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# Port connectivity study: An analysis framework from a global container liner shipping network perspective

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ABSTRACT

This paper introduces an analysis framework for port connectivity from a global container liner shipping network perspective: it is defined in terms of the impact on the transportation network when the transshipment service is not available at the evaluated port. Under this framework, two models for port connectivity are introduced from transportation time and capacity. Compared with existing measures, the strength of our framework and models is not only that it provides scientific methods to compute port connectivity, but it is able to capture a global effect on how port connectivity contributes to the overall network for given shipping services.



## 1. Introduction

The globalization and internationalization of economies around the world has contributed significantly to the rapid growth of maritime transportation and it has become the major transportation mode for domestic and international trade of many countries. In comparison with other modes, maritime transportation is commonly regarded to be clean, safe and cheap and as a result many nations' trades heavily depend on this mode of transportation. With the sustained and stable increase in maritime transportation, transshipment services have become a major function of many ports and a tremendous growth in the numbers of so-called transshipment ports has emerged. A transshipment port is a port where cargo is transferred from one service to another, either through direct transfer or temporary storage at the port while awaiting another service. Transshipment services facilitate and support maritime transportation not only in providing more route choices for cargo, but also possibly reducing travelling time and transportation cost. Another main reason for the increasing proportion of transshipment services is the growing importance of larger container ships and the associated economies of scale, as well as the increase in containerization (Meng and Wang, 2011;Wang and Meng, 2012; Wang et al., 2013). According to Heymann (2006), over 80 percent of the containers handled in Singapore port belong to the transshipment category, while for the port of Tanjung Pelepas in Malaysia its transshipment traffic even reaches 96 percent of all its handled containers.

Along with the rapid increase in world trade and maritime transportation, there has been a corresponding increase in competition among ports, especially those specializing in transshipment services. Port competitiveness is closely related to the port selection decisions of carriers and shippers and in general those ports who can provide reliable, efficient and economical services prove to be more attractive to both carriers and shippers. Moreover, carriers can often reroute services

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to take advantage of superior port services. For example, Maersk and Evergreen moved the majority of their operations to Tanjung Pelepas in the earlier part of the last decade, but have since rerouted several services back to Singapore to capitalize on the superior feeder network. The topic of port selection criteria has been well studied for several decades. For example, Slack (1985) analyzed the selection criteria by investigating the containerized traffic between the North American Mid-West and Western Europe. The author indicated that among all factors the price and service are more important than others. Bird and Bland (1988) stated that the frequency of service is the main reason for port choice. Murphy et al. (1992) presented an analysis framework to reveal the differences in port selection factors among different transportation players. Tiwari et al. (2003) suggested a discrete choice model to simulate port choice behavior and they found that the distance to destination, the distance from origin, port congestion, and shipping line's fleet size play an important role in port selection decision. Malchow and Kanafani (2004) employed an alternative form of the discrete choice model to analyze the distribution of maritime shipments among US ports and concluded that the most significant factor of a port **is** its location. Tongzon and Heng (2005) summarized eight key determinants of port competitiveness and selections on the existing literature, which included port operation efficiency level, cargo handling charges, reliability, adaptability to the changing market environment, etc. Lee et al. (2006) developed a network model to analyze the flow of containers within the Asia Pacific region by varying terminal handling charges and turnaround time and some conclusions about port selection and port throughout in the Asia Pacific region were drawn. Tongzon (2009) attempted to evaluate the major factors affecting port choice from the Southeast Asian freight forwarders' perspective, their decision-making style and port selection process. The author found that efficiency is the most important factor followed by shipping frequency, adequate infrastructure and location. Steven and Corsi (2012) examined some factors within management controls that affect the attractiveness of a port for containerized shipments. They revealed that the importance placed on each factor varies by the size of the shippers. Analytic Hierarchy Process (AHP) is a multi-objective, multi-criteria theory of measurement created by Saaty (1977) and has been employed to determine the predominant factors in port selection decisions. Lirn et al. (2004) used AHP to reveal important service factors for transshipment port selection by global carriers. With the use of the framework of AHP, Song and Yeo (2004) identified the competitiveness of container ports in China and provided managerial and strategic implications. Ugboma et al. (2006) employed AHP to determine the factors that carriers and shippers consider important and their findings showed that the carriers and shippers place high emphasis on efficiency, frequency of ship visits and adequate infrastructure.

However, with the growing focus on transshipment services and the rise of transshipment ports, it becomes clear that any analysis of port competitiveness must include a means of measuring the strength of transshipment services available at a port, i.e., to what extent a port is providing transshipment services to ocean liners. One major factor which is highly related to the capability of a port to provide effective transshipment services is the connectivity of the said port. Briefly speaking, port connectivity means how well one port connects to others in the maritime transportation network and its ability to be reached by regular liner services. This knowledge can help both port operators and ocean liners to position their strategies that can benefit them. For example, port operators who want to position themselves to be a transshipment hub port can use this knowledge for benchmarking to improve their services while ocean liners can use this knowledge to select a hub port if they want to redesign their shipping network services following a hub and spoke system. In general, the higher the connectivity level of a port, the more attractive it will be in terms of facilitating the transportation of cargo and reducing transportation cost and time, which will result in it being more competitive than others. Conversely, a port which is highly competitive makes it more attractive for liners to set up their transshipment operation at the port, which results in more port calls and therefore enhances its connectivity. Besides, port connectivity can also reveal the contribution of individual ports to the maritime transportation network. For a port which has a high level of connectivity, since there are many transportation options for the cargoes which pass through this port, the carriers are able to choose a preferable option to further transport these cargoes, which may result in the reduced transportation time of these cargoes and the increased transportation capacity of the network. It follows that this port will make a great contribution to the transportation network and is relatively more important than others in the network. On the contrary, for a port which has a low connectivity level due to only a few options available at this port to transport cargoes, its contribution to the network is accordingly relatively less.

Several authors have examined the topic of port connectivity from a few aspects in the recent decade. For example, Wilmsmeier et al. (2006) investigated maritime trade among 16 Latin-American countries and their findings revealed that inter-port connectivity has significant impact on international maritime transport costs. Márquez-Ramos et al. (2005) used principle component analysis (PCA) methodology to build three complex connectivity component variables and analyzed the determinants of maritime transport costs of Spanish exports and their effect on international trade flows. Wilmsmeier and Hoffmann (2008) analyzed the impacts of liner shipping connectivity on intra-Caribbean freight rates and the relationships between the structure of liner services, port infrastructure and liner shipping freight rates. These studies mainly focus on examining the relationship between port connectivity and other factors involved in maritime transportation. Though they do not focus specifically on generating a quantitative means of measuring port connectivity, these studies are quite helpful in analyzing the role of port connectivity in maritime transportation. Some other studies focus on measuring the maritime connectivity of countries. For example, Hoffmann (2005) combined nine factors of maritime transportation, including fleet assignment, liner services, vessel and fleet sizes and so on, to generate an overall Liner Shipping Connectivity Index (LSCI) for 162 coastal countries, which was published by the United Nations Conference on Trade and Development (UNCTAD). Since then, the annual LSCI has been published by UNCTAD to capture trends and differences in countries' maritime connectivity, see e.g., Haji and Hoffmann (2007), UNCTAD (2011). The maritime connectivity of countries is important and understanding a country's maritime connectivity will allow policy makers to promote better service and reduce the costs of transportation