Bibliometric analysis and trends in container transport development: An approach from route planning and optimization

Análisis y tendencias en desarrollo del transporte de contenedores: Un enfoque desde la planificación y la optimización de rutas

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Abstract

The incidence of container transport in foreign trade has enhanced the growing scientific and organizational interest in the study of efficient behavior and the variables that affect the exchange of goo ds between countries. In this research, a bibliographic review related to container transport was carried out based on the documents registered in the Scopus and Web of Science databases in the last 12 years. Bibliometric tools were used for the development of scientific mapping and network analysis in the definition of the characteristics of the documents published in the area, the main authors, journals and countries. The study identified three research trends related to logistics distribution network, intermodal transport and route optimization. Finally, future research perspectives derived from the analyzed documents are proposed.

Keywords: Optimization, distribution networks, intermodal transport, planning

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Resumen

En la presente investigación se realizó una revisión bibliográfica relacionada con el transporte de contenedores a partir de los documentos registrados en las bases de datos Scopus y Web of Science en los últimos 12 años. Se aplicaron herramientas bibliométricas para el desarrollo de un mapeo científico y análisis de red en las características de documentos publicados en el área, principales autores, revistas y países. Se identificaron tres tendencias de investigación relacionadas con la red de distribución logística, el transporte intermodal y la optimización de las rutas. Finalmente se proponen las futuras líneas de investigación derivadas de los documentos analizados.

Palabras clave: Optimización, redes de distribución, transporte intermodal, planificación

1. Introduction

Over time, trade relations between different countries have become closer and this has encouraged the development of economic globalization [1]. Goods exchange using containers has been a practice that contributes to organizational growth thanks to the efficiency obtained in the transport of products in terms of cost optimization, delivery times reduction, and quality [2]. Accordingly, containers are positioned as leaders worldwide [3], they have also become a fundamental piece for the circulation of goods nationally and internationally [4].

The global restrictions of 2020 and 2021 related to the mitigation strategies to reduce COVID-19 transmission significantly affected supply chain logistics. As a result, there was a decrease in the workforce and container retention in the ports, which increased times of goods delivery, slowed down industrial activities and led to global economy decline [5]. Likewise, regional port hierarchies had a decrease in the concentration of cargo ships in Europe and Africa, whereas in Asia and North America it grew [6]. However, the environmental sector, for instance, stressed the positive impact of such decrease on the reduction of pollution because of the limitations in passenger transport and air cargo capacity [7]. Hence, there is a motivation to develop research that promotes the balance between marketing and route optimization as a quality factor in container transport [8] for environmental and economic efficiency in container transport [9].

There are reviews on container transport focused on the risk of supply chain management, the promotion factors of logistics development, and the impact of barge transport. [10] identified the most important risks to transport of containers by sea and high-impact tools such as IoT, artificial intelligence, simulation and predictive risk management. In addition,[11] analyzed the force that the logistics of sea and bulk containers gained after the wars, specifically in East and South-East Asia after 1952 with the Korean and Vietnam wars. Furthermore, [12] emphasized the economic, environmental and logistical benefits of container transport by barge in terms of fuel, fuel emissions and port congestion.

Methodology

The methodology used for the development of this article considered two stages: scientific mapping and network analysis. The scientific mapping process aimed to carry out the bibliometric study of the publications registered in the Scopus and Web of Science databases between 2010 and 2022; and the network analysis aimed to

identify the elementary and structural studies of the subject and, subsequently, to determine the research trends related to container transport.

For the scientific mapping, the Web of Science and Scopus databases were used because of their great relevance worldwide [13], [14] and their broad contribution in multiple areas of knowledge [15]. Likewise, the Bibliometrix tool [16] was used for the articulation of databases and the generation of bibliometric networks, its validation in other studies also has great relevance [17]–[24]. Finally, the five bibliometric procedures recommended by Zupic and Cater [25] were used for the analysis: citation study, word co-occurrence study, cocitation study, co-authorship study and bibliographic coupling study.

Table I shows the search criteria considered for the relationship of the terms "transport" and "container". The results yielded a total of 499 documents and 98 duplicates; thus, an overlap level of 80.36% was obtained.

