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Publication date:
2013

Citation (APA):
Haahr, J. T., Lusby, R. M., Larsen, J., & Pisinger, D. (2013). The Rolling Stock and Depot Recovery Problem. Paper presented at Eighth Triennial Symposium on Transportation Analysis, San Pedro de Atacama, Chile.

The Rolling Stock and Depot Recovery Problem

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1 Introduction

In railway operations disruption management support is an area of research that has received relatively limited attention in the literature. In recent years, however, there has been a growing interest in this field. When a disruption occurs there is limited time to react. The impact of a disruption may be hard to comprehend and possible high quality recovery solutions may be very hard to find. Furthermore, if not handled promptly and thoroughly, the effects of the disruption can easily cascade, creating more problems.

In this work we consider the recovery problem of rolling stock and depot planning in passenger railway transportation. Both problems have been studied independently and at the respective strategic, tactical and operation planning levels (see e.g. Alfieri et al., 2006; Fioole et al., 2006; Folkmann et al., 2007; Peeters and Kroon, 2008; Groth, 2009). Planning the rolling stock and depot movements sequentially in separate phases often leads to infeasible or sub-optimal solutions. In our research we consider an integrated approach for real time planning. Integrated approaches typically have a high runtime and the plans require a high level of detail. Several disruptions can occur every day and some of these can be absorbed by network buffers. Other disruptions will, however, require the

Figure 1: DSB S-Tog line plan (December 2011)

dispatchers to alter the existing rolling stock plan. The timeframe is very limited and a new plan cannot be set in motion before details of train-routes, rolling stock and shunting requirements for the depots are available.

This research is part of the larger research project "RobustRailS" supported by DSF[1] and is carried out in collaboration with the Danish train operator DSB S-Tog. RobustRailS focuses on railway transportation and how it can be made robust, environmentally friendly, and sustainable by improving the transport system such that it becomes more punctual, reliable, high-frequent and comfortable. The overall aim is to increase the number of travellers using railway transport.

2 Problem Description

Passenger railway transportation consists of three main planning problems which are timetable, rolling stock and crew planning. A timetable is determined for every line defining all train arrivals and departures. Such a plan is typically cyclic and implicitly defines the set of all train-tasks that must be serviced. Figure 1 shows the line-layout at DSB S-Tog. A crew schedule specifies how every train-task should be manned according

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[1] The Danish Council for Strategic Research

to different physical and union constraints.

A rolling stock plan specifies three central decisions: the train-composition for every task, the individual car routes through the infrastructure, and the (de-)couplings which must occur. A composition is an ordered sequence of individual train-cars which are coupled and drive together from station to station. A composition must satisfy several constraints. First, the car-types must be compatible and at least one locomotive must be present unless the units are self-propelled. Second, the length of the composition must not exceed the smallest platform on the trip. A car route must start and end in some depot, and it may also be parked at depots in-between tasks. Initially the route must originate from the car's initial position and we can only park a limited number of cars at every depot. The number of possible routes is limited by the network infrastructure and moves that are prohibited, e.g., for safety or robust reasons. Cars also have maintenance constraints, e.g., at DSB S-Tog every car must be inspected and serviced at a workshop before it reaches a certain mileage limit. Similarly, sand (used when braking) has to be filled regularly and during winter the cars must be sprayed with anti-icing liquids. Couplings and decouplings cannot occur arbitrarily. Depending on the station, safety-regulations, time-constraints, depot-track layout, the train composition and orientation some (de-)couplings are not feasible. The objective function of the rolling stock optimization problem is a balance between operational costs, number of (de-)couplings (robustness) and demand shortage.

When solving the rolling stock problem it is often assumed that a feasible depot plan exists as long the fixed length of parking tracks is respected. This may however not be the case, especially if the space depots is limited as is the case at many depots at DSB S-Tog. The depot problem is in it self a hard problem to solve, see Kroon et al. (2008). In addition to the available parking space we need to consider the station and depot infrastructure and park trains in a LIFO ordering at every track-segment. Further, every available shunting personnel can only do one task at a time and she needs time to walk between different locations.

3 Solution Methods

Given the size and complexity of both the rolling stock and depot planning problems as well as the urgency of efficient solutions in a disrupted setting, we present optimization based heuristic procedures for repairing a disrupted rolling stock and depot plan. In repairing the solution we attempt to restore the original rolling stock and depot plans with minimal changes. The procedures utilize a rolling time horizon and are built around the notion of a *disruption neighbourhood*. Initially, the disruption neighbourhood is small, perhaps only considering the rolling stock units that are directly affected by the disruption, and enlarged while infeasibility persists or if time allows to find an improved solution. Emphasis is given to the construction of robust rolling stock and depot plans in an attempt to reduce the susceptibility of the repaired plans to further disruption and minimize the propagation of delays. To ensure robustness of the revised plan we attempt to limit the number of couplings (respectively decouplings) necessary in restoring feasibility. If coupling and/or decoupling is required, we try to schedule them when there is more than just the sufficient time to execute the operation. By restricting the set of train units we can reschedule to those in the disruption neighbourhood, we also ensure a degree of robustness by limiting the total number of possible changes. The solution methods from this project are tested on data provided by DSB S-Tog and comparisons are drawn with their current approaches. Furthermore, where possible, exact methods are used to benchmark the quality of the obtained solutions.

4 Outlook

The work in this project describes an optimization framework for managing the rolling stock and depot movements for train units in a disrupted setting. It is envisaged that this will be a key subcomponent of a larger, holistic recovery framework which integrates several other important factors (timetable, rolling stock, and crew) that must be considered to obtain a complete disruption recovery tool for passenger railway transportation.

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