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Empty container exchange among liner carriers

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ABSTRACT

In an attempt to reduce the empty container repositioning costs, this paper studies an empty container allocation problem considering the coordination among liner carriers. We further measure the perceived values of empty container at different ports. The perceived values of empty container at the surplus (deficit) ports are described by the profits (empty container exchange costs paid) for delivering empty containers. To solve our problems, we propose a two-stage optimization method. In stage I, liner carriers are guided to pursue a centralized optimization solution of empty container allocation for all related liner carriers. In stage II, the inverse optimization technique is used to determine the empty container exchange costs, which are paid to liner carriers for exchanging empty containers and following the centralized optimization solution. The profits at the surplus ports are calculated with respect to the empty container exchange costs at the deficit ports. Finally, numerical experiments on an Asia–Europe–Oceania shipping service network are discussed.

1. Introduction

In the liner shipping industry, empty container repositioning is a challenge for liner carriers due to the high costs. Since 1993, empty container movements have constituted about 20% of the total ocean container movements (Song and Dong, 2011). In 2003, the repositioning cost was up to $11 billion (Bonney, 2004), and that in 2010 was about $23.4 billion (Drewry, 2011; Tran and Haasis, 2015). Song et al. (2005) estimated that the repositioning cost accounts for 27% of the total world fleet running cost. Because of the trade imbalances between the major trading regions, empty container movements cannot be avoided completely. However, minimizing these costly activities would considerably reduce the operating costs of liner carriers. In an attempt to reduce the cost on repositioning empty containers, this paper proposes an empty container allocation problem considering the coordination among liner carriers, where empty containers of any single liner carrier can be repositioned to serve the needs of other liner carriers. Hence, empty containers are exchanged among liner carriers. Similar to slot exchange agreements between liner carriers in a strategic alliance, empty container exchange agreements can be signed between liner carriers to reduce the repositioning costs of liner carriers. Generally, empty container movements do not generate revenue for liner carriers. In order to motivate liner carriers to follow a centralized optimization solution of empty container allocation for all related liner carriers, the extra incentives should be introduced to guide liner carriers. Generally, these incentives can be described by the profits (costs paid) for delivering empty containers from (to)

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the surplus (deficit) ports, which have a surplus (deficit) of empty containers. This motivates us to measure the perceived values of empty container at different ports.

There have been many studies related to the empty container allocation problem or the empty container repositioning issue. Crainic et al. (1993) developed two dynamic deterministic formulations and a stochastic formulation for empty container allocation in a land distribution and transportation system. Cheung and Chen (1998) investigated the dynamic empty container allocation problem, which is formulated as a two-stage stochastic network model. A stochastic quasi-gradient method and a stochastic hybrid approximation procedure were applied to solve the problem. Erera et al. (2009) developed a robust optimization framework for dynamic empty repositioning problems modeled using time–space networks. Li et al. (2004) discussed empty container management at a port and derived the optimal pairs of critical policies, (U, D) for this port. Namely, if the number of empty containers at this port is less than U, empty containers are imported up to U, or empty containers are exported down to D if the number of empty containers at this port is larger than D. Later, Li et al. (2007) extended this problem by considering multiple ports. Jula et al. (2006) studied empty container movements by optimizing the empty container reuse. The dynamic empty container reuse was modeled and optimization techniques were developed to optimize the empty container operations. Lam et al. (2007) presented an approximate dynamic programming approach, in order to obtain the effective empty container relocation strategies. Feng and Chang (2008) investigated the repositioning of empty containers for intra-Asia liner shipping. Song and Carter (2009) studied general empty container balancing strategies depending on whether shipping lines are coordinating the container flows over different routes and whether they are willing to share container fleets. Moon et al. (2010) proposed an empty container repositioning problem considering leasing and purchasing. To address this problem, they presented a mixed-integer linear optimization model and developed a genetic algorithm to solve it. Shintani et al. (2010) analyzed the possibility to save the container fleet management costs in repositioning empty containers by using foldable containers. Later, Moon et al. (2013) compared the foldable containers with the standard containers on the cost for repositioning empty containers. Numerical experiments demonstrated the economic feasibility of foldable containers. Di Francesco et al. (2009) addressed an empty container repositioning problem under uncertainty, where the historical data were inappropriate for estimating uncertain parameters. In order to solve this problem, a time-extended multi-scenario optimization model was developed. Later, Di Francesco et al. (2013) studied an empty container repositioning problem under uncertain port disruptions. Long et al. (2012, 2015) investigated an empty container repositioning problem with uncertainties, by using a sample average approximation method. Song and Dong (2011) discussed an empty container repositioning policy with flexible destination ports. Bell et al. (2011, 2013) proposed two types of container assignment models (i.e., a frequency-based container assignment model and a cost-based container assignment model), in which both laden containers and empty containers were considered. Recently, Wang et al. (2015) extended these two container assignment models by proposing several profit-based container assignment models. In addition, readers can refer to the references in two reviews on empty container repositioning (Braekers et al., 2011; Song and Dong, 2015).

Furthermore, some researchers explored the combined optimization problems in liner shipping with empty container repositioning. Shintani et al. (2007), Meng and Wang (2011), Song and Dong (2013) investigated the liner shipping network design problem, as well as considering the repositioning of empty containers. Dong and Song (2009) addressed the joint problem of container fleet sizing and empty container repositioning. Brouer et al. (2011) studied the cargo allocation problem with the repositioning of empty containers. Song and Dong (2012) investigated cargo routing, together with empty container repositioning. For more optimization problems related to ship routing and scheduling in liner shipping, please refer to some review papers (Christiansen et al., 2004, 2013; Meng et al., 2014).

To the best of our knowledge, there is currently no optimization model on the empty container allocation problem considering the coordination among liner carriers. Le (2003) studied a related problem based on a neutral Internet-based information exchange platform, which may facilitate empty container reuse and sharing empty containers among liner carriers. Theofanis and Boile (2009) mentioned that empty containers of a liner carrier can be used to match the needs of other liner carriers. Both of these works discussed the empty container repositioning strategies from a qualitative point of view.

Obviously, the coordination among liner carriers increases the flexibility of an empty container repositioning system by exchanging empty containers among liner carriers and offers an opportunity to reduce the repositioning costs of liner carriers. However, the coordination formation among liner carriers is challenging. Generally, the goal of a liner carrier is the maximization of its own profit (or minimization of its own cost). Furthermore, some liner carriers may collude to obtain a larger profit (or a lower cost), as compared with the coordination among more liner carriers. Hence, the coordination stability among liner carriers is also a challenge. This paper aims to resolve these problems in the study of empty container allocation considering the coordination among liner carriers. Furthermore, we will measure the perceived values of empty container at different ports, under the coordination among liner carriers.

The rest of this paper is organized as follows. Notation, assumptions and problem description are described in Section 2. A two-stage optimization method is presented in Section 3. Numerical results are given in Section 4. The conclusions are shown in Section 5.

2. Notation, assumptions and problem description

Some mathematical notations have to be defined in order to facilitate description and formulation of the problem.