The impact of platform optimization in train routing problems

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1 Introduction

Providing a good passenger service is one of the main tasks of a railway infrastructure manager and a passenger railway operator. Among others, a major concern is to bring all passengers from their origin to their destination as soon as possible and in a travel time as close as possible to the published travel time. Although the prescribed schedule is conflict-free, there always are unavoidable disturbances that cause conflicts; for sure around large cities or, more general, in the neighborhood of railway bottlenecks. To assess the performance at a bottleneck, we will use the following definition of local robustness: "A railway system is locally robust whenever the real total travel time of the passengers in the considered area is minimal in case of small disturbances." This is a slightly modified version of the definition discussed in detail in [2] for robustness of a whole network.

In the light of this definition, we try to improve the local robustness of the railway system on the compact and highly used network of the Brussels' area, the bottleneck of the Belgian railway system. Trains coming from all over the country run through Brussels and dwell at the three major stations, i.e., North, Central and South, forming a crisscross of lines with many intersecting routes in the station area as a consequence. In total there are about 80-85 trains per hour during rush hour that travel along the 11 minutes passage through Brussels with as result a nearly saturated capacity utilization. The paths of all these trains need to be merged from the larger outer stations to the six platforms of the Central station where the average dwell time is about 1.5 minutes instead of the planned 1 minute.

As the amount of trains that depart from Brussels without delay is very limited, the Belgian railway infrastructure manager Infrabel wants to know how to improve the train routing or more generally, the performance, in this area. In our research, we focus on the offline optimization of the local railway system. Therefore, the timetable and the train routing through the whole area are considered to be flexible during the planning phase. In a previous study, for which Infrabel requested that the platform allocations was rigid with an eye to short term improvements, we have proven the effectiveness of our approach [3, 4]. However, in this study, the impact of platform flexibility is to be evaluated. We want to analyze what would be the impact on local robustness of (offline) changing the currently assigned platforms in the stations.

2 Procedure

Due to the specific situation in the Brussels' area, there are numerous acceptable routes (including platform choices) for each train. That is why, in this research, we try to find the allocation of routes to trains that leads to the fewest possible conflicts when disturbances arise during execution of the schedule. However, not only the route choice or the chosen platforms influence the chance of a conflict, also the local timetable that determines the buffer times has its influence. Note that due to the high capacity usage, there are no running or dwell time supplements inserted in the local schedule for the Brussels' area.

The idea of our method is to iteratively solve the train routing problem for the Brussels bottleneck network and to successively improve the local timetable by allowing some shifts in arrival and departure times. The train routing problem is solved using a node-packing approach. In contrary to (e.g.) [1, 5], our approach is provided with an objective function that considers all pairs of trains and not only the most vulnerable ones. Thanks to a thorough preprocessing phase in which the amount of candidate routes is decreased with about 90%, the train routing problem can be solved to optimality in less than 5 seconds. Note that changing the platform or the timetable is not allowed in this phase.

The next step of our iterative approach is the improvement of the local timetable. From the outcome of the train routing module, the minimal time span between any two trains that pass through the Brussels' area is known. In the timetabling module, the arrival and departure times of the trains will be modified in order to increase -one by one- the most critical timespans between two possibly conflicting trains, without increasing our objective function value. This objective function is the same as in the train routing module and minimizes the sum of all the inverse timespans between two trains. As we consider all pairs of trains in our objective function, a full assessment between the increase and decrease in timespans is made for each timetable change. The procedure of changing the arrival and departure times of one train at a time is embedded in a tabu search environment.

After the train routing problem and the timetable optimization phase have ended, the procedure restarts unless a local optimum is reached. On average only a few iterations are needed before this happens. For more details of the full procedure, we refer to [3, 4].

The performance of this iterative procedure, without changing the platforms, is quite good. The simulation results indicate an average improvement in robustness of 4%, a decrease in knock-on delay of more than 25%, and a reduction in the expected number of trains that are confronted with conflicts of more than 25%. The computation time is limited since a local optimum is reached in about 20 seconds for all scenarios [4].

Now that the case with fixed platforms is solved, the question is raised how the results will improve if platform flexibility is added. At the moment of writing, full platform flexibility at the Central station is inserted in the model. However, due to the high capacity usage, feasible platform alternatives are limited and no performance gain is obtained for the current schedule. If the amount of trains is reduced, i.e., by removing all trains that pass platform 1 in the Central station, the robustness of this particular instance can be further improved from a 7.6% improvement after the iterative procedure has reached its local optimum to 9.6% when there is no fixed platform in the Central station. To further increase the robustness of the area, platform flexibility in the North and South station is currently added. Furthermore, the interaction between the routing solution, the timetabling module and the platform allocation and their influence on the minimal timespan between any two trains is analyzed.

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