Passenger-oriented Integrated Disruption Recovery in Railway Systems

Keywords: disruption management, passenger recovery, linear programming, network scheduling, multi-commodity flow

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Background

The efficient operation of railway systems is critical for ensuring reliable and punctual transportation services. However, railway networks frequently face disturbances and disruptions that necessitate immediate and effective responses to minimize delays and maintain service quality. These include, for instance, delays, infrastructure blockages, equipment malfunctions, etc. (Cacchiani et al., 2014).

This research project addresses the integrated disruption recovery problem in railway systems, focusing on algorithmic approaches to optimize railway rescheduling in real-time. The complexity of this problem arises from the need to simultaneously manage timetable rescheduling, rolling stock rescheduling, and passenger satisfaction, necessitating sophisticated optimization models and algorithms. Traditional approaches often handle timetable and rolling stock rescheduling separately, which can lead to suboptimal solutions (Schiewe, 2020). This research addresses integrated approaches, combining timetable and rolling stock rescheduling, with a focus on passengers.

Problem Description

The passenger demand does not remain invariant in the context of disruptions in railways. In unplanned disruptions, unexpected passenger flows are likely to occur along the possible detour routes (Kroon et al., 2015). Some publications have addressed passenger flows or passenger behaviour in the context of railway rescheduling (Dollevoet et al., 2012; Cadarso et al., 2013; Binder et al., 2017; Szymula & Bešinović, 2020; Trepat Borecka & Bešinović, 2021).

Explicit consideration of passenger flows adds additional complexities to the disruption recovery problem. Several publications consider passenger flows or behaviour indirectly (Cadarso et al., 2013). The works of Szymula & Bešinović (2020) and Trepat Borecka & Bešinović (2021) model passenger flows as a multi-commodity flow problem using a path-based formulation. By contrast, in Binder et al. (2017), passenger flows are modelled using an arc-based formulation. The shortcomings of these approaches include the assumption of constant travel times, ignoring transfers, and difficulty in incorporating passenger behaviour.

Several works use the multinomial logit model to represent the passengers' behaviour, such as in Cadarso et al. (2013); Binder et al. (2017); Szymula & Bešinović (2020). Szymula & Bešinović (2020) estimates passenger cost in the objective function based on the logit model of probabilistic route choice. In Cadarso et al. (2013), authors precompute the anticipated disrupted demand using a multinomial logit model and model passenger flows using an arc-based formulation. In this publication, the demand is characterized by an origin, a destination, and a departure time.

Dollevoet et al. (2012) address the problem of delay management, which consists in deciding whether or not trains have to wait for delayed connecting train services (i.e. slight timetable adjustment), taking into account passenger rerouting resulting from passenger behaviour in reaction to a disruption.

Veelenturf et al. (2017) focuses on timetable adjustment by changing stopping patterns in the context of disruptions, typically consisting in adding new stops, which provides additional travel options to passengers affected by the disruption. Passenger flows are evaluated using the simulation model from Kroon et al. (2015).

Lastly, related work considers the option of scheduling extra train services, which are inserted into the schedule during the disruption to help alleviate negative effects on passengers (Cadarso et al., 2013; Binder et al., 2017; Trepat Borecka & Bešinović, 2021).

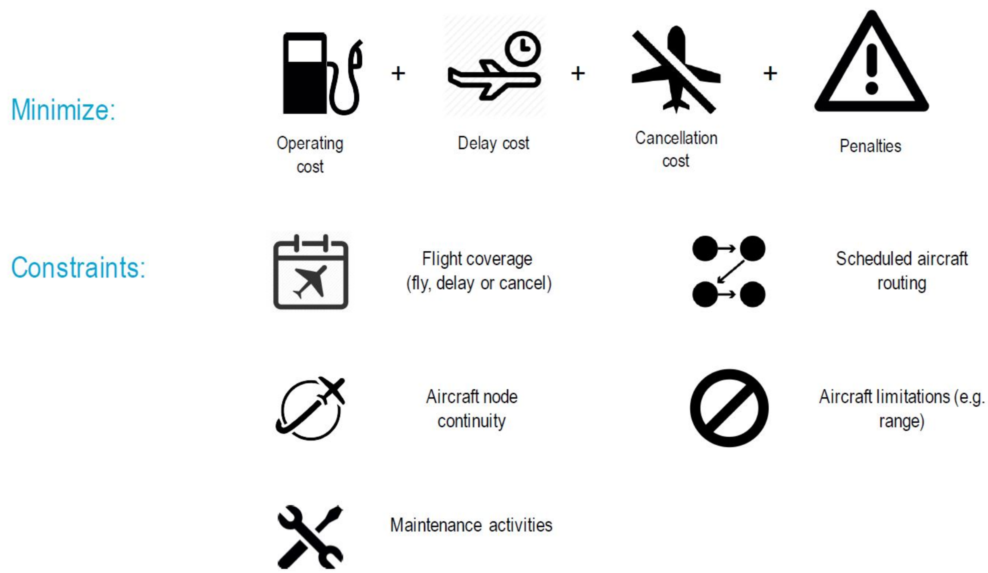

Figure 1: Disruption recovery in air transport.

Research Questions

The main research question of this project is the following: Can the passenger perspective be integrated efficiently within the disruption recovery problem in railway systems? Therefore, the focus of this work is on the algorithms. Follow-up research (sub)questions can be formulated by the student.

Approach

The student will review existing algorithmic approaches in the literature to model and incorporate the passenger perspective in the disruption recovery problem (e.g. explicit modelling of passenger flows, indirect modelling considering the effects of passenger demand, etc.).

Besides, the student will be given a program with an implementation for the disruption recovery problem formulated as a mixed-integer linear programming and the necessary data. The student will extend the mathematical model in Python with Gurobi and make the necessary adjustments / tuning to the model if needed. Ideally, the student will test different formulations and assess the quality and computational advantages or disadvantages of each approach.

The student is expected to have knowledge of coding with Python and Gurobi. Experience in multi-commodity flow problems is an advantage.

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