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A maritime container repositioning yield-based optimization model with uncertain upsurge demand

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ABSTRACT

The role of container repositioning has become more important under the severe cargo shipping environment, affected by world trade growth, trade imbalance, slow steaming strategy and high container manufacturing cost. Low cost, better routing, and supplying equipment to higher yield cargo become the top criteria. A yield-based container repositioning framework is developed, followed by a constrained linear programming optimizing the container repositioning from surplus to deficit locations. The model incorporated change of destinations of empty containers and adjustment factors handling upsurge demand. The model is applied to optimize daily container repositioning operations with a better route, costs and equipment supply.

1. Introduction

The seaborne trade reached over 9 billion tons in 2012, the world fleet expanding to 1.5 billion deadweight tons (DWT) in 2012. This contributed an increase of over 37 percent from the economic and financial crisis of 2008 (Panitchpakdi, 2012). The seaborne trade is subsequently having a 4.3 per cent increase in 2013, driven by the growing demand in China and increased cargo volume in Intra-Asia trade (United Nations, 2013). Søndergarrd et al. (2012) reviewed the outlook for world trade and container shipping volume, indicating that the world trade value was expected to grow by 19% from 2011 to 2014. Chestney (2013) presented a report by ship classifier Lloyd's Register, defence technology firm Qinetiq and the University of Strathclyde that the global seaborne trade will reach between 19 and 24 billion tonnes a year by 2030, compared to the 9 billion tonnes during 2013. With the increase in world trade volume, the imbalance between the export and import trade enlarges (Mongelluzzo, 2004; United Nations, 2007; Theofanis and Boile, 2009). The imbalance in Trans-Pacific trade has an average of over 6 million TEUs each year from 2008 to 2012. Large imbalance exists in Asia-Europe Trade as well as some regions in Intra-Asia and Trans-Atlantic Trade. The imbalance will further raise higher container leasing and manufacturing costs and more frequent use of slow steaming strategy.

Trade imbalance results in a need of empty container repositioning. In current global trade activities, the container flow between Trans-Pacific trade and Europe-Asia trade is prominently imbalanced. Regions, with imports exceeding exports, or vice versa, exhibit trade imbalance behavior. In a container yard facility, for example, container terminal, depot, rail ramp, etc., container deficit behavior is exhibited when the volume of empty container released for cargo loading exceeds the volume of empty container returned. The facility exhibits a surplus pool of containers when the volume of empty return

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containers is larger than the quantity of empty release containers. Container repositioning from surplus to deficit locations is needed as one of the supply sources for the locations showing deficit behavior. Ship liners often suffer from significant repositioning costs if the repositioning volume is large. Other sources of empty container supply include manufacturing newly built containers and leasing in containers. The container repositioning costs are also affected by the costs in container manufacturing and leasing (Theofanis and Boile, 2009). Low manufacturing or leasing cost favors purchasing or leasing in containers rather than repositioning. Otherwise, container repositioning is required as a source of supply from surplus to deficit locations.

With the global container traffic rising steadily and the continuous increase in the trade imbalance, the costs in empty container movements of ship liners have increased substantially, incurring over millions of US dollars each month (Wong et al., 2009). Investigations on effective and efficient empty container repositioning strategies have drawn the attention of liners in recent years. There is abundant literature on modeling and optimizing container repositioning (Feng and Chang, 2008; Di Francesco et al., 2009; Meng and Wang, 2011; Song and Dong, 2011; Saeidi et al., 2013). Early literature on empty container planning could be traced back as early as the 1970s. White (1972) started a research on the development of an algorithm to solve the problem of empty container distribution. Ermol'ev et al. (1976) investigated a network model for planning empty seaborne containers with the consideration of shipping cost and container rental costs. Florez (1986) was one of the earliest researchers in the 1980s developing a dynamic and stochastic model for empty container repositioning. Dejax and Crainic (1987) initiated a review of empty container flows and fleet management in freight transportation. More factors were included in the research of empty container allocations during the 1990s. Crainic et al. (1993) discussed the empty container dispatching problems with dynamic deterministic formulations for single and multicommodity considerations. They further proposed a mathematical dynamic and stochastic model for empty container allocation problems. Shen and Khoong (1995) suggested a decision support system for multiperiod repositioning of empty containers while Ting et al. (1996) developed a stochastic and dynamic network optimization model to minimize empty container allocation costs. Cheung (1998) reviewed the dynamic empty container allocation problem with the objective of repositioning empty containers and determining the number of leased containers required to meet customer demand. A two stage stochastic network is proposed.

