Theory-Based Studies of Maritime Networks: A Literature Review

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This article reviews the literature regarding maritime networks, including identifying the essential articles and authors and suggesting a categorization of associated topics. Network theory in logistics demonstrates strategic information about and competitive advantages of maritime transport between regions. We analyzed 145 technical/scientific studies of maritime networks, including articles, theses, patents, dissertations, and conference proceedings. After defining the inclusion and exclusion criteria, we selected 103 technical and scientific studies, whose analysis allowed us to suggest six categories of interest: Ports, Economy, Containerized Cargo, Maritime Safety, Clusters, and Technological Solutions and Innovations.
Keywords: Network Theory. Maritime Networks. Systematic Review. Category of Analysis. Maritime Systems.

Introduction

The heading of each section should be numbered with Arabic numerals and left-aligned, with uppercase and bold letters. A space should be added between the end of a section and the heading of the next section.

In recent decades, worldwide trade growth has resulted in significant changes in maritime transport and the port system. Maritime transport is responsible for approximately 90% of goods currently transported worldwide. Changes, such as increasing the size of bulk cargo ships, oil tankers, and container ships and the intensification of the use of containers for freight transport have led to significant improvements in the sector, e.g., the emergence of economies of scale stemming from larger ships, applied technology resulting in increased safety and decreased losses in cargo transportation, a decrease in the time ships are at berth, greater operational agility, the emergence of large shipping companies, and the enhancement of intermodal operations with the creation of logistical networks, with ports being the main hubs of that model.

Received on 20 January 2022; revised 28 May 2022.
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J Bioeng. Tech. Health 2022;5(2):141-145

Research studies regarding maritime transport and technological applications to waterways have emerged as direct consequences of the importance of maritime navigation to the world economy. The theory of social and complex networks is presented as a strategic tool capable of generating significant competitiveness markers for international maritime transport in these studies.

The available reviews regarding maritime networks still approach the use of network theory superficially. The present article presents a systematic literature review regarding maritime networks. Systematic reviews are useful to impartially gather as much information available about a phenomenon of interest (e.g., a research problem) over a given period, where the current date usually defines the end of the period [1].

The present paper aims to examine the state of research regarding maritime networks between 1957 and 2018; focusing on the following question: what are the analytical-qualitative categories of maritime networks that have been employed by researchers to develop maritime transport worldwide?

The present article is divided into different sections: contextualization of existing work related to maritime networks; a presentation of the research methodology employed in the construction of this systematic review, which enumerates its stages of implementation; a discussion of the results obtained; and finally, presentation of conclusions about the state of the art of this field and future research suggestions.

Maritime Network Reviews

Secondary headings should be left-aligned, and bold, and the first letter of each word should be capitalized. A systematic review of a given subject is a means to evaluate and interpret all available research relevant to a particular scientific question, scientific topic area, or phenomenon of interest [1]. Reviews aim to present an overview of a given research topic using a reliable and auditable methodology. We used the articles about reviews by Kitchenham (2007) [1], Insfram and Fernandez (2008) [2] and Borgati and Foster (2003) [3] as theoretical and methodological guidelines for the present article.

A few studies have developed theories about maritime networks and their applicability to maritime transport. A review article by Ducruet (2012) [4] published in the Journal of Transport Geography focuses on the existing scientific literature about the subject and notes the scarcity and fragmentation of empirical studies. The main reason for this lack of publications stems from the unavailability of detailed maritime traffic information, including vertices (ports), edges (shipping lanes), and flows (traffic). The authors also emphasize four research approaches to the topic: Geographical Coverage of Logistics Operators, Maritime Network Connectivity, Maritime Network Efficiency, and Complex Networks.

Although not the main focus, there are maritime networks that emphasize the economic strategies of logistics operators, such as alliance and integration [5-7] or the performance and competition of a given port within a network [8,9]. There are some relatively limited reviews about these subjects.

Likewise, some geographers have blazed a path for the study of maritime networks by analyzing maritime transport company strategies, considering the spatial extension and expansion of port networks, such as the study about Maersk [10] and those about regional maritime transport networks in Asia [11-14].

Material and Methods

This section presents the stages of constructing a systematic review:

Stage 1: The first stage consists of planning the literature review, where the need for the review is identified and the research questions and literature review protocols are determined. A literature review about the application of network theory in the maritime navigation context is sorely needed because of the lack of effective studies on this subject, in addition to the subject's importance to society, because it can provide social, competitive, and economic benefits to a given country or region.

We considered the following research question: what are the categories of analysis of maritime networks that have been used by researchers in the development of world maritime transport? This research question will enable summarizing the existing knowledge of marine networks and identifying gaps; future research topic areas are suggested.

Data Sources

The principal sources used for the construction of this review of maritime networks consisted of five digital databases and three books: Web of Science (Thomson Reuters); Scopus (Elsevier); Portal Periódicos from Capes/MEC/Brazil; ScienceDirect; Scientific Electronic Library On-Line (all countries). We analyzed publications between 1957 and 2018. In the period 1950-to 1980, marine network studies were scarce. Nevertheless, some works published during this period are seminal and are still used by researchers. Data collection was performed from July 1st, 2014 to April 2nd, 2018.

