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Operational flexibility in the truckload trucking industry

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ABSTRACT

Inspired by a real-life logistics provider, this study addresses a dynamic pickup and delivery problem with full truckload (DPDFL) for local operators. The primary purpose of this work is to investigate the impact of potential factors on the carriers' operational efficiency. These factors, which are typically under managerial influence, are vehicle diversion capability, the DPDFL decision interval, and how far in advance the carrier knows of the clients' shipment requirements (i.e., advance load information (ALI)). Through comprehensive numerical experiments and statistical analysis, we found that the ALI and decision interval significantly influence the total cost, however, the diversion capability does not. The findings also reveal that the impact of the re-optimization interval depends on the subcontracting cost and the amount of advance load information provided. A major contribution of this work is the development of an efficient benchmark solution for the static version of the DPDFL through the discretization of time windows. We observed that using three-day ALI and an appropriate decision interval can reduce deviation from the benchmark solution to less than 8%.

1. Introduction

According to the American Trucking Associations (2014), freight transportation service providers (also known as carriers) face numerous challenges such as highly variable demand from clients. The most common concerns, which are corroborated in Canada by the Ontario Trucking Association, include tight hours of service regulations as well as shortage and high turnover of drivers.[1]

Due to the numerous challenges that exist, carriers are continuously investigating strategies to improve operational efficiency to survive in this environment. One of the major and indisputable operational issues is the empty repositioning of assets (Crainic, 2000; Ergun et al., 2007a; Wieberneit, 2008; Özener et al., 2011). The statistics on empty repositioning signal sub-optimal operational efficiency in the trucking industry. For example, empty mile as a percent of total miles is 22% for reefer fleets, 27.5% for private fleet flatbeds, and 21% for bulk operations in the U.S.[2] Similarly, Barla et al. (2010) reported that one in every three heavy trucks on major Canadian highways travel empty. Given the size of North America's trucking industry, empty repositioning costs carriers over a hundred billion dollars annually (Ergun et al., 2007b).

It is important to keep in mind that efforts to eliminate empty repositioning are rarely successful since several determinants are not fully within the control of managers (e.g., geographic imbalance, market conditions, hours of service rules, and

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[1] http://ontruck.org
[2] http://www.logisticsmgmt.com

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the trip length of loads). There are also other potential factors (e.g., fleet size) over which managerial influence is limited, at least in the short run (Repoussis and Tarantilis, 2010). In such circumstances, collaboration among logistic participants is viewed as an attractive alternative to reduce empty repositioning. A low cost method of collaboration between carriers and their clients is the communication of timely load information (from clients to carriers) and pickup and delivery plans (from carriers to clients). For this reason, we consider the sharing of advanced load information (ALI), the potential benefits of which have been examined in a few research studies in the truckload context (e.g., Tjokroamidjojo et al., 2006; Zolfagharinia and Haughton, 2014; Scott et al., 2017).

Aside from ALI, other strategies can help carriers to improve operational efficiency. One of these strategies is diversion capability which was first defined by Regan et al. (1995) as a dispatcher's ability to divert an empty moving vehicle to serve a new request for delivery. Several studies indicate the potential benefit of diversion capability in the context of vehicle routing problems (VRPs) (Ichoua et al., 2006; Branchini et al., 2009; Klundert et al., 2010; Respen et al., 2014; Ferrucci and Bock, 2015). However, other than Regan et al. (1998), we are not aware of any other study that investigates this strategy in the context of the truckload trucking industry.

Another key strategy is to set an appropriate decision interval; i.e., the duration between time points at which the dispatcher makes the core operational decisions for serving shipment requests (e.g., deciding which vehicle will serve a given request). A longer interval (i.e., lower decision frequency) involves delaying these decisions to account for additional information on loads to be delivered. However, the benefit of more informed decisions comes at the detriment of newly arrived loads waiting longer to be processed. Most studies in the VRPs literature consider a continuous decision interval triggered by a new load arrival (Ichoua et al., 2006; Jaillet and Wanger, 2006; Branchini et al., 2009; Respen et al., 2014). An exception to this is Klundert et al. (2010) who discussed the possible benefit of extending the decision interval to one minute instead of every 30 s. Still, to the best of our knowledge, no study investigates the potential benefit of choosing an appropriate decision interval on the performance measure of a carrier.

Our present study to address this gap and several other gaps in the research literature is inspired by a low asset-based third party logistics provider (3PL) located in Ontario, Canada. They have a small number of drivers and tractors that operate in a relatively small geographic area. The next-day load information is often collected until late evening and the dispatching decision is made daily. The decision is whether to handle new loads using their trucks or to outsource them to other carriers. This problem is a pick-up and delivery with full truckload (DPDFL) in which load requests are realized as time progresses (i.e., dynamic nature). The primary goal of this article is to simultaneously investigate how a carrier's performance is affected by the three strategic factors previously mentioned: ALI, diversion capability, and decision interval. A contribution of jointly studying multiple strategies over which a carrier has some control is to extend the scope of analysis beyond ALI only. To achieve that goal, we deploy a three-part approach. First, we design a mixed integer programming model that is flexible enough to handle the problem's dynamic aspects correctly. Second, an efficient algorithm is developed based on time-window discretization is developed and its convergence to optimality is proven. This algorithm is helpful for solving the problem's much larger static version: the version in which the carrier has advance information on all loads in the planning horizon of interest (e.g., a one-month horizon). Finally, we examine the impact of potential factors including the aforementioned strategies. For the purpose of this paper, we define the term policy to mean any combination of the three strategic factors of interest here.

The rest of this article is organized as follows. In Section 2, we review the related research works to position the current study in relation to the existing literature and to present its novelty. Section 3 is devoted to defining the problem, stating its underlying assumptions, and formulating the proposed problem. In Section 4, we explain how a special case of the problem formulation is used to develop an efficient algorithm for the static version. The major focus of Section 5 is on dynamic implementation of the model, designing the experiments, solving the test problems, and conducting the statistical analysis. In Section 6, we first evaluate the performance of the proposed algorithm (to obtain the benchmark solution) for the static version under different network settings. Then, multiple policies are compared against each other based on their deviation from the benchmark solution. This comparison helps us to draw valuable managerial insights. Finally, in Section 7, we conclude our work and propose interesting future research directions.

2. Literature review

In this section, the related studies are reviewed and classified based on the primary features of each. Although the proposed problem is a truckload case, we also consider less-than-truckload studies that consider or test at least one of the following factors: advance load information, diversion capability, or decision interval.

2.1. Advance load information (ALI)/knowledge window (KW)

The dispatcher's KW is the amount of advance notice the dispatcher has about relevant particulars on clients' loads (shipment requests), e.g., earliest and latest pick-up time. That is, the KW increases when the client of transportation services communicates load information further in advance of the load's availability for pick-up. A few studies have investigated the importance of ALI. The study by Powell (1996) introduced a stochastic dynamic load assignment problem formulation that, by incorporating some stochastic information on future demand, outperforms its deterministic counterpart, which is updated