Table I. Search Criteria

Search Criteria	Scopus	Web of Science
Date Range	2010-2022	
Search Terms	(TITLE ("transport") AND TITLE ("container"))	
Type of document	Article, Book, Book Chapter, Conference Paper	
Search Date	28/04/2022	
Results	384	115
Total without duplicates	**401**	

In the network analysis, the R-studio software was implemented to form a citation network based on graph theory, a methodology that relates information by type and network characteristics considering the references of the publications consulted in the databases [26], [27]. Subsequently, a cocitations map to visualize the research currents in the field of study was made [28], [29], it allowed giving continuity to the analysis of three indicators Indegree, Betwenness and Outdegree through the techniques validated methodologically in various studies [30]–[39]. The indicators Indegree [27] and Betwenness [40] were used to categorize publications into elementary and structural, and [27] was used to identify research trends in container transport.

Results and Discussion

Bibliometric analysis of container transport. Figure 1 lists the results obtained in the WoS and Scopus databases regarding the number of publications on container transport between 2010 and 2021. According to the total number of documents, there is evidence of a variable behavior with an increasing trend in a range between 20 and 50 studies in the 12 years of the date range. Additionally, 2020 had a slight decrease in the number of publications compared to 2019, which was possibly related to the isolation measures taken by governments due to the COVID-19 pandemic during that year. Such measures also caused information accumulation and 2021 showed the highest number of publications since 2010.
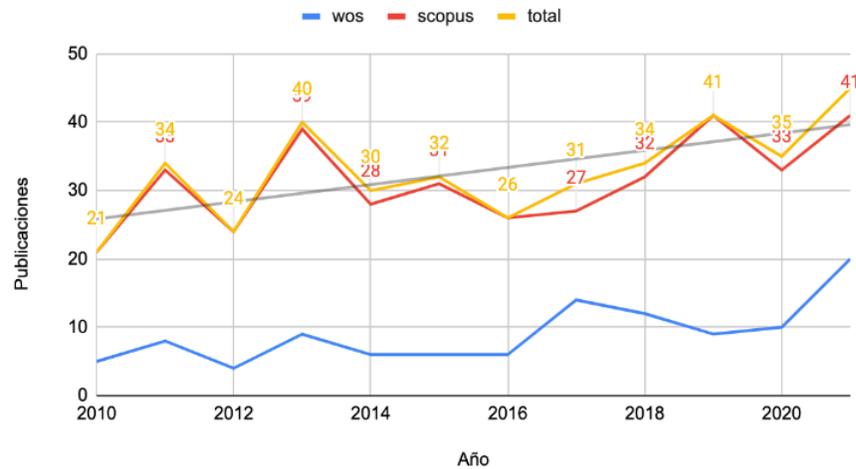
Figura 1. Publications history

Table II shows the top 10 countries that have made publications related to container transport. China, Germany and the Netherlands occupy the top three positions with 99, 19 and 18 documents, respectively. China is the country with the greatest predominance, accounting for 24.7 % of the total number of documents identified. Its contribution is significant in all the Asian countries of the list (China, Korea and Japan) with a value of 29.7%. Meanwhile, the European continent has a total of 72 publications corresponding to 18% by the countries of the top 10, Germany, the Netherlands, Italy, the United Kingdom, Poland and Belgium, together.

Table II. Publications by country

Country/Region	Number of Publications	Percentage of participation
China	99	24.7%
Germany	19	4.7%
Netherlands	18	4.5%
United States	15	3.7%
Korea	14	3.5%
Italy	11	2.7%
United Kingdom	10	2.5%
Poland	9	2.2%
Japan	6	1.5%
Belgium	5	1.2%

