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# Foldable and standard containers in empty container repositioning

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ABSTRACT

Strategies to reposition empty containers are an unabated issue for shipping companies. This study compares the repositioning costs of foldable containers to those of standard containers. Mathematical models are used to minimize the total relevant cost, which includes the folding/unfolding cost, the inventory storage cost, the container purchasing cost, and the repositioning cost. Heuristic algorithms are proposed to solve the mathematical models. Numerical experiments are carried out in several scenarios to demonstrate the economic feasibility of foldable containers. The sensitivity analysis shows that the purchasing cost and the transportation cost affect the use of foldable containers.



## 1. Introduction

The acceleration in the rate of the world economic growth and the consequently widened global trade network have led to an increasing demand for transporting goods. The explosion of global trade has also been accompanied by the increase in the use of containers as a safe and inexpensive mode of transportation of goods. A container that is fully loaded with goods from the shipper is transported across the ocean to the destination port and then delivered to the consignee and unloaded. Subsequently, the container is usually emptied and stored at the destination port until it is required for another consignment. When there is an imbalance in the number of import and export containers, some ports have a surplus of empty containers, while others have a deficit. Shipping companies must then reposition empty containers from surplus ports to deficit ports or lease or purchase containers for deficit ports. At surplus ports, empty containers are stored in depots.

In 1995, the container cargo flow from Asia to the US involved 4 million twenty-foot equivalent units (TEUs), while that from the US to Asia involved 3.5 million TEUs. By 2005, the annual flow had increased to 12.4 million TEUs from Asia to the US and 4.2 million TEUs from the US to Asia. In 2007, the annual flow was 15.4 million TEUs from Asia to the US and 4.9 million TEUs from the US to Asia (source: http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/worldcontainerflows.html). These data show that not only have containerized cargo flows increased very rapidly in a short amount of time, but also that the growth of flows has been dramatically larger in the trade route from Asia to the US than from the US to Asia. As a result, the imbalance in the container flows between these regions has also significantly increased: from 0.5 million TEUs in 1995 to 8.2 million TEUs in 2005 and 10.5 million TEUs in 2007. The situation is similar for container flows between Asia and Europe. It is evident that repositioning empty containers is unavoidable to balance the flow of cargo containers, although it is quite costly.

The use of foldable containers can be an effective strategy to reduce the repositioning cost as well as to save more than 75% of storage space, depending on their design. Several foldable (collapsible) container designs have been developed.

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Fallpac AB developed a Fallpac container in which four folded units can be stacked inside a fifth erected unit. In this way, the complete package of five empty containers occupies the space of a single standard container. The Six-in-One Container Company introduced a six-in-one container where six folded, bundled containers have exactly the same dimensions as a single standard container. More recently, two professors from the Department of Mechanical Engineering of the Indian Institute of Technology designed a new type of foldable container that allows four foldable containers to be folded into the size of a single standard container. Additionally, foldable containers are currently being developed by Holland Container Innovations (HCIs) and Cargoshell in the Netherlands and Compact Container Systems (CCSs) in the US. All these designs are also based on the 4:1 folding principle. These recent initiatives have refreshed the interest in using foldable containers as a way to control container repositioning cost and, hence, have also encouraged further research into this trend.

Several studies have looked at the application of foldable containers in the real world. Konings and Thijs (2001) identified several conditions that are necessary for the success of foldable containers. Konings (2005) analyzed the opportunities for the commercial application of foldable containers and considered the costs and profits of using them. Recently, Shintani et al. (2010) studied how the use of foldable containers could reduce repositioning costs in the hinterland.

In this paper, we compare the empty container repositioning costs of foldable and standard containers. The scope of our research is ocean transportation in which empty containers are repositioned by vessels. The paper is structured as follows. Section 2 reviews the current literature. The problem definition and mathematical models are discussed in Section 3, and heuristic algorithms are presented in Section 4. The numerical experiments are presented in Section 5, and some conclusions are shown in Section 6 to end this paper.

## 2. Literature review

There have been many recent studies in the literature related to empty container repositioning. Crainic et al. (1989) proposed models for the multi-commodity capacitated location problem with balancing requirements (MCLB) with inter-depot balancing requirements. The decision variables of MCLB included a set of binary variables that determined the opening or closing of depots and a set of continuous variables that represented the empty container flows between supply customers, depots, and demand customers. The objective function was to minimize the total cost, which involves the cost of opening the depot and transportation costs, while satisfying the demand for empty containers. Many other studies have also attempted to solve the MCLB problem. Crainic and Delorme (1993) developed dual-ascent procedures for the proposed model. Crainic et al. (1993a) solved the problem using a Tabu search procedure. Crainic et al. (1993b) developed deterministic and stochastic models to support decisions on a short-term land transportation planning problem. Gendron and Crainic (1997) presented a parallel branch and bound approach, which is based on the dual-ascent procedure previously proposed by Crainic and Delorme (1993). Gendron et al. (2003) also solved the problem using a Tabu search procedure, but they used the slope scaling method to identify the initial solution. Li et al. (2004) analyzed the management of empty containers in a port with stochastic demand based on a multi-stage inventory problem and Markov decision processes with discrete time. They focused on optimizing the pair-critical policy ($U$, $D$), which implies that, if the number of empty containers at a port is less than $U$, empty containers are imported up to the amount $U$; if the number is greater than $D$, the empty containers are exported until $D$ containers are left behind. Li et al. (2007) extended the problem for multi-port applications. Shen and Khoong (1995) proposed a decision support system (DSS) for empty container distribution planning based on network optimization models. In the network, they considered the leasing-in, off-leasing, repositioning-in, and repositioning-out at a port. The problem was decomposed into three levels; terminal (port) planning, intraregional planning, and interregional planning considering a single type of container. Dong and Song (2009) studied container fleet sizing and empty container repositioning for multi-port, multi-vessel, and multi-routing systems under uncertain demand and proposed an algorithm that combines simulation and a genetic algorithm (GA) to solve the problem. Song and Zhang (2010) considered an optimal policy for empty container repositioning with stochastic demand by modeling the flows of empty containers as continuous fluids. The optimal policies were given in terms of threshold levels. Song and Dong (2010) studied another aspect of empty container repositioning. They considered the case in which destination ports are unknown in advance and empty containers are unloaded from vessels when they are required. Song and Dong (2011) conducted a study on empty container repositioning in shipping service routes. Two types of repositioning policies were considered in their study: a point-to-point repositioning policy based on point-to-point balance and a coordinated repositioning policy that considered the empty container balance in the whole service. Recently, Moon et al. (2010) studied an empty container repositioning problem that considered leasing and purchasing. To solve the overall cost-minimization problem, they developed a mixed-integer linear optimization model and proposed genetic algorithms to reduce the computation time.

Few papers have examined the use of foldable containers in empty container repositioning. Konings and Thijs (2001) reported several conditions for the success of foldable containers based on the folding/unfolding cost and the production cost. Additionally, the technical features of foldable containers, the choice of the logistic concept, and product marketing were also considered. Recently, Shintani et al. (2010) investigated the repositioning cost savings in the hinterland. Based on the possible movement of empty containers and the locations available for folding and unfolding activities, three unique scenarios were proposed for investigation. In this paper, we focus on the potential cost savings in the repositioning of empty containers at sea by using foldable containers.