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Review

An overview of recovery models and algorithms for real-time railway rescheduling ☆

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A B S T R A C T

This paper presents an overview of recovery models and algorithms for real-time railway disturbance and disruption management. This area is currently an active research area in Operations Research, including real-time timetable rescheduling and real-time rescheduling of the rolling stock and crew duties. These topics are addressed in this paper. Also research dealing with the integration of more than one rescheduling phase is discussed. Currently, the developed methods have been tested mainly in an experimental setting, thereby showing promising results, both in terms of their solution quality and in terms of their computation times. The application of these models and algorithms in real-life railway systems will be instrumental for increasing the quality of the provided railway services, leading to an increased utilization of the involved railway systems.

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1. Introduction

This paper gives an overview of the research that has been carried out recently in the area of recovery models and algorithms for real-time railway disturbance and disruption management. Here *disturbances* are relatively small perturbations of the railway system that can be handled by modifying the timetable, but without modifying the duties for rolling stock and crew. *Disruptions* are relatively large incidents, requiring both the timetable and the duties for rolling stock and crew to be modified. Disturbance and disruption management are currently active research areas in Operations Research. This research has lead to many papers on algorithmic tools for real-time rescheduling of the timetable, the rolling stock and the crews.

Research in this area is scientifically challenging, but also promising from a practical point of view. Indeed, in many countries increasing the market share of public transport, and especially railway transport, is considered as one of the solutions for mobility problems. Moreover, railway transport is seen as a *green* mode of transportation. Thus increasing the market share of railway transport is one of the top priorities of many governments.

However, many potential railway passengers consider the perceived service level and unreliability of railway systems (caused by e.g. train delays, insufficient seating capacity, broken passenger connections, canceled trains) as a disqualifier to use the train. Thus improved service and reliability will be needed to seduce these potential passengers to travel by train. The application of recovery models and algorithms for real-time disturbance and disruption management, implemented in user-friendly decision support systems, is considered as a key element for improving the service and reliability of railway systems. It will lead to improved capacity and delay management, and to less train cancelations.

The basis of a railway system is formed by an extensive planning process, resulting in a timetable and resource duties, often already long time ahead of the real-time operations. Here the resources are the rolling stock and the crews. Note that the infrastructure might be considered as a railway resource as well (in most cases it is actually the most expensive one), and the timetable as the corresponding resource schedule. However, in this paper we will not use this terminology. The timetable and the resource duties usually represent an optimized trade-off between service, efficiency, and robustness of the railway system.

Unfortunately, the real-time operations of a railway system are more or less unavoidably subject to unexpected disturbances and disruptions, which result in infeasibilities in the timetable and possibly in the resource duties. The passengers experience these disturbances and disruptions as delays of trains, broken connections, insufficient seating capacity, and canceled trains. Also freight trains suffer from disturbances and disruptions, mainly in the form of delays and rerouted trains. Thus there is a need to recover from a disturbed or disrupted situation, and to restore the normal railway services as quickly as possible.

Recovering from a disturbed or disrupted situation to a feasible situation requires to change the timetable, and, if necessary, the rolling stock and crew duties as well. Currently, the involved dispatchers in practice take these decisions mainly manually, based on their experience and craftsmanship, without *intelligent* decision support.

However, recently a large number of mathematical recovery models and algorithms have been developed to support the dispatchers in their decision making processes. This paper presents an overview of this research. Since this is an active research area, we do not pretend to give a complete overview, but we mention at least the most relevant recent papers.

In this overview paper we restrict ourselves to mathematical models and algorithms that have been developed for algorithmically solving railway rescheduling problems. We do not cover organizational nor communication aspects that also play an important role in railway rescheduling. For a brief introduction to these subjects we refer to Jespersen-Groth et al. (2009). We also restrict ourselves to the rescheduling problems related to the timetable, the rolling stock and the crews. We do not focus on the logistic problems related to the cause of the disturbance or the disruption, such as repairing broken railway infrastructure.

This paper is structured as follows. Section 2 presents some background information on railway systems. Thereafter, Sections 3–5 deal with models and algorithms for timetable rescheduling, rolling stock rescheduling, and crew rescheduling, respectively. Next, Section 6 covers models and algorithms that integrate different rescheduling phases. Various approaches to solve these problems are discussed in terms of the type and scale of the disruptions dealt with, the network infrastructure and topology, the objective function and constraints considered, and the utilized optimization methods. This paper is finished with conclusions and a perspective on further research in Section 7.