An iterative auction for carrier collaboration in truckload pickup and delivery

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ABSTRACT

While carriers can collaborate to reduce empty traveling miles in truckload shipping, this is difficult to realize because each party is self-interested who may not share his private information that is necessary for the cooperation. In this paper, we propose an iterative auction scheme, which enables carriers to collaborate by exchanging their shipping requests iteratively. The auction is shown to be incentive-compatible, individually rational, budget balanced, monotonic, and convergent. Computational experiments indicate that it has small efficiency loss and can significantly improve carriers’ profits. We also develop two acceleration methods and extend the auction to more general problems.

1. Introduction

Collaboration is increasingly popular in logistics industry. Through asset sharing, carriers can collaborate to reduce overall operating expenses and carbon emissions, improve asset utilization levels, and create a win-win solution for the industry and the society (\textit{U-TURN} Project, 2015; \textit{World Economic Forum}, 2016). In the highly competitive full truckload (TL) shipping industry, traditionally carriers operate independently without cooperation, and receive only very low profit margins. The profits of carriers are further eroded by costs on the empty traveling miles because of the imbalance of freight requests from different shippers. \textit{The Economist} (2016) reports that truck drivers in the United States log about 50 billion empty miles each year, which is approximately 28\% of the total traveling miles; in Europe, 25\% of the containers on the road are empty. In China, the empty traveling rate of road freight transport even reaches the level of 40-50\% (Qianzhan.com, 2015).

This paper considers carrier collaboration in truckload shipping, where the transport of goods takes up the space or weight limit of an entire truck. Specifically, a TL carrier operates a fleet of trucks to pick up and deliver customers’ TL freight requests. A TL request consists of picking up a full truckload at one location and delivering it to another location. After completing the delivery, a truck typically runs empty on the way to pick up the next request or backhaul. Fulfilling a request generates a revenue but traveling empty with no freight incurs only costs. To reduce deadhead empty traveling miles, carriers can strategically collaborate with each other by jointly creating a freight movement solution that reduces one-way movements and empty traveling miles (Barbara et al., 2012). Request exchange in the collaboration allows carriers to sell or buy requests so that each carrier can strategically optimize his pickup and delivery routes to improve profit.

Our study is motivated from the increasingly popular industry practice in collaborative pickup-and-delivery among carriers. The importance of this problem is widely recognized in the literature; See, e.g., Liu et al. (2010a), Adenso-Díaz et al. (2014), Li et al.

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Collaborative transportation has become increasingly important in logistics and the related literature has dramatically grown during the last decade. Gansterer and Hartl (2017c) and Zhang et al. (2017) present extensive reviews on the state of knowledge in collaborative transportation. The main methodologies include centralized collaborative planning (Liu et al., 2010b; Adenso-Díaz et al., 2014; Wang et al., 2014a; Gansterer et al., 2017a; Kuyzu, 2017; Zhang et al., 2017; etc.), cooperative game theories (Özener and Ergun, 2008; Agarwal et al., 2009; Hezarkhani et al., 2016; Guajardo and Rönqvist, 2016; etc.), non-auction exchange mechanism (Özener et al., 2011; Houghtalen et al., 2011; Wang and Kopfer, 2015; etc.), and auction-based exchange mechanisms (Berger and Bierwirth, 2010; Li et al., 2015; Xu et al., 2016; etc.), applied to collaboration in varied transportation modes. As our work is to improve profitability for truck freight carriers through collaboration facilitated by an iterative auction, in the following we review the relevant literature on mechanism design for less-than-truckload (LTL) carrier collaboration and truckload (TL) carrier collaboration. For other types of the literature, please refer to the reviews of Gansterer and Hartl (2017c), Lai et al. (2017), and Zhang et al. (2017).

Mechanism design studies for collaborative transportation are mostly based on lane/request or capacity exchanges. Through...
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