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Dispatching trucks for drayage operations

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ABSTRACT

We propose a novel model for dispatching trucks given the constraints and sources of uncertainty that arise in drayage operations. The proposed model is designed to minimize the expected cost and is generally applicable to cases including different distributions of random parameters. Numerical examples illustrate this robustness of the model, as well as the potential for reducing the drayage cost by increasing the available storage capacity and permitted number of terminal truck entries. Mathematical results derived within this paper (e.g. expected dwell time) can be used more generally in analyzing transfers in transportation networks under stochastic conditions.

1. Introduction

Truck-rail intermodal transport experienced rapid development since the 1980s when the double-stack rail-cars were first introduced in the USA (Resor et al., 2004). The double-stack rail-cars significantly reduced the rail-haul costs and made intermodal transport competitive at distances of about 500 miles, whereas previously it could compete with trucks only at distances greater than 750 miles. However, the cost of the highway portion of truck-rail intermodal transport called drayage remained relatively high (Resor et al., 2004). This paper aims to reduce the cost of drayage operations, which is crucial in making the truck-rail intermodal transport more competitive. Its main contribution lies in developing a novel model for dispatching trucks that takes into consideration constraints and sources of stochasticity that arise in the real-world. The proposed model is general as it makes few assumptions about the applicable distributions, and it can be applied to optimizing drayage operations for different types of intermodal terminals and truckloads (containers and trailers). The following two paragraphs introduce the relevant aspects of truck-rail intermodal that must be considered in modeling drayage operations.

The typical concept of intermodal truck-rail transport is now explained. A tractor with an empty container or trailer is dispatched from the terminal to a shipper's location in order to pick up a load. The tractor and driver wait with the trailer/container while it is being loaded and then, in a first drayage operation, transport it to the intermodal terminal (Morlok and Spasović, 1995). If the truck arrives at the terminal slightly before the train departure, it is directed to a queue associated with the train loading process and the freight is directly loaded on the train (Rizzoli et al., 2002). In this situation, only one crane operation is required to directly transfer the load from truck to rail car. Otherwise, the truck is directed to the storage area and at least two crane moves are needed to unload the truck and later load it on a rail car (Rizzoli et al., 2002). After the freight is hauled to the destination terminal, a second drayage operation delivers the freight to its final destination (Morlok and Spasović, 1995).

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Drayage operations are constrained by several factors. Besides the capacities of trucks, trains and terminal storage facilities, the number of trucks accessing the terminal within a time slot may also be limited (Namboothiri and Erera, 2008). Unscheduled arrivals at a terminal may cause potential problems to both terminal and drayage operations. Terminals would have their resources idle during the off-peak periods, whereas drivers would experience unnecessary waiting time if they arrive during the peak periods. In addition, excessive truck queuing causes higher diesel engine emissions, which is a major environmental problem especially for terminals in large metropolitan areas. As a result of growing truck congestion both within and outside terminals, many terminal operators in US are deploying access control systems limiting the total number of appointments available within each time slot (Namboothiri and Erera, 2008).

The remainder of this paper is organized in seven sections. Section 2 defines the problem and states assumptions and types of costs built into the model. Section 3 reviews related literature on drayage and truck-train intermodal transport. Sections 4 and 5 compute the costs that are built into the mathematical formulation provided in Section 6. The numerical results are presented in Section 7. Finally, conclusions are drawn and main contributions of this work outlined in Section 8.

2. Problem definition and assumptions

Consider a drayage firm serving a truck-train intermodal terminal and a set of surrounding shipper locations in an export-oriented region. The firm attempts to serve a set of requests to move trailers to the terminal with its available fleet. Trucks are assigned consecutive roundtrips whose durations are randomly distributed. Upon a truck's arrival at the terminal, the trailer is unloaded at a storage facility where it waits to be loaded to the connecting train. If the truck arrives slightly before the train departure, it can unload its trailer directly on the train; this requires fewer crane moves and therefore lower in-terminal operation cost. In case the trailer does not connect to the designated train, it has to wait for the next connecting train with available capacity.

The trains may not necessarily depart according to schedule and delays may occur due to various reasons, such as late arrivals of the locomotive(s) or delays in other operations or trains. Therefore the train departure is assumed to be randomly distributed over an interval. The duration of the interval may vary from country to country and in some applications it may be a point (i.e. the train departs punctually). However, we wish to consider the most general case and allow a potential user of our model to input these intervals or exact departure times based on actual conditions and experience.

Our objective is to develop a model that optimizes truck departure times given the following assumptions:

1. The number of roundtrips that a truck is assigned, as well as their sequence and randomly distributed durations, which include driving and loading/unloading times, are all given.
2. Durations of truck roundtrips are independent.
3. Departures of trains are randomly distributed over the non-overlapping intervals and independent (i.e. the first departure may be uniformly distributed from 12:00–12:15 pm and independent from the second one distributed from 3:30–3:50 pm). Their distributions can be determined based on historical data.
4. The number of trailers in the terminal must not exceed the terminal's dedicated storage capacity with the probability α (e.g. $\alpha = 0.9$).
5. The drayage firm is limited to a maximum number of truck entries to the terminal per time slot. Therefore the expected number of arrivals within a time slot shall not exceed the slot capacity (or a multiple of this capacity).
6. Trucks carry one 40 ft trailer per roundtrip. This assumption can be relaxed to consider possibility of transporting different types or number of trailers if more complex notation is introduced.
7. There are enough trailers at the terminal.

We wish to optimize the truck departures while minimizing the total expected cost. In calculating total cost the following are considered:

1. Storage cost, which refers to the cost of storing trailers in terminal's storage facilities while waiting for a connection;
2. Cost of in-terminal operations, which includes the cost of unloading and loading trailers. The cost of in-terminal operations is lower in cases where trucks arrive slightly before train departures and unload directly on trains;
3. Penalty for late delivery, reflecting the decrease in the freight's value as delivery is delayed. The penalty associated with a trailer depends on the departure time of a train on which the trailer is loaded.

After reviewing related research in Section 3, the types of costs listed above are computed in Sections 4 and 5, and included in the mathematical formulation of the problem presented in Section 6.

3. Related literature

Morlok and Spasović (1995) provide an excellent overview of drayage for truck-rail intermodal service and some of their explanations were already cited in the introduction. Spasović (1990), Morlok and Spasović (1994), and Morlok et al. (1995) model the drayage operations using integer programming and argue that central planning for several drayage companies in