Regarding collaboration between countries, articles published by China in the field of container transport have had strong collaboration with authors from Japan and Singapore, and to a lesser extent with the United Kingdom, Hong Kong and the United States (Figure 2). There are also three smaller networks, the first one between the Netherlands, Serbia, Germany and the United States; the second one between Switzerland, South Africa and Belgium; and finally, the third one between France and Tunisia. This relationship suggests the importance of a perspective based on contexts different from their own and how it expands to build scientific knowledge on other perspectives.
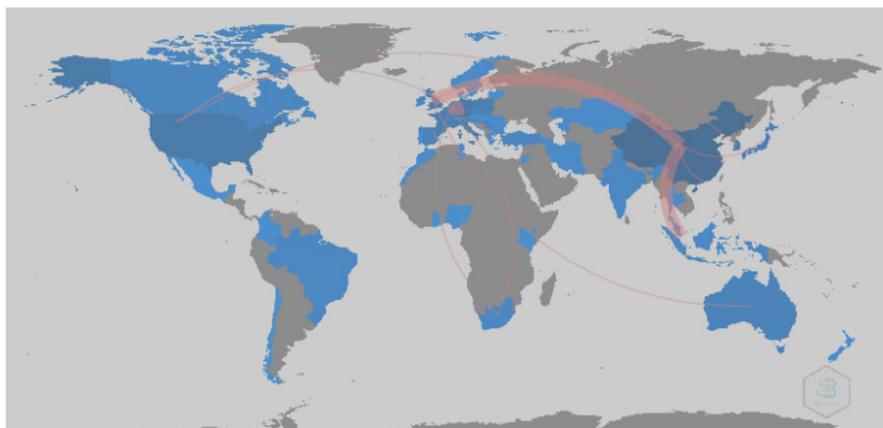
Figura 2. Cross-country collaboration

Table III shows the scientific journals with the highest number of publications in the field of study. Despite the fact that IOP Conferences Series: Earth and Environmental Science does not have a rank, according to the Scimago Journal Ranking, it is in first place thanks to the 13 publications related to container transport. In addition, the Journal of Transport Geography and Sustainability (Switzerland), classified as Q1, with 6 publications each, and with a value of 118 and 109 in the H index, respectively, prevails. As for the countries of origin of the journals, the United Kingdom and China predominate with the largest number of documents published, a total of 24, each. In addition, engineering, environmental and social sciences are prevalent as knowledge areas.

Table III. Main Journals

Journals	No.[a]	%	Q[b]	H[c]	SJR-2020	Country	Area
IOP Conference Series: Earth and Environmental Science	13	3%	-	34	0.2	United Kingdom	Earth sciences, environmental sciences, astronomy
Journal of Transportation Systems Engineering and Information Technology	10	2%	Q4	29	0.22	China	Computer Science, Engineering, Mathematics, Social Sciences
Journal of Dalian Maritime University	9	2%	Q4	11	0.15	China	Engineering
Journal of Transport Geography.	6	1%	Q1	118	1.85	United Kingdom	Environmental sciences, social sciences
Sustainability (Switzerland)	6	1%	Q1	109	0.66	Switzerland	Energy, environmental sciences, social sciences
Nase More	5	1%	Q3	17	0.37	Croatia	Chemical engineering, engineering, environmental sciences, social sciences
Transport Means - Proceedings of the International Conference	5	1%	-	15	0	Latvia	Social sciences
Transportation Research Procedia	5	1%	-	51	0.5	Netherlands	Social sciences
Wit Transactions on Ecology and the Environment	5	1%	Q4	24	0.17	United Kingdom	Environmental Sciences
Wuhan Ligong Daxue Xuebao	5	1%	Q4	14	0.13	China	Engineering

[a] Number of records   [b] Quartile of the journal in Scimago Journal Ranking   [c] Indexation H in Scimago Journal Ranking

Regarding the authors who participate in publications about container transport, Table IV shows how Zhongzhen Yang, linked to Ningbo University of China, ranks first in the top 10, with a total of 11 documents, 3,291 citations and an H index of 26, values that show the importance and quality of his publications. Other noteworthy authors are Walter Lang, linked to the University of Bremen, Germany, and Rudy Negenborn, linked to the Technological University of Delft, Netherlands, thanks to the number of citations and h-index that suggest a greater impact of their publications in the academic field.

