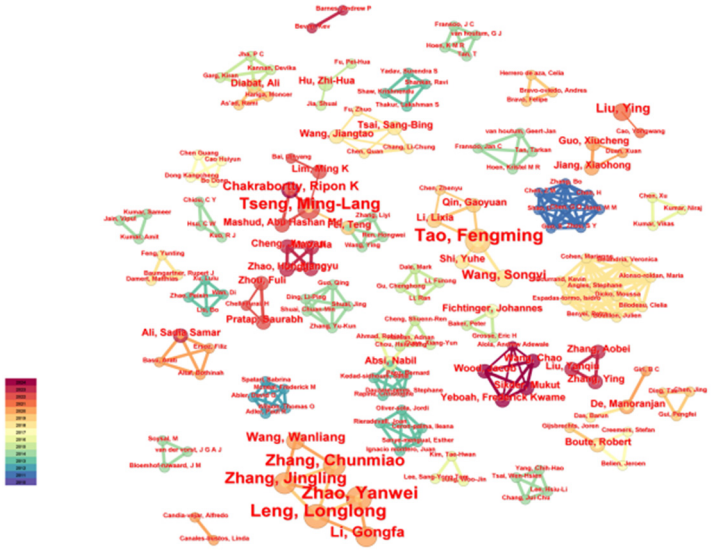

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Fig 2. Mapping of co-authors

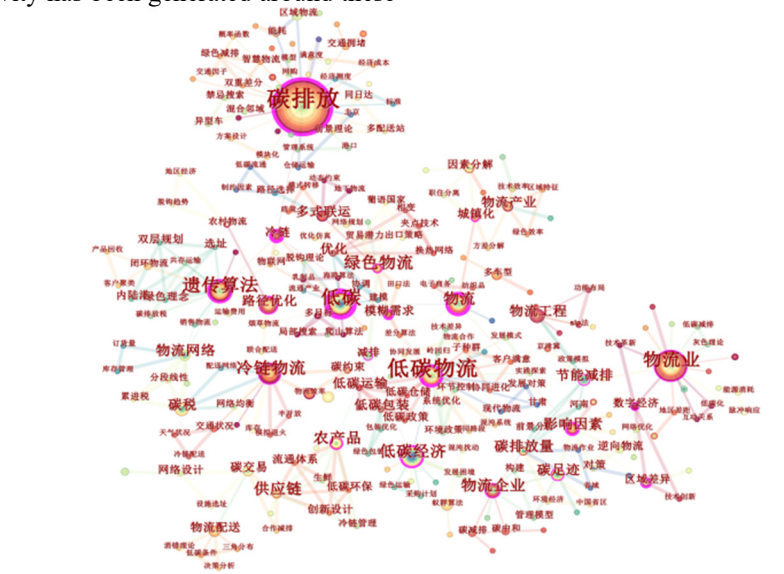
3.3. A study of Co-occurrence Analysis of High-Frequency Keywords at Home and Abroad

Keywords are words or phrases of substantial significance extracted from the paper, they can reflect the core theme and content of the paper. The higher frequency and centrality represent the larger keyword nodes, reflecting the importance of the band you in the network. In Cite-Space this paper analyzes the keywords of CNKI to get 295 nodes and 403 links, and the keywords of WOS to get 367 nodes and 871 links. After that, g-index node filtering is applied to filter the nodes within each time period slice.

$$g^2 \le k\sum_{i\le g} c_i, \quad k \in Z^+ \tag{2}$$

The network size is adjusted by increasing or decreasing the proportion parameter threshold k. The setting of the threshold affects the formation of the keyword co-occurrence mapping, and the corresponding adjustments are made through the data running condition until the structure of the mapping is clearly laid out, and the thresholds at home and abroad are ultimately set to be k=25 to draw the keyword co-occurrence mapping of low-carbon logistics. From Fig. 3, we can see that the keywords co-occur to analyze the hot-spots research in the field of cash, and the larger the node represents the more important the node is in the network. The hot-spots in China are "carbon emission", "low carbon", "low carbon

economy", "logistics industry" and so on, while the hot-spots in foreign countries are "Green Logistics", "Model", "Carbon emissions" and so on. emissions" and "Green Logistics" and "Model" and "Carbon emissions" in foreign countries, indicating that there is a relative advantage in the frequency of these keywords in the literature sample. Meanwhile, a wide range of radial connectivity has been generated around these keywords, indicating that more research directions and contents have been derived from the keywords as the core and gradually become the key nodes, e.g., synergistic development has been derived from low-carbon logistics, and the research based on carbon emission radiates to multi-distribution stations and so on.



