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Ship type decision considering empty container repositioning and foldable containers

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ABSTRACT

This paper addresses a problem of ship type decision considering empty container repositioning and foldable containers, which determines the capacity of ships deployed in a given shipping route at a tactical level and empty container repositioning between ports at an operational level. It considers the use of foldable containers and aims to find under what conditions, a shipping liner needs to use the foldable containers. To solve the problem, we formulate a network flow model with a revised network simplex algorithm, based on which an exact solution approach is designed to determine the optimal ship type.

1. Introduction

A shipping liner normally operates weekly-serviced ship routes with fixed schedules to transport containers (Zhen et al., 2016). Given a shipping route, a shipping liner deploys a fleet of container ships for the operation over a planning horizon, e.g., six months. One of the critical decisions for the shipping liner on the fleet is ship type decision, which determines the capacity of container ships of the fleet deployed on the shipping route. Empirically, the shipping liner deploys a suitable fleet type of ships on each route based on the laden container transportation over the planning horizon, which guarantees that the deployed ships have the capacity to accommodate all the laden containers in all the voyages. Under this circumstance, the shipping liner would not deploy a ship fleet with a larger capacity as it increases the fixed operation cost for maintaining the fleet. It is reasonable for the shipping liner to make such decision only considering the laden container transportation. However, if we further consider the empty container repositioning on the route, the ship type decision can be more complicated.

The empty container repositioning originates from the imbalance of container flow between different regions in liner shipping routes. Take the trans-Pacific trade lane for example: according to UNCTAD (2016), in 2015, the annual container flow from Asia to North America (i.e., the eastbound) was around 15.8 million twenty-foot equivalent units (TEUs), and the container flow in the opposite westbound direction was 7.4 million TEUs, which generated the imbalance of container flow for 8.4 million TEUs. This imbalance contributes to tremendous empty container accumulation in import-dominant areas (North America) and the serious empty container shortage in export-dominant areas (Asia). This leads to a critical problem on the empty container availability for the laden container transportation consignment in those export-dominant areas or ports. In those export-dominant ports, the arriving laden containers from incoming ships become empty and are stored in depots after devanning, which can only fulfill part of the empty container requirement for the sake of their export-dominant characters. As a result, the empty container repositioning from the

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Fig. 1. Four foldable containers and a standard container. .
Source: Shintani et al. (2010)

surplus ports (i.e., import-dominant ports) to the deficit ports (i.e., export-dominant ports) becomes necessary. However, the empty containers repositioned between the ports occupy the capacity of the container ships traversing the corresponding voyages in the shipping route. Henceforth, the ship type decision is no longer straightforward when considering the empty container repositioning.

Storing empty containers in the depots and repositioning empty containers among the ports inevitably incur storage cost and repositioning cost for the shipping liner, respectively (Lee and Yu, 2012). To reduce the costs, the usage of foldable containers is an effective method. The idea of foldable containers is not so new, and several container companies have developed foldable containers, such as Fallpac AB and Holland Container Innovation. Those foldable containers have equivalent storage capacity and size as standard containers and a foldable container only occupies one-quarter storage space of a standard container in folded status, as shown in Fig. 1 (See Appendix A for the specification comparison between a standard container and a foldable container). After becoming empty, the foldable containers will be in folded status for the storage in the depots or for the repositioning to other ports. As four foldable empty containers in the folded status equal one standard empty container, it saves 75% storage space by using foldable containers, which leads to significant decrease in the repositioning cost and the storage cost. However, using the foldable containers could incur additional costs for the shipping liner. Firstly, the purchasing fee or long-term leasing cost of the foldable containers is higher than that of the standard containers. Secondly, folding and unfolding processes involve labor cost in the ports for the empty container repositioning. Therefore, there is a trade-off by using foldable containers between reducing the storage cost and the repositioning cost and incurring the additional costs.

Currently, foldable containers are not widely used in the liner shipping industry and stakeholders of the industry are trying to make the foldable containers prevalent. Here, we summary two practical concerns that may impede the usage of foldable containers at present. Firstly, maintaining a foldable container fleet needs a considerable investment at the first phrase, as the building cost of a foldable container is double as that of a standard container (Goh and Lee, 2016). Considering the shipping market is experiencing a depression (UNCTAD, 2016), the majority of shipping lines may not have enough funding to replace the standard containers in their container fleet with foldable containers. Secondly, folding and unfolding activities in container terminals incur additional labor operations. Henceforth, container terminals and shipping lines need to negotiate a comprehensive agreement on maintaining the operations and training technicians, which may not be achieved in the moment. Although these concerns can exist in practices, the usage of foldable containers is still promising in the near future. We take Holland Container Innovations (HCI), the manufacturer of 4FOLD foldable container, as a typical example to illustrate industry trends of using foldable containers. Holland Container Innovations (2017a) reported that some major shipping lines (e.g., APL, Samudera Indonesia and Seatrade) have used 4FOLD foldable containers in their shipping routes, and an increasing number of shipping lines have signed the contracts with HCI to promote the usage of the foldable containers, such as Emirates Shipping Line (Word Cargo News, 2017). Meanwhile, HCI is providing the folding training programs for some container terminals around the world in the preparation for using foldable containers, such as Tetris Container Terminal in Moscow, Ljubljana Container Terminal in Slovenia and Qingdao Shitengkeyun Depot.

Motivated by the above problem justifications and industry trends, our study aims to solve a problem of ship type decision considering the empty container repositioning and foldable containers, in order to minimize the total cost that occurs in a given planning horizon for the shipping route. The problem focuses on related decisions in both tactical and operational levels. In the tactical level, it first determines the ship type of the container ship fleet (denoted as ship type decision), which decides the capacity (in TEUs) of container ships deployed in the shipping route. Then, the problem determines the number of foldable and standard containers leased (or kept) in the ports initially for the usage of the planning horizon, which is a container fleet sizing in essential (denoted as long-term container leasing). In the operational level, upon each weekly service, if there are empty containers surplus in some ports, the problem decides the number of empty containers that the visiting ship should reposition to other deficit ports. In case of the empty container deficit, the shipping liner can lease empty containers in origin ports and return them in destination ports (denoted as short-term container leasing) to fulfill the transportation consignments. Here, we summarize the empty container repositioning and the container fleet sizing as the empty container allocation.

If the empty container repositioning is not involved, the ship type decision is to guarantee that the deployed ships have the capacity to accommodate all the laden container transportation and a ship fleet with a larger capacity will not be an option. However, involving empty container repositioning complicates the ship fleet deployment. The empty container repositioning provides the shipping liner with the motivation to deploy a ship fleet with a larger capacity. Although it will raise the fixed operation cost, it gives