Transportation Research Part C 80 (2017) 133–147

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Passenger oriented railway disruption management by adapting timetables and rolling stock schedules ☆

Lucas P. Veelenturf [a,*], Leo G. Kroon [b,c,1], Gábor Maróti [c,d]

[a] School of Industrial Engineering, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
[b] Rotterdam School of Management, Erasmus University, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands
[c] Process quality and Innovation, Netherlands Railways, Utrecht, The Netherlands
[d] Faculty of Economics and Business Administration, VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 30 April 2016
Received in revised form 30 January 2017
Accepted 24 April 2017

Keywords:
Railways
Disruption management
Rolling stock
Timetable

ABSTRACT

In passenger railway operations, unforeseen events require railway operators to adjust their timetable and their resource schedules. The passengers will also adapt their routes to their destinations. When determining the new timetable and rolling stock schedule, the railway operator has to take passenger behavior into account. The operator should increase the capacity of trains for which the operator expects more demand than on a regular day. Furthermore, the operator could increase the frequency of the trains that serve stations with an additional demand.

This paper describes a real-time disruption management approach which integrates the rescheduling of the rolling stock and the timetable by taking the changed passenger demand into account. The timetable decisions are limited to additional stops of trains at stations at which they normally would not call. Several variants of the approach are suggested, with the difference in how to determine which additional stops should be executed.

Real-time rescheduling requires fast solutions. Therefore a heuristic approach is used. We demonstrate the performance of the several variants of our algorithm on realistic instances of Netherlands Railways, the major railway operator in the Netherlands.

1. Introduction

In passenger railway operations, unforeseen events (such as infrastructure malfunctions, accidents or rolling stock breakdowns) can make parts of the railway infrastructure temporarily unavailable. Then it is not possible to operate the timetable, rolling stock schedule and crew schedule as planned. Within minutes, or even better, seconds, a new timetable and new resource (rolling stock and crew) schedules must be available. In Cacchiani et al. (2014) an overview is given of recovering models and algorithms to solve these rescheduling steps. In this overview it becomes clear that, although the schedules are interdependent, most research focuses on rescheduling one of the schedules at a time. By the complexity of the rescheduling problems, there is not enough time to solve the integrated problem. In this paper we partly integrate the rescheduling of the rolling stock plan and the timetable. Our particular focus lies on passenger service, and we take passenger behavior explicitly into account.

☆ This article belongs to the Virtual Special Issue on "Integr Rail Optimization".

* Corresponding author.

E-mail addresses: l.p.veelenturf@tue.nl (L.P. Veelenturf), lkroon@rsm.nl (L.G. Kroon), g.maroti@vu.nl (G. Maróti).

[1] This paper is dedicated to the dear memory of Leo Kroon who passed away unexpectedly on the 14th of September, 2016.

http://dx.doi.org/10.1016/j.trc.2017.04.012

Current literature on integrated rescheduling of the timetable and the rolling stock schedule is scarce. Adenso-Díaz et al. (1999) and Cadarso et al. (2013) applied research on integrated rescheduling of the timetable and rolling stock on cases of the Spanish railway operator RENFE.

Like the main focus of this paper, (Cadarso et al., 2013) take the dynamics of the passenger behavior during a disruption into account. In the current paper, however, the fundaments of the approach are from Kroon et al. (2015). There, the focus is on improving passenger service by considering passenger behavior while rescheduling the rolling stock. They use an iterative procedure for rescheduling the rolling stock and evaluating the resulting passenger behavior which is inspired by the iterative framework of Dumas and Soumis (2008). Changing the timetable can also improve the passenger service. Therefore we extend the iterative procedure by allowing the timetable to be slightly adapted as well.

It is important to focus on the passenger service since a disruption does not only affect the timetable and the resource schedules, but also the passengers. However, it is difficult for railway operators without a seat reservation system to reschedule the passengers: the passengers choose their new travel plan by themselves.