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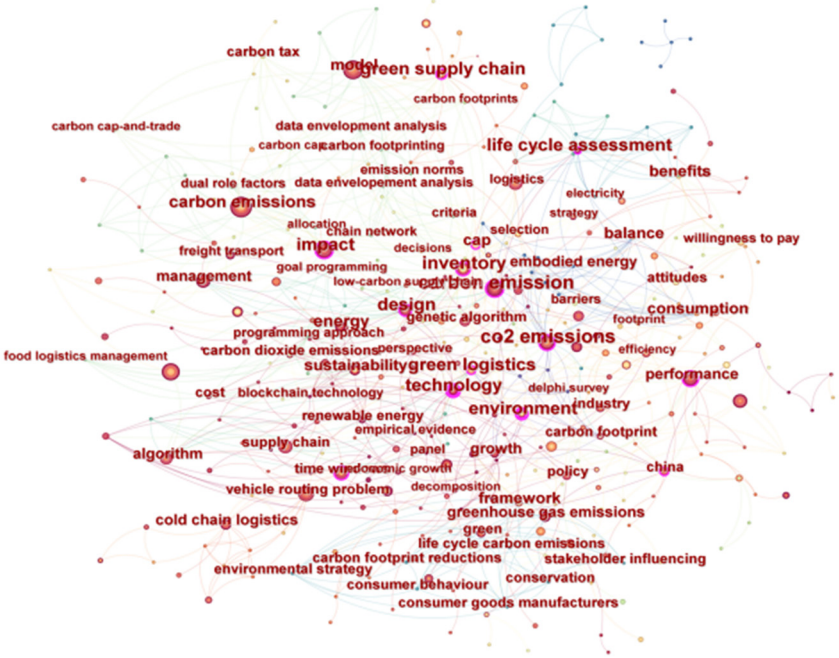


(b)

Fig 3. Domestic and foreign keyword co-occurrence mapping

Centrality is an important metric to measure the nodes in the network as a whole. From Table 1, it can be seen that the research hot-spots in the field of low-carbon logistics in China are mainly based on the frequency and centrality analysis, mainly focusing on the words with high frequency and centrality, such as "Low Carbon Logistics" "Cold Chain Logistics" "Carbon Emissions", and constructing the corresponding relationship structure. It is highly supportive of the network as a whole and plays an important role in the evolution of research in the field.

Table 1(a). Keywords and centrality in China

Number	Keywords	Frequency	Centrality	Year
1	Carbon footprint	119	0.45	2010
2	Logistics industry	47	0.18	2011
3	Low-carbon logistics	28	0.44	2010
4	low carbon	20	0.62	2011

Based on the keyword co-occurrence mapping and keyword centrality co-analysis, it is found that "carbon emission", "policy" and "path optimization" are the terms with higher frequency and centrality together. The latest

research conducted for several of these keywords found that in terms of green development policies M. Ma [21] calculated the carbon emission intensity of the logistics industry by looking at the energy consumption data, transportation, warehousing, postal output and carbon emissions in the last ten years, and assessed the green efficiency of different provinces.

Table 1(a). Keywords and centrality in China

Number	Keywords	Frequency	Centrality	Year
5	Cold chain logistics	18	0.12	2012
6	Genetic algorithm	18	0.24	2013
7	Low carbon economy	17	0.27	2010
8	Logistic	16	0.46	2011
9	Path Optimization	11	0.11	2016
10	Policy influences	8	0.34	2016

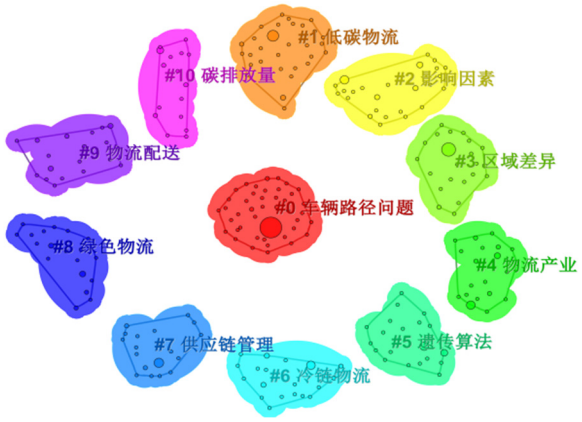
Table 1(b). Keywords and centrality outside China

