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# Impact Analysis of Mega Vessels on Container Terminal Operations

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**Abstract**

Mega vessels currently play a vital role in maritime transportation and their deployment may have significant impacts on container terminal operations. This study is concerned with the impact analysis of mega vessels on container terminal operations. First, the container operation process at a container terminal is formulated as a queuing network. Based on the queuing network, a simulation model is then developed. Because of the computational complexity of the simulation, the ARENA© software tool is used to solve the developed model, based on a realistic case involving the Hong Kong port. The case analysis comprises ten scenarios that represent current and possible future situations regarding the utilization of more mega container vessels. The results suggest that the current port facilities may not be sufficient to accommodate more mega container vessels.


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*Keywords:* Simulation; Container Terminal; Queuing Network; Ship Size

## 1. Introduction

The container shipping industry has witnessed fast growth in the last three decades due to the increase in the demand for containerized cargo delivery. As reported by Ebeling (2009), more than 90% of the world's trade goods are transported in containers. As stated by Cullinane and Khanna (2000), a larger container vessel may produce lower unit costs, owing to the existence of scale economies, thus making shipping liners disposed to use more large-sized container vessels.

Although there are no global standards, container vessels can roughly be classified based on their dimensions and carrying capacities. As reported by MAN Diesel (2008), the Panama Canal is often used as a standard to classify container vessels. Due to the restrictions of the Panama Canal, the capacity of a container vessel cannot exceed 5,000 TEUs (twenty-foot equivalent units) before 1988. Since the 1990s, the Post-Panamax vessels, with capacities of 5,000-10,000 TEUs, have made up the majority of fleets serving the Asia-Europe and Trans-Pacific lines. The Panama Canal has planned to build a new lane to handle the larger container vessels and the project is expected to

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be completed in 2014. The New-Panamax vessels, with capacities of 12,000-14,500 TEUs, will be able to travel through the canal after the project is accomplished.

The major ports, such as the port of Singapore, Hong Kong port, and the port of Rotterdam, could be greatly affected by this increase in the use of large-sized container vessels. The main issue is that, when a large container vessel arrives, the terminal needs to handle thousands of containers within a short time window. From the viewpoint of port operators, examining the impacts of the increasing calls from the mega vessels at their ports is of great interest, as it could help them make better-informed decisions, such as whether or how much to expand their existing port infrastructure and facilities, and how to enhance their productivity to attract more business. On the other hand, shipping companies are also interested in this impact analysis. Although mega vessels are cost-efficient in terms of dollars per TEU·mileage, their turnaround time may cause serious concerns, especially in light of the high capital investments and maintenance costs.

This study aims to investigate the productivities and efficiencies of container terminals under an assumption that calls from mega vessels will continue to increase in the future. The results of this study will shed some light on the impacts brought by the increase of mega container vessels' visits. Bottlenecks at current container terminals for accommodating more mega vessels, and the turnaround time of mega vessels will be investigated in this study.

### *1.1. Literature review*

Research topics related to container terminal operations can be divided into three categories. The first category focuses mainly on the planning and development of container terminals, including the studies of container terminal equipment, layout planning, implementation of information systems, and the automation of transport trucks (e.g., van Hee and Wijbrands, 1988; Gademann and Van De Velde, 2000; Nam and Ha, 2001; Alicke, 2002; Lokuge and Alahakoon, 2007; Roy and De Koster, 2012). The second category is concerned with solving problems associated with container terminal operations, such as the berth allocation problem, the quay crane allocation problem, human resource scheduling problems, strategies for stacking containers, strategies for using yard cranes, and rules for dispatching transport trucks using optimization models (e.g.,Daganzo,1989; Peterkofsky and Daganzo,1990; Steenken et al., 1993; Kozan and Preston, 1999; Imai et al., 2001; Bish, 2003; Chen et al., 2007; Imai et al., 2007; Said et al., 2014). The third category includes various case studies which provide links between the theories and their practical applications (e.g., Nam et al., 2002; Shabayek and Yeung, 2002; Steenken et al., 2004; Cordeau et al., 2007; Stahlbock and Voß, 2008).

The queuing network model has been used to investigate container terminal operations for decades. Edmond and Maggs (1978) applied queuing models to address berth assignment and investment decision problems. Legato and Mazza (2001) presented a queuing network model of logistic activities related to the container terminal operations, and used it to solve berth planning and optimization problems by considering the case of the Gioia Tauro terminal in Italy. A simulation model was also developed based on the queuing network model, in which the number of quay cranes was considered a decision factor and the waiting time of a container vessel was viewed as a performance measurement. Lagana et al. (2006) further simplified this queuing model, and solved the problem using a distributed computation approach. More recently, Canonaco et al. (2008) constructed a queuing network model to represent loading and unloading procedures in a container terminal. They aimed to provide decision aids for quay crane and transport truck assignments. A simulation model was developed in the Delphi software. Roy and De Koster (2014) used new integrated queuing network models to rapid design evaluation of container terminals with Automated Lift Vehicles (ALVs) and Automated Guided Vehicles (AGVs). Shabayek and Yeung (2000) used a queuing model to analyze a Hong Kong container terminal. However, the model only took into account the uncertainty associated with vessel arrivals and the quay crane service rate and is therefore over-simplified. Shabayek and Yeung (2002) later took into account more uncertainties and used a simulation approach to analyze their model. However, the model still did not capture the inter-correlation between yard side and quay side operations. Since it is well accepted that the queuing network can appropriately represent container terminal operations, we will also apply this idea in our study.

Simulation has been used extensively to analyze container terminal operation processes, since analytical methods are hardly feasible for solving detailed large-scale problems (e.g., Khatiashvili et al. 2006; Gambardella et al., 1998; Kia et al., 2002; Kozan, 1997). Liu et al. (2002) evaluated the performances of four different automated terminal