Stage 2: The second stage consists of (i) determination of scientific research data inclusion and exclusion criteria, (ii) construction of a summary with results of the application of the descriptors to digital databases, and a table that lists the resulting technical and scientific products (i.e., articles, books, patents, theses, and dissertations), and (iii) analysis of the categorization.

Inclusion Criteria

We defined two inclusion criteria for the selection of technical and scientific literature about the subject: (IC1) works that propose and/or describe methods for construction and analysis of maritime networks applied to different regions of the world and (IC2) works that apply network theory as a method theoretical framework to maritime transport.

Exclusion Criteria

The need for filtering the resulting technical and scientific output in digital databases led us to define five exclusion criteria: (EC1) works that did not analyze maritime transport, whether long distance or cabotage; (CE2) works that did not refer to network theory; (EC3) repeated works (appearing more than once in different digital databases); (EC4) full or summarized works published in technical or scientific proceedings of conferences/events; and (CE5) patents.

Descriptor Definitions

Definition of descriptors was necessary to search for technical and scientific publications about the subject. The terms Maritime Network, Network Maritime, Complex Maritime Networks, and Complex Networks were used as descriptors of maritime networks. We found a total of 145 works. A hundred three were from scientific journals (n=96, 93.21%), doctoral theses (n=2, 1.94%), master's theses (n=2, 1.94%), and books (n=3, 2.91%).

Characterization of the Technical and Scientific Output

We built a theoretical matrix to detail the selected technical and scientific output and thus address the need for their characterizations. The following aspects were considered: application of network theory; definition of categories of study, i.e., focused on a theoretical framework or computational modeling (or both); and research method used. Figure 1 represents a framework of the method.

Results and Discussion

This section analyses the main publications on maritime networks, and their authors. We divided this section according to publication typology: Clustering, Containerized Cargo, Ports, Economic Conditions, Technology Solutions, Innovations, and Maritime Safety.

Clusters

The analysis of clustering and its direct influence on the existence of maritime networks is a research field experiencing remarkable growth. Vieredyte (2013) [15] demonstrates the importance of clustering for the competitiveness of maritime businesses in Europe. However, the author does not focus directly on building complex systems to develop competitiveness in that region but rather on the difference between top-down clusters (financed by public organizations) and bottom-up clusters (financed by companies). Vieredyte (2013) [15] also highlights the need to build a European cluster database for the development of new strategies and strengthening maritime organizations in the region.

We realize that research about clusters and maritime networks is still in its infancy compared with other categories. However, the benchmarks presented herein indicate a worldwide growth of Clustering studies, with impacts on international maritime geography. This growth will enable future exploration of the theme with the aid of network theory.

Containerized Cargo

The use of containers for the shipment of goods in international maritime transport has grown substantially during the last decade. For

Figure 1. The framework of Review Method.

example, the handling of containerized cargo grew proportionally 81% more compared with liquid and dry bulk in the last eight years in Brazil alone [16]. In this sense, the number of publications related to containerized cargo utilizing maritime networks marks the relevance of this analysis.

Regional Economic Conditions

Some publications about maritime networks emphasize the importance of economic data in their construction [17]; discussed the influence of the Tehran port and its economic drivers in maintaining maritime networks. Sen (2006) [18] investigated the political history, especially the economic history, in the formation of South Asian maritime networks. The article depicts historical trade relations in Asia and their direct influence on the establishment of maritime networks in South Asia. From the surveyed benchmarks, we found that economic factors are relevant to the formation of maritime networks. However, the importance of this issue in international competitiveness demands a deeper analysis and additional specific research regarding the economy and these network formations.

Port Location

The importance of port location is reinforced in published works concerning maritime networks and their construction. The majority of published methods use ports as vertices and the movement of ships between ports as edges. Thus, most publications about maritime networks focus on the importance of ports to establish an efficient maritime network infrastructure. The number of authors and publications in the international literature regarding maritime networks indicates the growth and importance of ports for determining maritime networks.

Technological Solutions and Innovations

Maritime networks, the focus of the present review, exhibit an important category of scientific research – technology applications in the optimization of movements between ports.

Maritime Safety

Regional and national protection, the development of national safety systems, and the survival of sea operators are directly related to the construction of maritime networks. This finding arises from the ability of complex systems in providing countries with technology that can be used in the fight against terrorism and the increasingly enhanced monitoring of sea movements.

Conclusion

This article presented a systematic review of the maritime networks and their applications between 1957 and April 2018.

The results of this literature review point to a vast field of research regarding maritime networks to be explored by the scientific community, especially the Clustering, Containerized Cargo, Regional Economic Conditions, Port Importance and Location, Technologic Solutions and Innovations for Maritime Navigation, and Maritime Safety, qualitative categories and the possible intersections among them.

The number of categories may be expanded based on the significant number of associated publications; critical topics include dry and gas

cargo handling, oil tankers, insurance in cargo handling (all types), and boarding operations. We emphasize the need to conduct additional research regarding Network Theory use and simulations as logistical support instruments to existing maritime systems. Finally, we believe in the importance of this review article as a summary of recent theoretical benchmarks for those seeking to investigate maritime networks. Academics in general, consultants, researchers, and other interested parties can use this review to more objectively guide their research.

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