Number	Keywords	Frequency	Centrality	Year
1	Carbon missions	151	0.47	2014
2	Model	74	0.06	2014
3	Logistic	56	0.08	2012
4	Impact	52	0.11	2014
5	Green supply chain	45	0.18	2013
6	Vehicle routing problem	32	0.25	2019
7	Sustainable development	26	0.09	2017
8	Green policy	23	0.06	2018
9	Reverse logistics	18	0.04	2015
10	Time window	14	0.15	2015

Carbon emission intensity was found to show a decreasing trend, but there were significant differences in green efficiency between regions.

Development proposals such as government incentives for low-carbon transformation of enterprises, increasing the degree of supply chain synergy, and accelerating improvements in energy improvement were put forward. S.L. Zhao[22] takes carbon emissions from the logistics industry in the Beijing-Tianjin-Hebei region as the research object, analyzes the reasons for the differences in energy consumption and carbon emissions among the three regions, and finds that the imbalance of the administrative system and economic development will exacerbate the uncoordinated logistics infrastructure and transportation structure in the region. In order to deal with this problem, it is proposed that the three regions should establish a low-carbon synergistic development mechanism, clarify the development positioning, and adjust the transportation structure. J. Zhang[23] team deeply explored the spatial impact of digital economy in low carbon logistics efficiency of RCEP countries and found that there is a significant positive spatial correlation between digital economy and low carbon logistics efficiency. The digital economy promotes the low-carbon logistics efficiency of neighboring countries through spatial spillover effects, and the improvement of domestic low-carbon logistics efficiency positively affects the efficiency of neighboring countries. Increased levels of green energy are found to reinforce the spatial spillover effect of the digital economy, which promotes overall low-carbon logistics efficiency and provides RCEP countries with strategies to improve low-carbon logistics efficiency.

4. Multidimensional Evolutionary Analysis



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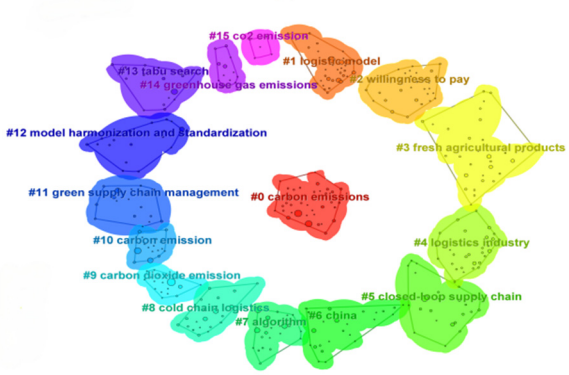

(b)

Fig 4. Clustering map of keywords within and outside China

Keyword clustering analysis identifies the major research themes within a given research area. Clustering operations were performed on the keywords using the Cite-Space tool and the clustering results were evaluated in terms of both structural and logical rationality dimensions. In general, if the clustering module index Q > 0.3, it indicates that the structure of the clusters possesses significance; if the average profile score S of the clusters > 0.5, it indicates that the clustering is reasonable; when the value of S is ≥ 0.7, the results of the clustering can be considered as persuasive and research meaningful. In this study, Q=0.8553 and S=0.9699 for the knowledge graph of keyword clustering within CNKI documents; The knowledge map of WOS key diagram has Q=0.7343, S=0.8678. S value is more than 0.7, which indicates that the knowledge map of domestic and foreign low carbon logistics literature is not only efficient but also has research value.

As shown in Figure 4, studying the field of low-carbon logistics can reveal domestic and foreign hot-spots research on related fields through keyword clustering mapping, and establish a multidimensional research framework accordingly.

