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Adjusting a railway timetable in case of partial or complete blockades

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ABSTRACT

Unexpected events, such as accidents or track damages, can have a significant impact on the railway system so that trains need to be canceled and delayed. In case of a disruption it is important that dispatchers quickly present a good solution in order to minimize the nuisance for the passengers. In this paper, we focus on adjusting the timetable of a passenger railway operator in case of major disruptions. Both a partial and a complete blockade of a railway line are considered. Given a disrupted infrastructure situation and a forecast of the characteristics of the disruption, our goal is to determine a disposition timetable, specifying which trains will still be operated during the disruption and determining the timetable of these trains. Without explicitly taking the rolling stock rescheduling problem into account, we develop our models such that the probability that feasible solutions to this problem exist, is high. The main objective is to maximize the service level offered to the passengers. We present integer programming formulations and test our models using instances from Netherlands Railways.

1. Introduction and motivation

Due to unexpected events, trains do not always run on time. Examples of such events are accidents, rolling stock breakdowns, track damages and bad weather conditions. When a disruption occurs, the timetable, rolling stock schedule and crew roster are not feasible anymore and need to be adjusted. The goal of the models developed in this research is to decide which trains of the normal timetable are still operated during the disruption and to determine the timetable of these trains.

Train delays, such as longer dwell times at stations in peak hours, and large disruptions, such as partial or complete blockades of a track segment, have a different impact on the timetable and require a different solution approach. Literature on *disruption management* is more scarce than literature on train rescheduling and delay management (see for instance Corman, D'Ariano, Pacciarelli, & Pranzo (2009) and Dollevoet, Huisman, Schmidt, & Schöbel (2012) for models that deal with small timetable deviations). We focus on large disruptions, which we define as the situation in which all or half of the tracks of a segment are blocked for at least one hour. Large disruptions occur on average about three times a day in the Netherlands.

We denote with a *complete blockade* the situation in which all tracks of a segment are blocked and no trains can be operated on this segment. Trains at either side of the blocked segment need to reverse at a station before the blockade and take over a train in the opposite direction. If only some of the tracks are blocked, the situation is denoted as a *partial blockade* and limited traffic is still possible. As a consequence of a complete or a partial blockade trains cannot be operated anymore according to the normal timetable and a rescheduled *disposition timetable* needs to be determined.

Jespersen-Groth et al. (2009) describe the general disruption management process of passenger railway transportation companies in Europe. The three main subproblems of the disruption process (timetable adjustment, rolling stock rescheduling and crew rescheduling) are discussed in detail. The current practice at Netherlands Railways, the main passenger railway operator in the Netherlands, is that modifying the timetable, rescheduling the rolling stock and rescheduling the crew are done consecutively. Fig. 1 shows a graphical representation of the current solution approach.

Currently, algorithmic support tools to reschedule the rolling stock (Nielsen, 2011) and crew (Potthoff, Huisman, & Desaulniers, 2010) according to the disposition timetable are tested and implemented. Tests with these tools in different settings have shown that they can provide good solutions within a short computation time. The aim of this paper is to develop models for the timetable adjustment. We will compare the results with disruption scenarios that are currently used in practice. Scenarios exist for different segments of the railway network. The scenarios specify which trains are canceled and how the timetable is adjusted accordingly. In general, they do not allow train delays. A scenario exactly corresponding to the disrupted situation can be implemented immediately.

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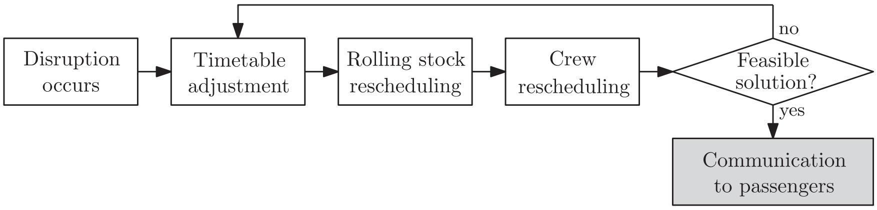

Fig. 1. Current solution approach.

