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ScienceDirect
Transportation Research Part B 42 (2008) 438–454
TRANSPORTATION RESEARCH PART B
www.elsevier.com/locate/trb

A time–space scheduling model for optimizing recurring bulk railcar deliveries

Mark Lawley [a,*,1], Vijay Parmeshwaran [a], Jean-Philippe Richard [a], Ayten Turkcan [a,2], Malay Dalal [b], David Ramcharan [b]

[a] *School of Industrial Engineering, Purdue University, 315 N Grant Street, West Lafayette, IN 47907, United States*
[b] *Union Pacific Railroad, 1400 Douglas Street, Stop 0420, Omaha, NE 68179, United States*

Received 2 October 2006; received in revised form 1 October 2007; accepted 2 October 2007

Abstract

This work presents a time–space network flow model for scheduling recurring bulk rail deliveries from suppliers to customers. The objective is to maximize demand satisfied while minimizing waiting times for loading and unloading the bulk commodity. The model uses a variety of information including customer demand, rail network characteristics, loading and unloading hours, and track and station capacities. The planning horizon length and planning period can be varied to provide solutions for both long term planning and short term daily operations. The paper includes computational studies that examine the tradeoff between planning period length and schedule quality.

Keywords: Railcar; Scheduling; Time–space model; Rail optimization; Train scheduling; Freight cars

1. Introduction

Train scheduling and freight car assignment are omnipresent problems in the operation of large commercial railroads. They arise because railroads not only transport commodities between different locations but also because they typically provide the railcars necessary for the transportation of these commodities.

Scheduling recurring bulk rail deliveries such as coal or scrap metal from suppliers to customers is a variant of the more general freight car assignment and the train scheduling problems. It is both important and difficult for commercial railroads. It is important because of the large volume of business it represents. It is difficult because it exploits all available rail resources and information to minimize congestion, maximize capacity, and reduce uncertainty in daily arrival and departure patterns. The benefits of effective bulk scheduling include

* Corresponding author. Tel.: +1 765 494 5415; fax: +1 765 496 1459.
E-mail addresses: malawley@purdue.edu (M. Lawley), parmeshw@purdue.edu (V. Parmeshwaran), jprichar@purdue.edu (J.-P. Richard), aturkcan@purdue.edu (A. Turkcan), madalal@up.com (M. Dalal), dramcha@up.com (D. Ramcharan).
[1] Weldon School of Biomedical Engineering, Purdue University, 206 S Martin Jischke Drive, West Lafayette, IN 47907, United States.
[2] e-Enterprise Center, Purdue University, 203 S Martin Jischke Drive, West Lafayette, IN 47907, United States.

0191-2615/$ - see front matter
doi:10.1016/j.trb.2007.10.001

reductions in demand shortage, staffing costs, and loading/unloading delays. Further, effective scheduling can give long range planners a clearer understanding of their true capacity, enabling them to make commitments consistent with their ability to deliver.

The scheduling of recurring bulk delivery is different from traditional empty freight car assignments and train scheduling models in three important ways. First, car assignment and scheduling is for a single commodity only. Thus, freight cars used to transport the commodity tend to be homogeneous, and there is no need to model car substitution. Second, shipment quantities between origin–destination pairs (O–D pairs) are very large, implying that shipments are only initiated when a completely loaded train can be sent from origin to destination. As a result, there is no need to model the demand on a car by car basis, and thus it is sufficient to model it on a train by train basis. Finally, demands are recurring and predictable. This follows from the fact that the demand for freight cars follows from a relatively stable production pattern of the railroad customers. In railroads modeling, there may be other sources of uncertainties such as variation of transit times and dwelling times, which will increase the necessity of using a stochastic modeling approach. In our study, the dwelling times are calculated considering the available capacity of the stations, operating days and times at stations. They are dynamic since they change according to the arrival time of the train to the station. The average transit times are calculated according to the traffic on the tracks and they change according to the day and time of the travel. In this study, we use a deterministic approach to solve the problem because of a fairly stable environment.

In this paper, we develop a model for the scheduling recurring rail deliveries of bulk commodities from a set of suppliers to a set of customers so as to maximize the demand satisfied during a given planning horizon and minimize total train waiting time. The model considers information on customer demand patterns, rail network characteristics (distance, timing, topology,...), supplier loading capacities and staffing schedules, customer unloading capacities and staffing schedules, and freight railcar characteristics (number, availability,...). The model proposed is a time–space network, encoded as a mixed-integer program (MIP), where the representation of the physical network (suppliers, customers, stations, rails, etc.) is replicated for each time epoch or planning period over a finite planning horizon. Time–space models are commonly used to model train scheduling (Sherali and Tuncbilek, 1997; Sherali and Suharko, 1998) and can be easily customized to deal with different practical situations faced by railroad operators and planners on a day to day basis. A feasible solution to the model consists of a set of paths through the network that represents the movement of a set of trains through space and time. We propose an algorithm to solve this model and study its computational characteristics on a set of realistic demand and rail network data provided by an industry partner. Because the complexity of the model increases with the resolution of the planning period and the length of the planning horizon, a major part of this work involves finding a good balance between solution time and schedule quality.

Because this model was developed and evaluated in collaboration with a major rail transportation company, we believe that it is practically relevant. Furthermore, we believe that our modeling and solution approaches are unique as they combine and support all of the following features:

1. The model can be used for both tactical planning and detailed daily operations by appropriately selecting the planning horizon, planning period, and network characteristics.
2. The model captures rail network information such as customer working hours, station capacities, and customer priorities that are practically important when coordinating daily activities.
3. The solution methodology produces high-quality solutions for large, realistic networks of the size encountered in practice. It can generate schedules that are highly detailed in the early part of the planning horizon and more aggregate towards the end.
4. The model explicitly considers train routings and yard operating hours to help avoid congestion on the rail network. It also schedules the return and repositioning of empty freight cars to avoid loading delays.
5. The solution approach supports both recurring and sporadic demands.

The remainder of the paper is organized as follows: Section 2 provides a literature review on the most relevant railcar assignment and scheduling research. Section 3 describes our scheduling problem and discusses the assumptions of our model. Section 4 presents the time–space model we propose. Section 5 explains