4.1. Macro Study

The macro level research focuses on the basic concept of low carbon logistics, its attributes and its value. The development of low-carbon logistics requires the support of national policies and the formulation of laws, focusing on reducing carbon emissions from logistics activities by optimizing logistics processes, adopting clean energy and improving energy efficiency [24]. Gu, LQ[25] et al. argue that governments and businesses, as policy enforcers, need to consider the adaptability of low-carbon behaviors. An appropriate carbon tax can enable enterprises to take the initiative to reduce emissions and also avoid the situation of overburdening enterprises [26][27]. Y. Wang [28] and others believe that low-carbon logistics throughout the logistics system, the need to strengthen the management level, to promote the formation of a virtuous cycle of development in this field. Under the perspective of a strong transportation country, China's transportation logistics should be oriented to the "dual-carbon" goal in the future, focusing on serving the society and improving organizational efficiency and international competitiveness [29]. A.X. Xu [30] analyzed that the imperfections of the low-carbon logistics system and the low popularity of technology are the factors hindering the development of the Greater Bay Area according to the development status of Guangdong, Hong Kong and Macao cities. X.M. Yuan [31] et al. concluded that the effects of emission reduction policies are from strong to weak in terms of carbon offsets, carbon taxes, carbon trading, and mandatory carbon regulation. Akram, MW [32] et al. emphasized the critical role of the logistics industry in environmental sustainability and economic competitiveness in Asia, analyzing data from twenty Asian economies to examine the determinants of the logistics industry in the region. It was found that environmental pollution impaired logistics performance, while increased Internet use and higher education levels were critical to improving logistics performance.

4.2. Chinese Middle Concept Study

At the meso level, the study of low carbon logistics should take into account the characteristics of different industries and geographical regions. Different regions have different levels of economic development and conditions, and the characteristics of their industries are different, and the implementation strategies of low-carbon logistics are also different. C.L. Wang[33] and others proposed four types of urban low-carbon common distribution, including common distribution relying on third-party logistics enterprises, logistics parks, large chain stores, and the end distribution of e-commerce express enterprises. Enterprise transportation resource sharing and cooperation is also a new idea to promote the development of low-carbon logistics. M.M.M. Huang [34] and others believe that the low-carbon logistics development model should be realized from the construction of symbiotic links between logistics enterprises and logistics activities to maximize the efficiency of the use of logistics equipment to achieve logistics closed-loop activities in two aspects. R.T. Sun[35] suggested that information sharing is a prerequisite for the smooth implementation of co-distribution, which allows the transfer of logistics information between different segments. X.L. Wang[36] constructed evaluation indicators for four aspects of low-carbon logistics environment, capacity, potential and level in Guangxi, Jiangxi and Zhejiang and found that regional economy and regional logistics have a strong relationship. B. Yang[37] argues that for the fresh agricultural products industry with high energy consumption, China's logistics efficiency shows obvious geographical differences, higher in the east and lower in the west. The government and enterprises should work together to promote the in-depth application of the digital economy in order to facilitate the low-carbon transformation of this industry. Liu, SJ[38] studied the coordinated development of regional logistics coordination and geography. By analyzing the relationship between evolutionary conditions, evolutionary dynamics and evolutionary stages, it is emphasized that internal and external environmental conditions, dissipative structural conditions, and lifting and lowering conditions are the specific evolutionary prerequisites for coordination under the perspective of low carbon economy. The problem of regional economic imbalance and its impact on the overall economic layout and economic efficiency of the country are discussed, pointing out the importance of improving the level of regional coordination. F. Li[39] and others focused on the efficiency and impact of low-carbon logistics in the provinces along the Silk Road in the last decade. Measured by the non-expected output SBM model, it was found to be influenced by external environmental variables into wave changes. Analyzing technical efficiency and technical change by using Malmquist index found that the match between efficiency and technology is key. Factors affecting logistics efficiency are explored through the Tobit regression model. It is proposed that economic upgrading among regions mainly depends on technology, elimination of backward industries and energy utilization. Li, J[40] et al. explored the symbiotic relationship between low-carbon freight transport and efficient freight transport development by establishing a synergistic measurement index system, and proposed to enhance the application of environmental protection measures and clean technologies to improve the synergy between low-carbon development and efficiency.

