Transportation Research Part E 108 (2017) 52–59

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

Efficient solution methods for the integer programming models of relocating empty containers in the hinterland transportation network

Young-Soo Myung

Department of Business Administration, Dankook University, Yongin-si, Gyeonggi-do 16890, Republic of Korea

ARTICLE INFO

Keywords:
Foldable container
Empty container
Hinterland transportation

ABSTRACT

Shintani et al. (2010) developed five integer programming models to analyze the effects of using foldable containers in hinterland transportation. They solved the models using a general purpose integer programming algorithm and mentioned that other powerful solution methods are needed to solve a large size model. In this paper, we develop analytical solutions for two of their models and show that a network flow algorithm solves another two models.

1. Introduction

One of the most challenging jobs of a shipping company is to allocate empty containers to meet demand. This is a complicated decision due to an imbalance in the demand and supply of containers and involves repositioning empty containers. Recently, a shipping company considers the use of foldable containers that are expected to save transportation cost. However, as their usage also incurs folding and unfolding costs, it is an interesting issue whether foldable containers can save on the total cost of container allocation.

Numerous studies on empty container repositioning can be found in the literature. Most of the studies dealt with only standard containers (Crainic et al. (1993), Shen and Khoong (1995), Cheung and Chen (1998), Cheang and Lim (2005), Li et al. (2007), Shintani et al. (2007), Dong and Song (2009), Song and Carter (2009), Moon et al. (2010), Song and Dong (2010, 2011, 2013, 2015), Song and Zhang (2010), Meng and Wang (2011), Brouer et al. (2011), Zhang et al. (2014), Chen et al. (2016)). Researches investigating the effects of using foldable containers have been started after Konings and Thijs (2001) and Konings (2005) analyzed the potential cost savings of foldable containers. Shintani et al. (2010) considered cost savings of foldable containers in hinterland transportation, and Shintani et al. (2012), Moon et al. (2013), Myung and Moon (2014), and Moon and Hong (2016) in ocean transportation.

In the study of Shintani et al. (2010), the authors have developed the five integer programming models to formulate the cases with three different repositioning scenarios and two different container types. The details of their models will be discussed in the next section. When solving the integer programming models, they used a commercial code, LINGO and found that a huge CPU time would be needed to solve a large size model. This observation is no wonder since LINGO is a general purpose algorithm. In this study, we show that among the five models developed by Shintani et al. (2010), four models can be solved efficiently using the special structures of the models. We will show that two of them can be solved analytically and the other two models can be solved by a special purpose linear programming algorithm.

The remainder of the paper is organized as follows. In Section 2, we describe the four models introduced by Shintani et al. (2010), and discuss the structural properties of the models. In Section 3, we present four solution methods each of which solves each of the

E-mail address: myung@dankook.ac.kr.

http://dx.doi.org/10.1016/j.tre.2017.10.008
Received 14 July 2017; Received in revised form 9 October 2017; Accepted 10 October 2017
1366-5545/

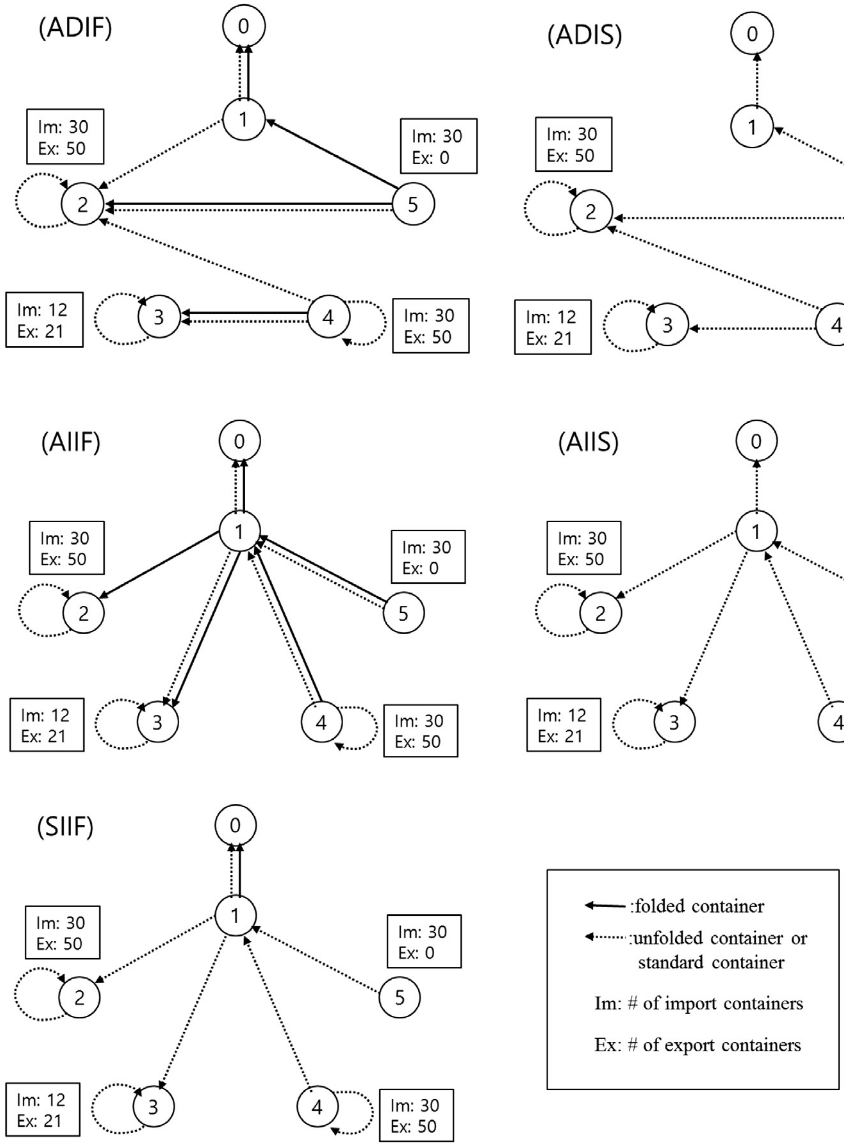

Fig. 1. Five hinterland transportation networks.

four models efficiently. Some concluding remarks are presented in Section 4.

2. Model formulations

In this section, we present four empty container planning models in the hinterland of a seaport that are introduced by Shintani et al. (2010). They considered various models with different repositioning scenarios and different types of containers. They addressed three different repositioning scenarios, advanced direct interchange (ADI), advanced indirect interchange (AII), and simple indirect interchange (SII). ADI assumes that empty containers are directly interchanged between customers, while empty containers are interchanged via an inland depot in AII and SII. When using foldable containers, folding and unfolding operation is possible at the customer's site in ADI and AII, while only in an inland depot in SII. Therefore, six different models are possible with each of three different scenarios and either of standard and foldable containers. Among six possible models, Shintani et al. (2010) developed the integer programming formulations for ADI with foldable containers (ADIF), ADI with standard containers (ADIS), AII with foldable containers (AIIF), AII with standard containers (AIIS), and SII with foldable containers (SIIF). They skipped the formulation for SII with standard containers since it is similar to AIIS. For more details of each model, refer to Shintani et al. (2010).

In their models, the hinterland transportation network was defined to describe the flow of empty containers. The nodes of the network correspond to a seaport, an inland depot, and multiple customers. Let $N = \{0,1,\cdots,n\}$ be the set of nodes. We assume that node 0 always represents a seaport and node 1 does an inland depot. The set of arcs is defined differently in the models with different