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Container drayage problem with flexible orders and its near real-time solution strategies ☆

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ABSTRACT

This article studies a container drayage problem with flexible orders defined by using *requiring* and *releasing* attributes as a unified formulation of various order types. A determined-activities-on-vertex (DAOV) graph introduces a temporary vertex set to formulate different truck statuses. The problem is formulated as a mixed-integer nonlinear programming model based on the DAOV graph. Four strategies including a window partition based (WPB) strategy are presented and evaluated extensively to solve the problem. Results indicate that the WPB method could solve the problem effectively and efficiently. Furthermore, this method is robust considering the operating time biases compared to other algorithms.

1. Introduction

Container logistics has grown rapidly in the last two decades. Correspondingly, there have been many substantial literature solving operational research problems in container logistics. A series of review articles such as those by Vis and de Koster (2003), Steenken et al. (2004), and several special issues including those by Chew et al. (2010, 2011) about seaport container terminal operations and freight transportation logistics have been published.

The long distance of container transportation usually requires vessels or trains as main transportation tools. However, a short distance of transportation by truck is necessary in most scenarios since the transportation by vessel or by train lacks door-to-door services (Zhang et al., 2010). As shown in Fig. 1, both the transportation from an initial consignee to a terminal (seaport or railway hub station) and that from a terminal to a final receiver use trucks. This segment of transportation by truck is usually called a drayage. Container drayage service in a local area is a critical issue in container logistics. It accounts for a significant portion of the total transportation costs and is the key source for shipment delays, road congestions, and disruptions in international logistics (Cheung et al., 2008).

Container drayage problems are usually considered as pickup-and-delivery problems (PDPs). See Parragh et al. (2008a, 2008b) for a comprehensive review and a classification of normal PDPs. However, container drayage problems differ from normal PDPs in several ways. On one hand, containers are another type of transportation resources besides trucks in container drayage problems. Freight must be packed within containers before it is transported. On the other hand, some drayage

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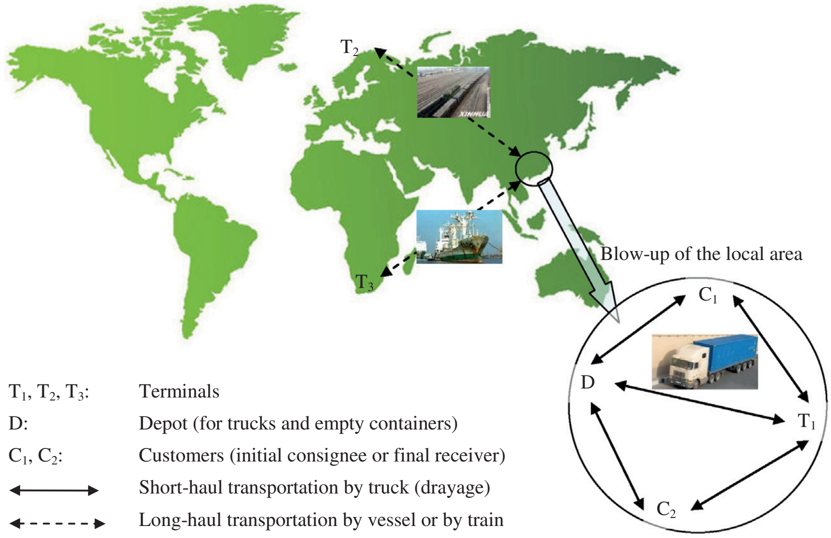

Fig. 1. Container drayage by truck in a local area.

orders (tasks) are flexible. Some properties of flexible orders are not given in advance. Orders of empty containers are typically flexible orders in container drayage problems. For example, in certain orders, an empty container located at a terminal should be picked up and delivered to a depot or another alternative location, e.g., a shipper of some freight (Braekers et al., 2013).

Quite recently, a few articles, e.g. Zhang et al. (2010, 2009), study container drayage problems with both well defined and flexible orders. In their problems, containers are not only transportation resources but also goods to be transported, which is a more realistic viewpoint compared to that of most existing articles. However, real-life scenarios in container drayage are more complicated. For example, some containers could be immediately ready for future use after they are delivered to their shippers and emptied. On the other hand, some containers might be returned to a depot and cleaned (and/or repaired) before further packing of freight. This paper defines two binary attributes of drayage orders which reflect whether an order requires and releases an empty container. The definition of orders using these attributes as well as the origin and the destination of orders covers all the situations mentioned above.

Container drayage problems are static problems in most existing articles such as those by Jula et al. (2005). In such articles, container drayage schedulers collect information about drayage orders, truck maintenances, and road conditions once in each time horizon (typically each day). This information is used when schedulers make decisions (e.g., at eight am every morning) and the decision does not change until the next decision-making point.

Recently, the concept and use of Internet of Things (IoT) have spread rapidly (Atzori et al., 2010). In the era of IoT, almost everyone and possibly every device can communicate and connect with each other based on the technologies of radio frequency identification (RFID) and communication (de Saint-Exupery, 2009; Ngai et al., 2008). For example, certain containers have RFID tags to provide schedulers with their location and freight information. Various sensors might monitor trucks' health or maintenance conditions. This information would be critical to alter drayage decisions to limit the impact of logistic disruptions. Thus, some container drayage problems in real-life are becoming or will become quite dynamic.

However, few articles now consider container drayage problems as dynamic problems. For example, Yang et al. (2004) studied a dynamic multivehicle truckload pickup-and-delivery problem. Escudero et al. (2013) also proposes a dynamic approach to solve a daily drayage problem with time uncertainties. Certain information about the future, e.g., probabilistic information, is required in most of these articles. But such information is usually not available. Furthermore, the definition of drayage orders in such articles differs from that which is used in this research. See Section 2 for a detailed review and a comparison of related literature.

This research investigates a dynamic container drayage problem with flexible orders. Firstly, a unified definition of drayage orders is proposed. The container drayage problem with this definition of orders involves both fixed and flexible orders. The double properties of containers (as transportation resources and goods) are considered in this problem. This dynamic container drayage problem is first formulated as a determined-activities-on-vertex (DAOV) graph inspired by Zhang et al. (2009) with temporary vertices introduced to describe the trucks working at the decision epoch. Then, based on the DAOV graph, a mixed-zero-one nonlinear programming model as an extension of the asymmetric multiple-traveling salesman problem with time windows (am-TSPTW) formulates this problem. Secondly, a number of strategies are presented to solve the drayage problem. One strategy handles only the updated information when interruptions occur. The other strategies re-solve the drayage problem each time when interruptions occur. These re-optimization strategies include solving the problem using commercial software directly, or after a simple discretization scheme, or based on a partition of time windows. Finally,