Improving the Robustness of the Railway System in Brussels

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Abstract

In order to improve the robustness of a railway system in station areas, this paper introduces an iterative approach to successively solve the route choice problem in station areas to optimality and to improve this solution by applying some changes to the timetable in a tabu search environment. Using a discrete event simulation model, the performance of our algorithms is evaluated based on a case study for the Brussels' area. The railway network of the Brussels' area is introduced and its relevance is emphasized. Computational results indicate an improvement in robustness of about 10%, a decrease in knock-on delay of more than 15%, and a 25% reduction in the number of trains that are confronted with conflicts.

Keywords: train routing problem, railway timetable, robustness, bottleneck scheduling, integer linear programming

Providing a good passenger service is one of the main tasks of a railway infrastructure manager as Infrabel and a railway operator as there is NMBS. Among others, a major concern is to bring all passengers from their origin to their destination 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, a definition of robustness of a railway system is used: A railway system that is robust minimizes the real total travel time of the passengers, in case of small disturbances.

In this paper, the timetable planning for and the route choice problem in bottlenecks is considered. When a train approaches a station, it has a designated route towards its platform. That route is determined in advance and can be changed in real-time to avoid conflicts that are caused by all kinds of delay. In general, the assignment of routes through railway station areas happens after the timetable is created. Most often, planners are only concerned with finding a feasible solution and do not account for robustness while designing an appropriate route choice solution. In this paper, this approach is successfully enhanced with a robustness objective.

Based on an initial timetable, the route choice problem is solved using an independent-set method with a conflict graph and an objective function that minimizes the time span between any two trains. The obtained route choice solution is used as input in the next step, a tabu search algorithm that, one by one, tries to increase the smallest time span in the schedule. Both modifying the timetable or altering the routes through the station area can change the time span between two trains. That is why we increase the robustness by alternating between the route choice module and the timetabling module until convergence is reached. On average, this requires only a few iterations.

The compact and highly used network of the Brussels' area, the bottleneck of the Belgian railway system, is used as a case study. 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 making the capacity utilization nearly saturated. 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.

A discrete event simulation model is used to evaluate the performance of the presented algorithms on our case study. In correspondence with the current situation, an improvement of about 10% in robustness and a decrease in knock-on delay of more than 15% is reached. Moreover the amount of trains that get delayed due to conflicts within the Brussels' area is reduced by 25%.
Concluding, it can be said that using a robustness objective during the scheduling phase helps to considerably improve the performance of the resulting timetabling and accompanying route choice solution.