Determining and Evaluating Alternative Line Plans in (Near) Out-of-Control Situations

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1 Introduction

Every once in a while, railway systems suffer from very large disruptions as the result of power outages, extreme weather conditions or other severe incidents. In the complex Dutch railway system, characterized by intensive use of the railway infrastructure and strong interdependencies between rolling stock and crew schedules, such disruptions easily propagate and accumulate. This ultimately results in an out-of-control situation, meaning that hardly any trains are running in the affected region, even though the required resources (infrastructure, rolling stock and crew) might be available.

This paper explores a newly proposed strategy to cope with (near) out-of-control situations. The core idea of this strategy is to completely decouple the operations in the disrupted region from the rest of the railway network, with the aim to isolate the disruption. In other words, trains and crew are not allowed to move from the disrupted region to the non-disrupted region and vice versa. This paper focuses on the operations within the disrupted region. Here, a simplified line system is required, allowing for smooth operations even when the information about the resources in the system degrades and centralized scheduling is impossible. We address (i) how such a simplified line system can be determined and (ii) how such a line system can be operated in a (near) out-of-control situation. In doing so we increase the scope of railway disruption management, which traditionally involves rescheduling the timetable, rolling stock schedule and crew schedule, by also modifying the line plan and how the system is operated (Jespersen-Groth et al., 2009).

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The contribution of this paper is threefold. The first contribution is a novel line planning algorithm. This algorithm generates profitable line plans that can be operated in (near) out-of-control situation. This is achieved by partially integrating line planning with timetabling and rolling stock scheduling. The second contribution is that we propose several dispatching strategies that can be applied in (near) out-of-control situations. These strategies instantiate a self-organizing railway system that is analyzed with respect to several performance measures by means of simulation. In particular, this paper illustrates that by applying the proper dispatching strategies, the line plans indeed lead to feasible operations, as intended.

2 Line Planning Algorithm

In the usual planning context, line planning is considered as a strategic problem and performed without regard of the timetable (which specifies the departure times of all trains) and rolling stock schedule (which specifies which rolling stock compositions perform the trips), as it is assumed that these problems can be solved in a later planning phase (Kroon et al, 2009). In contrast, in a disruption management context it needs to be certain that the produced line plan is feasible, meaning that a complementing timetable and rolling stock schedule must exist. In other words, to avoid finding ourselves with an infeasible line plan, it is required to consider timetabling and rolling stock scheduling while designing the line plan.

As complete integration of the three problems results in an intractable problem, we decompose the problem in a master and a slave problem according to Figure 1. The master problem amounts to finding the optimal line plan subject to certain restrictions. To increase the probability that the line plan has a feasible timetable and rolling stock schedule, we also include timetabling and rolling stock restrictions in the master problem. The line plan produced by the master problem serves as input for the slave problem. The slave problem checks whether the line plan has a feasible timetable. If affirmative, we terminate the algorithm. If not, we identify a combinatorial cut in terms of the line planning variables. The cut is added to the master, after which the process iterates. Such a decomposition of a problem into a master and a slave problem can be described as the integer variant of Benders’ decomposition (Codato and Fischetti, 2006).

![Diagram of Decomposition of the planning problems into a master and a slave problem.](image)
3 Train Dispatching Strategies

In regular operations trains are operated according to a timetable that specifies the exact departure and arrival times of trains and the routing through stations. Trains are dispatched according to the timetable and adjustments are made to the timetable in case of disturbances or disruption. Conversely, when operating a simplified line system in out-of-control situations, a timetable is not available. Therefore, radically different train dispatching strategies are required. Since out-of-control situations are characterized by a lack of complete and accurate information, these strategies should be simple and local, meaning that only information of the directly surrounding part of the railway network is required to decide what to do next.

The train dispatching strategies that we develop determine what to do next when a train arrives at a station. More specifically, the strategies specify (i) when the arrived train will depart and (ii) where to the train will depart. The information that is allowed to be used to make these decisions are previous departure times at the station and information from trains directly surrounding the station. We develop several of such strategies and test their effectiveness by simulating railway traffic in (near) out-of-control situations.

4 Results and Conclusion

We tested the developed methods on both a small and a large sub-network of the network of Dutch Railways (NS). The results indicate that the proposed line planning algorithm is able to find profitable and practicable line plans in real time. The results also illustrate the necessity of including rolling stock restrictions in the line planning model; not including these restrictions leads to overoptimistic line plans that cannot be operated with the available rolling stock. The conducted simulations show that reasonably smooth operations can be achieved using local coordination mechanisms.

References