The development of various container repositioning problems and proposed solutions came into attention in the 2000s. Choong et al. (2002) evaluated the effect of planning horizon length on empty container management within an intermodal transportation network. A mathematical model is developed to minimize the total cost of managing the empty container with the consideration of empty container availability to satisfy customer demand. Cheang and Lim (2005) proposed a network flow based method for empty container distribution. Lam et al. (2007) developed a dynamic stochastic model for a two-ports two-voyages relocation of empty containers, followed by the development of a multiple-ports multiple-voyages repositioning system to solve empty container allocation problems. Song and Carter (2009) proposed four strategies for container repositioning. The strategies with container-sharing were not able to execute in reality due to liners competition, global network complexity, and asset management issues. The other two strategies were suggested with container repositioning based on the imbalance situation of the locations. Song and Carter further evaluated these strategies through mathematical programming. Other models and algorithms were also developed in the 2000s to solve container repositioning problems (Li et al., 2004; Olivo et al., 2005; Song et al., 2007; Feng and Chang, 2008; Wong, 2010).

The context of container repositioning is becoming more important in the maritime industry as competition is more severe and costs reduction is crucial during the economic downturn environment. The principles and strategies of repositioning are mainly based on the imbalance of the container flows among various ports around the world. Song and Dong (2013) designed an empty container repositioning model by specifying the direction of the empty containers with respect to the surplus and deficit situations of the respective ports. This developed approach, termed Flexible destination port policy (FDP), further initialized the threshold values of empty containers inventory and determine the actual number of empty container to be repositioned. A further policy, Determined destination port policy (DDP), was introduced and compared to the FDP. Bell et al. (2013) proposed a cost-based container assignment model to minimize cost when assigning containers to routes. It is aimed to apply to large maritime networks assignment problems with the assistance of linear programming solver. This enables minimizing container handling costs, container rental and inventory costs in the daily container assignment operations. Braekers et al. (2013) developed a decision support model to determine the optimal shipping routes for roundtrip services between a major seaport and several hinterland ports in the context of empty container repositioning. Chaoa and Yua (2012) proposed a mathematical model for container repositioning in East and North China incorporating multi-commodity service network. Other recent publications, including different critical elements on service network, planning horizon, and inland transportation, were also based on principles and initiatives of container imbalance situation among ports (Wong et al., 2010; Meng and Wang, 2011; Yun et al., 2011; Saeidi et al., 2013). There is much literature incorporating revenue, lost-sales penalty, demand backlog cost, or slot purchase cost in the repositioning plan (Shintani et al., 2007; Brouer et al., 2011; Di Francesco et al., 2013; Wang, 2013).

This paper moves forward from imbalance-based to shipment network driven-based container repositioning. It begins with the outline of the seaborne trade trend and the importance of efficient empty container repositioning. The relevant literature on the problems, methodologies, modeling approaches, and application examples of container repositioning is reviewed. The common repositioning model adopted at present as well as a proposed shipment yield network driven-based model are discussed. A shipment network driven-based container repositioning framework is developed, followed by adopting dynamic linear programming to optimize the repositioning of containers from the surplus to deficit facilities located globally. The methodology, key assumptions, deterministic parameters, constraints, and objective functions are