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Trip plan generation using optimization: A benchmark of freight routing and scheduling policies within the carload service segment

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ABSTRACT

The rail freight carload service segment enables the distribution of freight volumes down to the unit of single rail cars, and stand as an important alternative to road transportation. However, this service segment is often associated with significant uncertainties and variations in daily freight volumes. Such uncertainties are challenging to manage since operating plans generally are established long in advance of operations. Flexibility can instead be found in the way trip plans are generated. Previous research has shown that a commonly used trip plan generation policy does not exploit the available flexibility to the full extent. In this paper, we therefore suggest an optimization-based freight routing and scheduling (OFRS) policy to address the rail freight trip plan generation problem. This OFRS-policy generates trip plans for rail cars while still restricted by the customer commitments. The policy involves a MIP formulation with a continuous time representation and is solved by commercial software. We apply the OFRS-policy on a case built on real data provided by the Swedish rail freight operator, Green Cargo, and assess the performance of the policy comparing the current industry practice. The results show that by using the OFRS policy, we can achieve a reduction in the total transportation times, number of shunting activities and potentially also a reduction in the service frequency given the considered transport demand.

1. Introduction

Rail freight operators manage a number of different service segments among which one is the carload service segment, also known as the single wagonload (SWL) service segment. Since the service segment enables the distribution of freight volumes down to the unit of single rail cars, rail freight carload transportation is an important alternative to road transportation. Less-than-truckload transportation is one example of strong competitors. However, at the same time as the carload service segment can be clearly motivated from a service-oriented perspective, it brings significant planning challenges. Especially such challenges can be related to the need for effective planning to reach economy-of-scale and profitability. That the carload service segment is subject to significant uncertainties and large variations in freight volumes is today widely recognized. At the same time, it is common to initiate the planning process up to one year in advance of operations. This approach limits the possibilities to adjust the operating plan according to fluctuations in transport demand over time. Flexibility can instead be found in the way trip plans are generated. Each transport request (i.e. rail car) is assigned a route and a schedule through the network of available train services. Such flexibility appears in terms of routing and scheduling options, where rail cars can be routed on to different paths of the service network, postponed at yards and scheduled on a number of different train services. However, in previous case studies (Backåker et al., 2011) we have observed that the type of routing and scheduling principles currently used by the main Swedish rail freight operator does not exploit the available flexibility to the full extent. It has come to our knowledge that the current planning principles do not select train services in an optimized way. We have also been given indications that the principle currently applied to manage capacity shortages on services, i.e. the First-Booked-First-Served (FBFS) principle, reduces the degree of flexibility even further (see Section 2.2).

In this paper, we therefore suggest an optimization-based freight routing and scheduling (OFRS) policy to deal with the rail freight trip plan generation problem. The OFRS-policy is configured to route and schedule rail cars onto the set of available train services. This is done freely, while still restricted by the customer commitments (e.g. agreed delivery time frames) and service characteristics (e.g. departure times and capacity limits). The policy involves a Mixed Integer Linear Programming (MILP) formulation which is solved by commercial optimization software. In contrast to previous models, our MILP formulation has a continuous time representation. In such way the formulation enables a more detailed representation of the service network and reduces the number of required binary variables. We apply the OFRS-policy on a

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case built on real data provided by the Swedish rail freight operator, Green Cargo. We also assess the performance of the OFRS-policy in a benchmark with the industry practice currently used by Green Cargo for the trip plan generation.

The structure of the paper is as follows; in Section 2 we provide an introduction to the rail freight planning and distribution process, and existing rail car priority principles. In Section 3, we provide an overview and discussion of related work followed by Section 4, which presents our proposed optimization-based dynamic trip plan generation policy (OFRS). In Section 5, we outline our experiments and the results are presented and discussed in Section 6. In Section 7, we provide conclusions and some directions for future research.

2. Rail freight carload planning and distribution

This section presents the planning and distribution process for rail freight carload transportation and primarily from a European perspective, where services operate according to pre-defined timetables.

2.1. The rail freight planning process

The complexity of planning rail freight operations has lead to the development of a step-wise, partly iterative planning process (Ireland et al., 2004). The process has been well described in literature; see e.g. Ahuja et al. (2005) for a comprehensive introduction, or Crainic and Laporte (1997) for a review of related planning models. Fig. 1 provides an overview of the general planning process including the most essential planning activities illustrated by dashed boxes. Solid lines are used to represent the information flows between these activities and also highlight the iterative workflow between activities.

