# An efficient algorithm for the multi-objective railway timetable rescheduling problem

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Major disruptions, such as the unavailability of railway tracks due to unexpected events (e.g., rolling stock breakdown, adverse weather conditions), occur regularly in railway networks. Due to its complexity, the recovery problem is usually broken up into three consecutive phases: timetable rescheduling, rolling stock rescheduling and crew rescheduling. In this research, we focus on the issue of timetable rescheduling, as the integrated problem cannot be solved in any reasonable time. We consider large-scale disruptions related to the unavailability of one (or more) tracks between two (or more) stations for a known time period. We therefore look at the rescheduling problem from a macroscopic point of view, disregarding details such as track assignments in stations or signalling.

When a disruption occurs in a railway network, the original timetable needs to be updated to a so-called disposition timetable. The latter needs to be conflict-free in terms of operational constraints (e.g., no two trains can be scheduled on the same resource at the same time) and as convenient as possible for the passengers. The objective of the railway operator is to minimize the operational costs, while the aim of the passengers is to receive the best possible level of service. The two goals are usually incompatible: the best possible service for the passengers may also be the most expensive option for the operator. This inadequacy is the key motivation for our work: constructing disposition timetables that take into account passenger satisfaction, while keeping operational costs low. Furthermore, the time to recover from the disruption is considered as a common objective to be minimized by both the passengers and the operator.

In Binder et al. (2017), we formulated the multi-objective railway timetable rescheduling problem as an Integer Linear Program. It minimizes the passenger inconvenience and imposes upper bounds (using epsilon-constraints) on the operational cost and the deviation from the undisrupted timetable. The model was validated on a case study inspired from the Dutch Railway network. Small to medium-sized instances could be solved to optimality in reasonable computational time using CPLEX. However, the number of passengers the model can handle is limited, as every passenger adds another layer of decision variables to the problem. Also, the substantial number of rescheduling options for every train limits the size of solvable problems.

In order to overcome the shortcomings of Binder et al. (2017), we present in this extended abstract a framework to solve the problem more efficiently. An Adaptive Large Neighborhood Search (ALNS) meta-heuristic is implemented to construct the disposition timetable in an iterative manner. Similarly to Barrena et al. (2014), destroy and repair operators remove/add trains from/to the timetable at every iteration of the algorithm. The operators of the rescheduling heuristic are inspired from real-life recovery strategies (such as train cancellations, delays, reroutings and bus or taxi additions) and from optimization methods (e.g., feasibility restoration operators). A passenger assignment model then evaluates the convenience of the incumbent timetable from the passenger perspective. The acceptance criterion of the ALNS framework considers the improvement of the current solution for each objective function in order to address the multi-objectiveness of the problem. The algorithm keeps track of non-dominated solutions using an archive of solutions.

Using this heuristic to solve the rescheduling problem allows for an efficient investigation of its multiple dimensions, as we show on a real case study based on the morning peak hour of the S-train network of Canton Vaud, Switzerland. In the undisrupted timetable, 65 trains run on 8 train lines in a network of 13 stations, moving about 15,000 passengers between 5am and 9am. Every iteration of the heuristic takes less than one second, thus making it practical for the evaluation of several timetables. We compare the disposition timetables provided by the ALNS framework to the ones provided by the exact model (Binder et al., 2017) on a small synthetic instance. The performance of the timetables is similar (for all objectives), but computational times are much lower using the heuristic. On the real-life instance, the ALNS framework provides high-quality timetables, whereas the exact model cannot find the optimal solution in any reasonable time.

The multi-objective railway timetable rescheduling problem is a hard problem and this work proposes a novel heuristic that drastically reduces the computational time needed to solve it. The use of operators inspired from practice allows train operators to easily implement the framework in order to evaluate the trade-off between the multiple objectives when designing a disposition timetable. Further research will focus on the definition of additional operators, and on the inclusion of our model in a broader framework to solve the complete recovery problem.

## Key references

Barrena, E., Canca, D., Coelho L. C., and Laporte, G. (2014). “Single-Line Rail Rapid Transit Timetabling under Dynamic Passenger Demand.” *Transportation Research Part B: Methodological* 70: 134–50.

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