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Impact of railway disruption predictions and rescheduling on passenger delays

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ABSTRACT

Disruptions such as rolling stock breakdown, signal failures, and accidents are recurrent events during daily railway operation. Such events disrupt the deployment of resources and cause delay to passengers. Obtaining a reliable disruption length estimation can potentially reduce the negative impact caused by the disruption. Different factors such as the location, cause of disruption, traffic density, etc. can determine the disruption length. The uncertainty inherent to the variability of each factor and the unavailability of sufficient data results in a wide distribution of disruption lengths from which a certain value should be selected as the length prediction. The rescheduling measure considered in this research is short-turning the trains that are heading to the disrupted area. To investigate the impact of the disruption length estimates on the rescheduling strategy and the resulting passengers delays, this research presents a framework consisting of three models: a disruption length model, short-turning model and passenger assignment model. The framework is applied to a part of the Dutch railway network. The results show the effects of short (optimistic) and long (pessimistic) estimates on the number of affected passengers, generalized travel time and number of passengers rerouting and transferring.

1. Introduction

Railway operations are repeatedly disrupted by events such as technical and mechanical failures of infrastructure and rolling stock, traffic accidents and malicious attacks. Railway timetables are usually designed to compensate for some delays by including time allowances. However in case of long disruptions and infrastructure unavailability, these time allowances are ineffective and a new timetable should be designed with adjusted train services. Before making any decision regarding the traffic, the relevant information about the disruption should be collected. Upon occurrence of a disruption, there is usually a high level of uncertainty regarding the situation. It takes some time before the exact location and the nature of the disruption is known to the traffic controllers. Once the cause of disruption and the location is known, the traffic controllers are able to proceed with handling the disrupted traffic. An essential piece of information that has a crucial role in their decisions regarding the traffic is the predicted disruption length. Since any change in the timetable is costly, if the predicted length is shorter than a specific threshold then they might decide not to implement major changes to the timetable. In case the length is larger than the threshold, the prediction is used for rescheduling the timetable. Moreover the disruption length and the changes of the timetable should be communicated to the passengers so they can make informed decisions about their trips when they are disturbed. Thus a reliable disruption length prediction is key

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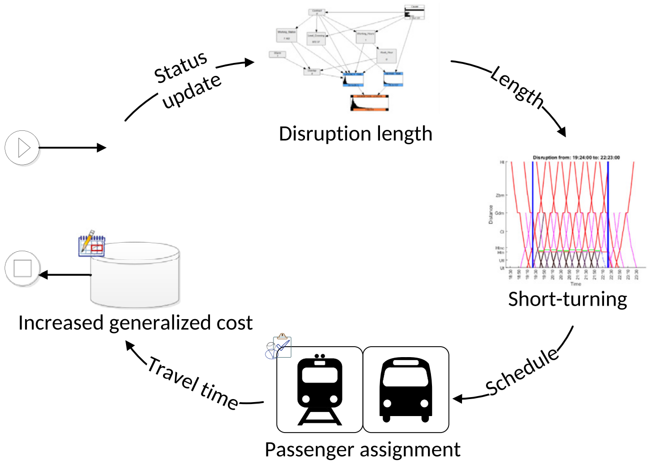

Fig. 1. The interaction between the models.

information in designing a new timetable that can limit the negative impact on the passengers.

The length of a disruption depends on many factors like the type of failure, the component that failed, the repair needed, and the spare parts that a repair crew has with them. However, data on most of these factors are not available, which leaves much uncertainty in any prediction of the disruption length. Zilko et al. (2016) developed a probabilistic Bayesian Network model to predict the disruption length using conditioning on information that becomes available about a disruption. However, most factors included are indirect, like accessibility of the disruption location. Hence, the obtained distributions of disruption lengths still exhibit a wide range. Then the next question is how to get a point estimate from this distribution that can be used by traffic controllers as a prediction of the disruption length and take actions accordingly. Simply taking the mean (expected value) may not be effective. On one hand, a point estimate could be optimistic and underestimate the disruption by which traffic controllers have to rethink their decisions and passengers may have taken the wrong decisions about their travel compared with the optimal choice if they would have known the exact disruption duration. On the other hand, a point estimate could also be pessimistic and overestimate the disruption which might lead to unnecessary train cancellations and long travel times for passengers.

In this paper a framework is proposed to investigate the effects of different choices of predictions on the rescheduling solution and consequently the passenger delay. The contribution of the framework is the unique integration of three components (see Fig. 1):

- Estimating the disruption length as a point estimate from a conditional distribution based on available data.
- Rescheduling the timetable given the estimated disruption length.
- Measuring the passenger delays based on the computed adjusted schedule.

The framework provides the possibility of reproducing different disruption scenarios, where the information about the disruption is gradually updated and accordingly the timetable is rescheduled and finally the impact on the passengers is measured. This allows testing the consequences of different disruption lengths and their over- or underestimation with the corresponding mitigation measures on passenger flows and travel time losses.

In the remaining of the paper, the process of handling disruption and the relevant literature is presented in Section 2. The three components are described in more details in Section 3. The modeling framework is then demonstrated using an application to part of the Dutch railway network in Section 4. In this Section the impacts of the optimistic and pessimistic estimates are modeled and assessed. Section 5 concludes with practical implications and directions for future studies.

2. Disruption management

The decisions regarding the rescheduling of resources need to be carefully communicated between the railway infrastructure manager, the train operators and other involved actors to ensure the feasibility of the plan. To facilitate the challenging task of the traffic controllers in such cases, many countries use contingency plans designed specifically for disruption scenarios (Chu and Oetting (2013)). In The Netherlands these plans are manually designed by expert traffic controllers and are specific for each location and disruption case regardless of disruption length.

The proposed solution in the contingency plans is based on the timetable (basic hourly pattern) and the remaining capacity of the disrupted location. The solution instructs the traffic controllers how to deal with the disrupted traffic by determining cancelled services, short-turned or rerouted services and services that are allowed to operate as in the original timetable. Short-turnings are particularly beneficial for isolating the disrupted area, while maintaining services on both sides of the disruption. This implies short-turning the arriving trains at a station before the disruption (on both sides) and continue service in the opposite direction. In case of short-turning, the stations where the short-turning should occur as well as the platforms and departure times also need to be