The long-term planning process is primarily based on forecasts of future transport demand which provides an indication of how large flows that may occur on different transport relations. When trains operate according to pre-defined schedules, four main planning activities are carried out in a step-wise manner. The *blocking plan* (A) specifies how rail cars are to be grouped, also known as classified, into blocks. The assignment is highly dependent on the origin and destination of the rail car and possibly also on the service class. These blocks then need to be transported on different regional train services defined by the *train make-up plan* and *the timetable* (B). This activity is also referred to as *train scheduling*. In Europe, where the railway sector is becoming increasingly deregulated, rail freight operators are required to apply for train slots. This is done well in advance of operations, and the final timetable is constructed and published by the independent infrastructure manager. The timetabling activity is known to be time-consuming and complicates the planning process from the operator's point of view. When the timetable is finalized, the *locomotive schedule* (C) is established to assign locomotives to each slot in the timetable. The crew schedule (D) is constructed by assigning staff to the locomotive schedule. Iterative loops and cycles are commonly introduced in between the above mentioned planning activities. The joint result of these four planning activities is then the *operating plan*, also known as the *production plan* or *master plan*, and concludes the long-term planning process.

In the operational planning phase, the continuously incoming stream of transportation requests (E) is managed by the operator in what is referred to as the booking process and for each rail car, a *trip plan* (F) is created. This trip plan specifies when the rail car is to be picked-up for transport and how it is supposed to be (1) routed through the pre-defined network and (2) assigned to specific train services. Each transportation request consists of a single, alternatively multiple, rail car(s) with certain characteristics; typically release time, origin, destination, weight, length, shipper (i.e. sender) and consignee (i.e. receiver). The general approach when generating trip plans is to (1) first let the classification scheme defined by the blocking plan determine which train services that are available for the individual rail cars and then (2) select among the available train services according to certain basic principles, e.g. first-available-departure. Capacity on services is in this phase roughly considered. In situations when services already are overbooked rail cars are simply scheduled onto the next available departure. The assignment principle is repeated at each intermediate terminal the rail car is planned to traverse between its origin and destination.

The transport demand may vary significantly and uncertainties in terms of daily freight volumes complicate the capacity requirement estimations during the long-term planning process. Consequently, the capacity of train services from time to time becomes insufficient. In Sweden, train capacities generally lie in the span of up to 630 m and between 1100 and 1600 tons. Since the Swedish railway network is shared among different actors, sidings are required for passenger trains to be able to overtake e.g. slower freight trains. The length dimension is thereby foremost restricted by the length of the available sidings.

The short-term planning also addresses the empty rail car distribution in the service network (G). The balancing of the flow of empty rail cars is crucial for enabling the distribution of loaded rail cars within the network.

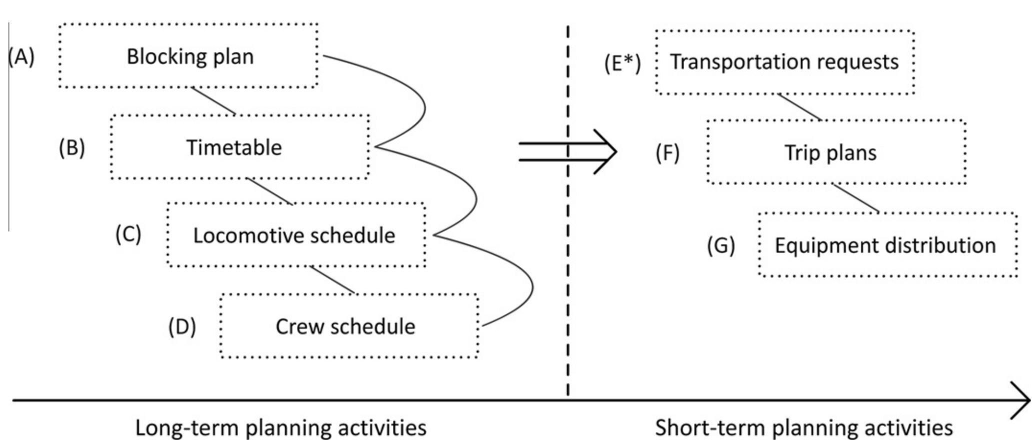

Fig. 1. Essential rail freight planning activities in the planning process (*external events).