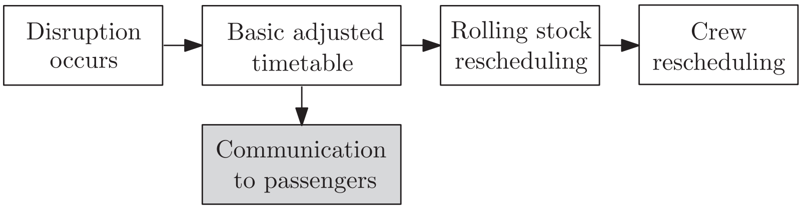

Fig. 2. Alternative solution approach.

However, it is not possible to design a scenario for each potential disruption. Different scenarios may need to be combined or a scenario needs to be adjusted to correspond to the current situation. Hence, the disruption scenarios are not optimal for most situations and we expect that by dynamically computing the disposition timetable the service offered to the passengers during large disruptions can be improved.

The contribution of this paper is fourfold. First, we formulate integer programming models for adjusting a timetable in case of partial and complete blockades. By using these models a tradeoff can be made between different objectives of the railway operator, namely canceling and delaying trains. Second, we solve these formulations to optimality and we present numerical results on real-world instances. Third, we show that by delaying some trains with a few minutes, the number of cancelations can be significantly reduced compared to current practice. Finally, we introduce inventory constraints in the model to determine the disposition timetable.

By introducing these inventory constraints, we take the first step towards an alternative solution approach by taking aspects of the rolling stock rescheduling problem into account when determining a disposition timetable. This alternative solution approach is shown in Fig. 2. An advantage of this approach is that modifications to the timetable can already be communicated to the passengers once the basic plan is determined.

The remainder of this paper is organized as follows. Section 2 provides a more detailed description of the problem we consider. Some literature on related topics is discussed in Section 3. In Section 4 the integer programming formulations for a partial blockade and a complete blockade are presented. We test our models using real-world data from NS. The computational results are given in Section 5. Section 6 gives some conclusions and ideas for further research.

2. Problem description

The railway disruption process consists of three phases. In the first phase the transition from the normal timetable to the disposition timetable takes place, in phase two the disposition timetable is operated, and phase three is the transition phase from the disposition timetable back to the normal timetable.

Let the utilization of the network be defined as the amount of trains running at a specific moment. Fig. 3 shows the utilization of the railway network during the different phases. Before the disruption occurs the utilization is at the normal level. In the first phase the utilization needs to be decreased to attain an utilization level that can be retained during the disruption. During phase two the disposition timetable is operated and, though at a lower level than in the normal timetable, the utilization level is stable again. Phase three covers the recovery from the utilization level of the disposition timetable to the utilization level of the normal timetable.

The first phase is more complex than the third phase because trains start to queue up immediately when a disruption occurs. In the first phase, decisions need to be taken quickly while a high level of uncertainty is involved. Moreover, the decisions taken in this phase can be crucial in the remainder of the disruption process. The transition phase from the disposition timetable back to the normal timetable is relatively easy as more time is available to make the decisions and less uncertainty is involved.

In this research, we focus on the second phase. As input for our models, we use the normal timetable and a forecast of the impact and the duration of the disruption. The output is a disposition timetable, denoting which trains are operated and determining their arrival and departure times.

The type and duration of the disruption are important factors when determining the time horizon and the problem area that we take into account. It involves a trade-off between solution quality and computation time. If the problem area considered is small, feasibility of the timetable outside the problem area is not ensured. However, if the problem area is large, the computation time might be too long. The same reasoning holds for the time horizon. We define a core problem and limit the time horizon and problem area. Note that because of the uncertainty of the duration of the disruption longer time horizons do not yield strictly better solutions.

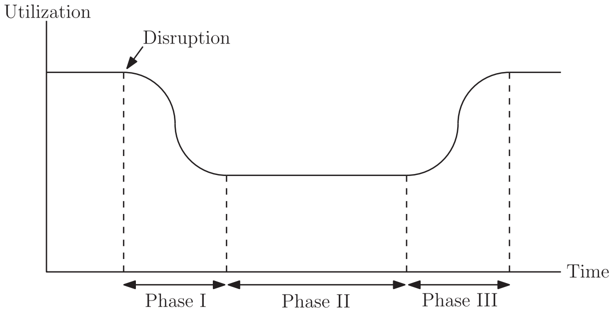

Fig. 3. Utilization during the three phases of the disruption management process.