Table IV. Publications by author

Author	Number of publications	No. of citations	h-index	Affiliation
Yang, Zhoongzhen	11	3,291	26	Ningbo University, China
Liu Di	7	55	4	Dalian Jiaotong University, China
Negenborn, Rudy R.	6	4,127	32	Delft University of Technology, The Netherlands
Russo, Francesco	6	1,864	26	University of Reggio Calabria, Italy
Yang, Hualong	6	174	7	Maritime University of Dalian, China
Lang, Walter	5	6,110	37	University of Bremen, Germany
Tavasszy, Lóránt A.	5	3,252	28	Delft University of Technology, The Netherlands
Caris, An	5	2,085	25	Logistics Research Group, Belgium
Konings, Rob	5	770	16	Delft University of Technology, The Netherlands

Figure 3 shows the collaboration (left) and cocitation (right) networks of the authors with greater participation in the field of study. With respect to collaboration, Liu G. and Yan Hl have the strongest network in terms of amount of joint work. Likewise, both authors actively participate in the cocitation (right figure) accompanying Wang, Zhang and Chen, who make the greatest contribution to the network.
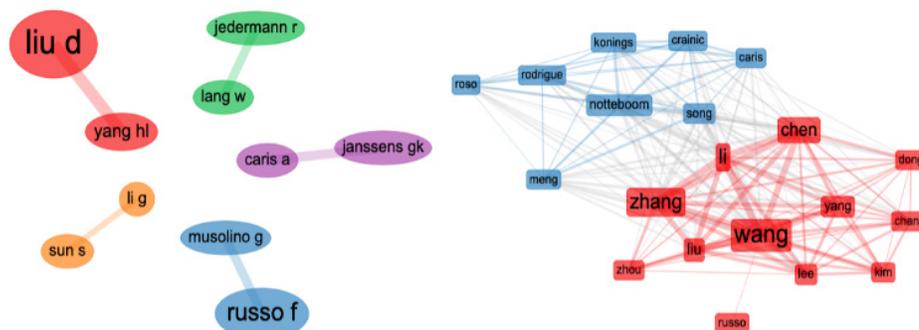
Figura 3. Collaboration and Cocitation Networks

Elementary and structural references in container transport. The elementary works of research related to container transport deal with the analysis of problems associated with port terminals connection considering the increase in merchandise flows. On that matter, [41] implemented mathematical models to support the planning and efficient execution of operations. Similarly, [42] focused the study of mathematical models on the analysis of directional flows balance considering the demand for containers.

Since its large-scale emergence in the 1960s, the container transport sector has improved its performance at an increasing rate with cost-oriented efforts [43]. Several studies have proposed the analysis of the network connection from the cost minimization perspective [44]–[46], which is one of the research bases in the field of study.

The work developed by [46], [47]Nossack, [46], [47] analyzes the concept of container and its impact on intermodal transport networks efficiency; it also emphasizes an approach on intermodal systems or components, such as postal services, intermodal rail transport and container terminals of maritime ports. The study also highlights the newness of the operations research implementation in intermodal freight transport for the year of publication.

Another approach adopted in the elementary documents identified is the design of service networks for transport considering the repositioning of empty containers [48]. The study by [49] used such approach and introduced a mathematical formulation that considered detailed specifications such as spatial dependence and substitution of products and services.

With regard to structural documents, two studies stand out. The first, developed by [50], describes the importance of the size of containers for transport by land, train or truck and the preference for sea transport. Thus, since 1995 work on the increase of container ships that went from transporting hundreds to thousands of containers in order to optimize transport routes has been done. The second, developed by V[51], deals with syncromodality and analyzes a new structure based on the differentiation between the price and the term of the delivery of the goods; each product is classified with a fixed rate and related services, hence, the number of customers and the revenues obtained increase.

Research Trends in Container Transport. The interaction of the documents published in the Scopus and WoS databases concerning container transport evidenced the use of three approaches with a predominance of the first one (Figure 4). Cluster 1 had more than 100 publications and ranked as the leader with a difference greater than 20 documents with respect to Cluster 2. However, the number of publications of the subsequent two clusters, above 60, indicated the importance of being considered in the identification of research perspectives, which were generated from the identification of the most recent articles and those with the highest page-rank in order to establish the topics of greatest interest and the most significant findings.

