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Innovative Applications of O.R.

A truck scheduling problem arising in intermodal container transportation

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ABSTRACT

We address a truck scheduling problem that arises in intermodal container transportation, where containers need to be transported between customers (shippers or receivers) and container terminals (rail or maritime) and vice versa. The transportation requests are handled by a trucking company which operates several depots and a fleet of homogeneous trucks that must be routed and scheduled to minimize the total truck operating time under hard time window constraints imposed by the customers and terminals. Empty containers are considered as transportation resources and are provided by the trucking company for freight transportation. The truck scheduling problem at hand is formulated as Full-Truckload Pickup and Delivery Problem with Time Windows (FTPDPTW) and is solved by a 2-stage heuristic solution approach. This solution method was specially designed for the truck scheduling problem but can be applied to other problems as well. We assess the quality of our solution approach on several computational experiments.

1. Introduction

Intermodal container transportation describes the movement of goods in standardized loading units (e.g., containers) by at least two transportation modes (rail, maritime, and road) in a single transport chain (Bontekoning et al., 2004; Macharis and Bontekoning, 2004). The change of transportation modes is performed at specially designed terminals by transferring the loading units without handling the freight itself. The route of intermodal transport is namely subdivided into the *pre*-, *main*-, and *end-haulage*, which denote the route segments from customer to terminal, terminal to terminal, and terminal to customer, respectively (refer to Fig. 1). The main-haulage generally implies the longest traveling distance and is carried out by rail or maritime, whereas the pre- and end-haulage are handled by trucks to enable house-to-house transports. The pre- and end-haulage is also referred to as *drayage*.

Intermodal transportation has received an increased attention, e.g., by support programs introduced by the European Commission's Directorate – General for Mobility and Transport, to divert freight transportation from road to rail and maritime in order to reduce road congestion and environmental pollution. However, despite of these efforts, the fraction of the overall freight transportation by rail is steadily declining, leveling off at around 10% in 2009, its lowest level since 1945 (European Commission, 2007, 2011; Boysen et al., 2010). To increase the attractiveness of intermodal container transportation, an efficient handling of the pre- and end-haulage will result, according to Morlok and Spasovic (1994) and Cheung et al. (2008), in a significant cost reduction.

In this paper, we address a truck scheduling problem that arises in the pre- and end-haulage. A trucking company (also called *carrier*) handles transportation requests that involve container movements from customers (shippers or receivers) to terminals and vice versa. Associated with each request are hard time windows imposed by the customers and terminals for pickup and delivery. The transportation requests are carried out by a fleet of homogeneous trucks that must be routed and scheduled under these hard time window constraints. Moreover, containers are regarded as transportation resources and are provided to the customers for freight transportation. The latter results in the need of empty container repositioning which is additionally addressed in this setting. The carrier's objective is to minimize the total traveling cost which is proportional to the total operating time of all trucks in use. The total operating time is thereby composed of the total traveling time and the waiting time at the terminal and customer locations (Imai et al., 2007; Caris and Janssens, 2009). Furthermore, we assume that the size of the truck fleet is fixed. A carrier typically invests in a moderate fleet size based on an estimate between highest and lowest demand (Imai et al., 2007). The demand forecast, however, is highly uncertain and in peak demands, the carrier either charters trucks (Imai et al., 2007) or subcontracts transportation requests to third party carriers (Wang et al., 2002). In either way, the assumption on the fixed fleet size is not very restrictive, since

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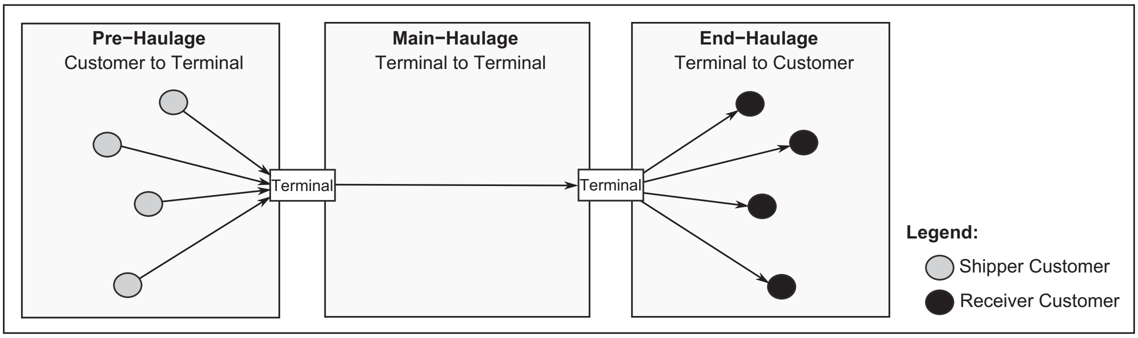

Fig. 1. Intermodal container transportation.

the truck fleet is either enlarged or the number of transportation requests is reduced, respectively.