4.3. Micro Study

At the micro level, research should focus on specific

technologies and ways to realize low-carbon logistics. At the micro level, the research should focus on the specific technology and realization way of low-carbon logistics. G.X. Yao[41] and others constructed an evolutionary game model based on evolutionary game theory and proposed that local governments use financial subsidies to guide logistics enterprises to achieve low-carbonization. Zhang, H[42] et al. evaluated China's regional logistics efficiency by considering technological heterogeneity and carbon emission factors through the DEA method. The main reasons for the loss of logistics efficiency were found to be technological gaps and management problems. X. Gong[43] et al. found that the development of low-carbon logistics industry was positively influenced by urbanization construction. For the government, it should consider strategies such as how to rationalize the logistics network and promote co-distribution models. Hou. B[44] and others investigated the improvement of multi-objective genetic algorithm to effectively enhance the demand fulfillment rate under the conditions of demand uncertainty and carbon emission constraints, as well as to reduce the carbon emission and distribution cost, and thus improve the logistics efficiency in rural areas. M.J. Zhang[45] et al. investigated the cold chain delivery path optimization problem for fresh products under the community group-buying model, aiming to minimize the total cost while considering the impact of carbon emission, and designed an improved Gray Wolf optimization algorithm to solve the problem. The co-distribution problem of products in different temperature strata can be further considered. Gupta, A [46] et al. in order to accelerate the transition to a low carbon energy system applied theories such as Technology, Organization and Environment Theory TOE and Innovation Resistance Theory IRT to address the low-carbonization of BCT in the logistics sector of developing economies. Blockchain technology is used to reduce carbon emission related hindrances to achieve carbon reduction. Ning, T[47] et al. investigated the modeling by introducing algorithms such as simulated annealing algorithm, improved hybrid ant colony algorithm, etc., to verify the effectiveness of cold chain logistics distribution order increase as well as low carbon emissions in the case of COVID-19 major public health emergencies.

5. Future Directions and Hot Trends Research

Based on the number of articles issued, keyword co-occurrence and keyword clustering knowledge map, the hot research directions of domestic and foreign low carbon logistics are derived from the following aspects.

(1) Study the sustainable development strategy of the logistics industry in the context of a low-carbon economy. The government should optimize the layout of outlets, reduce driving distances and waiting times, and conduct research on urban green logistics systems in response to traffic congestion and pollution in distribution. It should also introduce monitoring and management policies on carbon footprint, environmental protection, green taxes and incentives, and carbon emissions trading systems within the logistics industry. The policy environment and regulations have a profound impact on the sustainability of the logistics industry. Logistics companies need to pay close attention to changes in relevant policies and regulations and adjust their business strategies in a timely manner. Both sides should work together to solve the unfavorable factors hindering the development of logistics to ensure the realization of sustainable development.

(2) Research on the measurement of carbon emissions in the logistics industry and the factors affecting carbon emissions. In recent years for the study is mainly in the exploration of neighboring regions whether to realize the synergistic development of low-carbon economy and economic growth, the reasons for the uneven economic development of the far field region. Urban common distribution in relying on third-party logistics enterprises, logistics parks and other resources. The impact of differences in the level and conditions of economic development in different regions on logistics efficiency, as well as the promotion of low-carbon transformation of the industry through the application of the digital economy.

(3) Research on cross-regional logistics coordination and development in the logistics industry. The main focus is on the coordinated development of regional logistics coordination and geography. The study analyzes the relationship between evolutionary conditions, dynamics and stages, and discusses the issue of regional economic imbalance and its impact on the country's overall economic layout and economic efficiency. The importance of improving the level of regional coordination is emphasized, as well as the need to enhance interregional economic upgrading through technology, elimination of outdated industries and energy use.

(4) Research on site selection and path problems in the field of logistics. In the future, the logistics industry should pay more attention to the realization of low carbon and environmental protection, and at the same time concentrate on how to reduce the carbon emissions of low carbon logistics activities by optimizing the logistics network layout and distribution mode. More research on intelligent algorithms in site selection and path optimization will help to solve the complex problems encountered in the actual logistics process and promote the development of the whole industry in the direction of green and low-carbon.

6. Conclusion

If General Secretary Xi Jinping pointed out in the report of the 20th CPC National Congress that we must firmly establish and practice the concept of "green mountains are golden mountains", and plan for development in the context of harmonious coexistence between human beings and nature. Therefore, it is of great strategic significance to promote the green and low-carbon transformation of the logistics industry. In this paper, we utilize knowledge mapping to quickly understand the research hotspots in the field and discover the core issues in recent research. Cooperation and communication among scholars should be strengthened to promote the theoretical development of the field. Rural logistics, cold chain logistics, and the synergistic development of the logistics industry among regions are already research hotspots. Research on national policies should continue to be in-depth to solve the problem of regional imbalance in the development level of low-carbon logistics. Mobilize the enthusiasm of upstream, midstream and downstream enterprises to achieve economic benefits through technology, management and other aspects of innovation.

In summary, China's low-carbon logistics research should be from multiple perspectives, expanding research tools, and enriching the field of low-carbon logistics research in order to low-carbon development to drive the healthy development of

the logistics industry.

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