Research trend 1. Logistics distribution and optimization network. Cluster 1 uses an approach related to container routing, planning, and innovation (Figure 5). Regarding vehicle routing, research has taken special interest in optimization, network designs and fleet size. For instance, [52] used decision theory to determine the optimal transport route / between two points comparing the criteria of Hurwitz, Savage and

Laplace. Similarly, [53] did a holistic analysis on the intermodal shipping system network between intermodal maritime transport nodes. In addition, [54] modeled stochastic processes and compared analytical results under the Monte-Carlo simulation to determine fleet size and distribution centers in the management of a transportation system.

Figura 5. Keywords research perspective 1

The problem of vehicle routing has been studied in conjunction with other planning operations. For instance, [55] conducted research that simultaneously solved the problem of shipment and vehicle routing scheduling; they used a mixed whole linear programming model through an iterative search algorithm that allowed identifying an efficient use of transport capacities. Another methodology was proposed by [56] through the design of clusters based on the geographical location of ports; they developed a multi-objective solution that incorporated the design of the fleet, shipment scheduling and ship routing. Likewise, [57] outlined the combination of a dynamic model of foreign trade analysis resources and the simulation of a global intermodal logistics network to estimate the impact of policies and the prediction of container flow according to economic growth.

Two additional areas related to operations optimization have been considered: empty containers replenishment and berthing areas. [58] implemented the approach of Markov's decision processes to characterize the costs associated with empty containers.

Replenishment by establishing an optimal parking policy for the development of the activity, which would minimize leasing and inventory costs. [59] applied heuristics to solve the problem of berthing areas allocation in two stages, the first to identify a solution given a number of divided mooring stations and the second to relocate vessels.

Innovation has also played an important role in the development of strategies associated with container transport. [4] examined the effect of innovation on the performance of actors involved in container transport attributed to their ability to improve productivity, mobility and, therefore, usefulness. Meanwhile, [3] analyzed the efficiency of natural and human resources of port technological operations through the use of people's intellectual capacity in other activities such as process development and innovation.

Research trend 2. Planning of intermodal transport considering mathematical models. From this perspective, the study of problems associated with intermodal transport and its planning through mathematical models is identified (Figure 6). In this regard, [60] outlined non-convex sequential linear programming to model the variable and load-dependent transport time at the nodes of the road network in order to optimize freight flows of intermodal transport. Besides, [61] studied the problem of Intermodal

Transport (MTP) through the Dijkstra algorithms and the Ant Colony Optimization metaheuristic to provide a balance between time and the proper calculation of space. Another mathematical model was considered by [62] who combined a path-based formulation and a minimum flow network formulation to carry out seaport centralized container transport planning.

Fig 6. Keywords research perspective 2

The declining horizon, so named to cope with the dynamics of transport and traffic demand in the intermodal transport network, was considered to solve the problem of container allocation between the high seas terminals and the inland terminals of the Netherlands through the resolution of a non-linear programming problem and the prediction of the evolution of the network [62], [63]. [62]–[64] adapted this type of research to the problem of transport modal split for outbound cargo in container hubs, through Model Predictive Control (MPC) and the incorporation of two study variables: destination and time of arrival. Likewise, under the perspective of mathematical models for logistics planning[65] proposed a decision-making support model for the design of service networks in intermodal barge transport in order to determine the optimal maritime routes for freight transport services between maritime ports. Additionally, [66] formulated a stochastic dynamic scheduling model to minimize the total logistical cost of container loading and unloading planning in railway terminals considering uncertainty scenarios. Another approach from this perspective is directed towards studies such as the one proposed by V[67] regarding decision trees for the routing and planning of container land transport in road, water and rail connections between Rotterdam's deep-sea ports and others extended within Europe. Similarly, [68] conducted a research work on the problems of delivery, inventories and coordination of empty container management in intermodal transport in order to analyze the efficiency changes according to dry or maritime port type. In addition, Braekers [69] analyzed the decisions related to the repositioning of empty containers, the solutions proposed and the planning models considered, both at a strategic, tactical and operational level.