This outlined truck scheduling problem has been introduced and discussed by Zhang et al. (2010). The authors formulate the truck scheduling problem as asymmetric multiple Traveling Salesmen Problem with Time Windows (am-TSPTW) and solve it by a modified version of the window partitioning heuristic presented by Wang et al. (2002). A drawback of this solution method is the strong dependence of the solution quality and the computational time on the parameter settings of the time windows. We present a new formulation for the truck scheduling problem based on a Full-Truckload Pickup and Delivery Problem with Time Windows (FTPDPTW) and propose a 2-stage heuristic solution approach.

The remainder of this paper is organized as follows. A detailed description of the truck scheduling problem is given in Section 2. For ease of exposition, we follow the presentation of the truck scheduling problem by Zhang et al. (2010) and apply to a large extend their notation and terminology. In Sections 3 and 4, we review the related literature and present a FTPDPTW and an am-TSPTW formulation for the truck scheduling problem, respectively. The 2-stage heuristic solution approach is addressed in Section 5. Finally, we assess the quality of our solution algorithm in a computational study and conclude our research in Sections 6 and 7, respectively.

2. Detailed problem description

We address in this research a problem setting with multiple terminals and multiple depots, where the latter serve as truck parking space and empty container storage. We assume that the carrier knows all the transportation requests before the beginning of the time horizon. The considered transportation requests either originate from or end up at a terminal. To distinguish between these types of transportation requests the terminology *inbound request* and *outbound request* is used. An inbound request starts and an outbound request ends at a terminal. This classification is extended by differentiating between the container loading states, *full* and *empty*. Full requests denote the movement of fully-loaded containers and empty requests refer to the movement of empty containers. Hence, four types of transportation requests are considered: inbound full (IF), inbound empty (IE), outbound full (OF), and outbound empty (OE). An illustration of the different types of transportation requests is given in Fig. 2.

The consideration of full and empty transportation requests is motivated as follows. Inbound/outbound full requests are induced by customers (shippers or receivers) and imply the movements of fully-loaded containers from terminals to customers and vice versa. Inbound/outbound empty requests, on the contrary, are initiated by the carrier and are due to empty container trade imbalances. To accommodate the demand of empty containers in an export-dominant region, empty containers have to be imported from import-dominant areas. Thus, empty containers are delivered by trucks to terminals that are located in import-dominant regions, are further transported by rail or maritime to terminals located in export-dominant regions, and are thereafter picked up by the carrier. Inbound/outbound empty transportation requests arise in the pre- and end-haulage of this described transportation scenario. In relation to inbound/outbound empty requests, terminals are also referred to as receiver/shipper terminals because in a broader sense they receive/deliver empty containers over the intermodal transportation network (refer to Fig. 2).

Each transportation request defines an origin and/or destination, as well as further activities which are listed below in chronological order of their execution. The activities are categorized into origin (OA), destination (DA), fully-loaded container (FA), and empty container activities (EA).

- Inbound Full Request (Origin: Terminal, Destination: Receiver customer):
  OA: The fully-loaded container is picked up by truck at the defined terminal.
  FA: The container is delivered to the specified receiver customer.

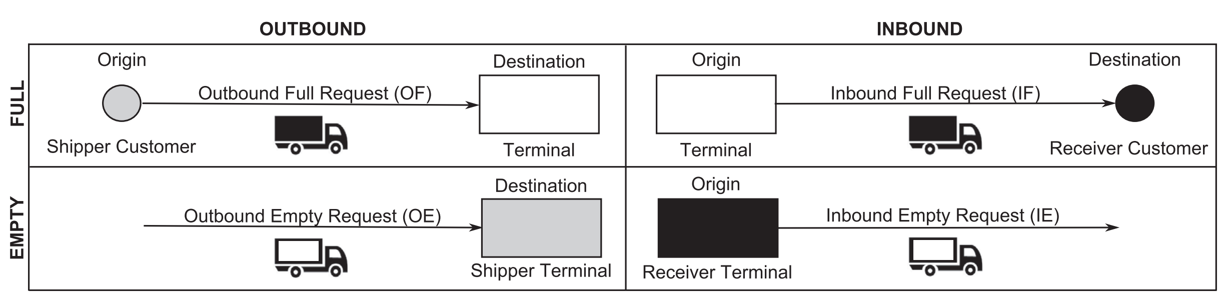

Fig. 2. Types of transportation requests.