By the changed passenger flows, the disruption causes changes in the demand for seats. Therefore, a rescheduling approach to handle a disruption must take the modified passenger flows into account dynamically, and not the passenger flows of a regular day. For example, since some passengers will take a detour, additional capacity on the detour routes is necessary. An increased capacity can be created by allocating more rolling stock or by timetable adjustments. The timetable adjustments can be achieved by inserting new timetable services or by introducing additional stops in existing services.

In this research we limit the timetable decisions to adapting the stopping patterns. More substantial timetabling measures, such as the insertion of additional services, would require non-trivial crew rescheduling efforts. In contrast, we assume that small delays caused by adapting the stopping patterns leave the crew schedule essentially intact.

Optimizing the stopping patterns form a key element in the approaches of Yue et al. (2016) and Jamili and Pourseyed Aghaee (2015) for medium to long term train timetabling. The time-dependent character of the passenger demand is explored by Niu and Zhou (2013) under oversaturated conditions and by Niu et al. (2015) under non-saturated conditions. To the best of our knowledge, our approach is novel in that we adjust the stopping patterns in a real-time rescheduling context, and we combine it with both with dynamic passenger flows, and with detailed rolling stock rescheduling.

Our focus lies on railway networks in which passengers have the free choice of taking trains, that is, they are not constrained by a seat reservation system. We consider rather large disruptions that lead to the cancellation of many services. Our method is best suited for disruptions where the traffic is not completely blocked; we hope to improve the service quality by applying careful changes to the stopping patterns besides rolling stock rescheduling measures.

Our algorithm is intended for network-level timetabling and rolling stock rescheduling. We consider a macroscopic view of the underlying network; the block occupation, signaling systems and the acceleration of the trains fall out of our scope. In particular, we assume that the very limited timetable adjustments of our algorithm result in a feasible timetable. For the sake of clarity we assume that the duration of the disruption is known upon its start. We note that the uncertain length of the disruption can be considered by embedding our models in a rolling horizon framework (see, e.g., Nielsen et al., 2012).

Delay management, which consists of deciding on whether or not trains have to wait for delayed connecting train services, is another problem in which slight timetable adaptations influence the passenger flows. Delay management is a hard problem on its own and thereby not considered in our approach. We refer the interested reader to Schachtebeck and Schöbel (2010), Kanai et al. (2011) and Dollevoet et al. (2012) for recent works on delay management approaches.

This paper is organized as follows. The framework of our rolling stock rescheduling approach is discussed in Section 2. We make use of an iterative procedure of which in Section 4 up to Section 5 the components are explained. A lower bound for the model is introduced in Section 6 and results of different variants of our approach, based on a scenario in the Netherlands are discussed in Section 7. Section 8 concludes this paper.

2. Problem description

2.1. Rolling stock and timetable rescheduling with dynamic passenger flows

We consider disruptions where passenger behavior has a large impact on the performance of the railway system if the timetable and rolling stock schedule are not changed. Passengers react to these disruptions by finding alternative routes to their destinations. However, the capacity on these alternative routes can be limited, resulting in overcrowded trains and thereby longer dwell times and delays.

Two ways to handle the increased demand on the alternative routes are to enlarge the capacity of the trains and to adapt the timetable. Adapting the capacity of the trains alone is not always enough. For example, it can be impossible to increase the capacity of a train by lack of time and/or reserve rolling stock or due to limited platform lengths. Therefore, timetable adaptations such as adding extra timetable services, rerouting timetable services or introducing extra stops in timetable services are worthwhile as well.

By adapting the timetable, the railway operator can influence the passenger flows: new alternative travel routes are provided and the demand for certain timetable services is changed. For example, a service can have an additional stop at a station to give passengers at that station an additional travel option with an earlier arrival time to their destination. At the same time, the demand is decreased for the next train stopping at that station and traveling in the same direction.