Research trend 3. Modal selection for route optimization with a focus on the European continent. Cluster 3 emphasizes the modal selection of various types of freight transport, the choice of the best route that allows time optimization and

the cost that such transport generates, with a particular emphasis on the European continent (Figure 7).

Figura 7. Keywords research perspective 3

With regard to modal selection, [70] conducted a study that used a survey to select between door-to-door road transport and short sea shipping on the South-West Europe Sea Motorway. The analysis carried out provides a tool to identify the areas that should be considered to boost maritime transport on the Mediterranean coast of Spain. Subsequently, [71] applied discrete choice models to analyze the variables that determine the means of transport of goods. The proposed model provided results to support decision-making processes regarding the diversion of road traffic to alternative modes between Spain and the European Union. Moreover, [72] developed analytical models to evaluate the performance of the intermodal and road transport system with a focus on the internal and total costs of both systems, which decreased proportionally as the distance increased.

The optimal route approach within the research perspectives was encouraged in works of research such as the one carried out by [73] who studied the problem of freight transport in metropolitan areas adjacent to seaports and the different algorithms to find the best trucks routes for freight transport. Similarly, [74] studied the time of the rail container transport chain and the travel reliability with the help of the HL-RF algorithm from the construction of an analysis method for the rail container transport chain. Likewise, [75] carried out a bibliographic and content analysis on the choice of routes and loading modes. In addition, [76] studied the relationship between freight transport demand and logistics through the calculation of marginal values with respect to time and the characteristics of reliability and frequency to calibrate costs in freight transport models.

Regarding cost optimization in freight transport, [77] studied the variables and costs associated with road and combined transport. Likewise,[78] studied the impact of increased fuel prices on intermodal transport terminal market through location analysis based on a geographic information system. The study recommended improving the analysis of intermodal versus unimodal transport by including other

types of variables such as service, transport time, generalized costs in the model and consideration of other European markets.

Conclusions

Container transport has been an area of great study interest for foreign trade and science. The number of publications registered in the Scopus and Web of Science databases shows the growing interest in the area, which has had an increase of 28.5% between 2020 and 2021. Although there are various literature reviews in the field of study, none has shown a global vision of container transport with bibliometric analyses using the two most relevant databases in the area along with the identification of the most relevant scientific actors and research trends that guide and point out the most frequent problems in the area. The author with the largest number of published documents is Zhoonghen Yang with a total of 3,291, while Walter Lang has the largest number of citations with 6,110. IOP conference Series: Earth and Environmental Science and Journal of Transport Geography are also relevant thanks to the number of publications and the H index, respectively. China is the country with the largest number of publications (24.7%) and the greatest collaboration index with countries such as Japan and Singapore. These research trends have mainly focused on three groups with an emphasis on the logistics distribution network, transport planning, and intermodal optimization where the cost minimization variable has been one of the most frequent objectives. The studies have focused on the optimal identification of routes by implementing mathematical models and algorithms to solve specific and generic problems.

Future Work Perspectives

Table V shows the future work perspectives identified in the three research trends analyzed.

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Perspective	Research topics	Reference
Logistics distribution and optimization network	• Uncertainty and security problems in transport operations. • Innovation of activities with the actors involved in container transport.	[53]
	• Vehicle routing problem with fleet design and shipment scheduling based on demand between regions.	[4]
		[56]
Planning of intermodal transport considering mathematical models	• Transportation times according to the loads in rail and inland waterway networks.	[60]
	• Problem of global repositioning from a strategic and tactical perspective.	[69]
	• Introduce a learning process guided to the decision tree for moving goods.	[67]
	• Sensitivity analysis in the design of the service network for transfer costs and penalty for delayed delivery.	[60]
	• Effect of the economies of scale on rail and inland waterway transport in the allocation of intermodal container flows.	[63]
	• Consider the number of people and flexibility of resources at seaport rail terminals.	[68]
Logistics distribution and optimization network	• Uncertainty and security problems in transport operations.	[53]
	• Innovation of activities with the actors involved in container transport. • Vehicle routing problem with fleet design and shipment scheduling based on demand between regions.	[4]
		[56]

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