Passenger robust timetables for dense railway networks

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This dissertation deals with passenger robust railway line planning, timetabling and routing in dense railway networks. The connecting thread throughout the thesis is to deliver the best possible service to railway passengers. Therefore, it focuses on minimizing the total travel time in practice of all passengers, i.e. in case of frequently occurring small delays.

The dissertation presents how the performance of an existing timetable and routing plan can be improved. By using the numbers of passengers that dwell on, leave or board the train and the distribution of buffer times between the trains, the impact and probability of the propagation of delays can be estimated. This information can then be used to improve the planning. If trains with many passengers are made less eligible to delays and more time is provided in the planning for trains that are recurrently delayed, this will have a positive effect on the performance of the railway system. This methodology is implemented as a matheuristic and is tested on Brussels complex station area.

Furthermore, a methodology to construct a timetable and routing plan from scratch is proposed and is also tested on Brussels complex railway area. This methodology focuses on the bottleneck of a railway network, since the performance of the bottleneck is often determining for the performance of the whole network. A bottleneck is characterized by a complex infrastructure layout and dense train traffic. First an integer linear programming model assigns the trains to routes. If train routes cross each other less, propagation of delays will be reduced. Therefore, the objective of the routing model is to minimize the number of train routes that cross each other without assigning unneces-

sary detours. Secondly a mixed integer linear programming model constructs the microscopic timetable (on the signaling level). Longer time margins between trains reduce the domino-effect of propagation of delays. Therefore, the objective of the timetabling model is to increase the buffer times between trains, taking the numbers of possibly affected passengers on the trains into account. Both models assume that the line plan is already determined and all the trains have to be planned. Furthermore, once the routing is fixed, all the travel times are fixed, so the timetable does not affect the planned travel times of the passengers. Another assumption is that the timetable is cyclic and thus all the trains have to be planned in one period of the timetable. Monte Carlo discrete event simulation shows that the planning resulting from the routing and the timetabling model succeeds in assuring short and reliable passenger travel times. The thesis shows that if the simulation output is used for adjusting the supplements in the travel times of the passengers, a new planning constructed with the routing and the timetabling models further improves the passenger travel time in practice. The information that is used from the simulation output consists of the propagated delays, the recurring delays and the used and non-used supplements. The methodology thus works iteratively and consists of the exact routing and timetabling models, a simulation phase and a phase in which the supplements are adjusted. The case study on Brussels shows that the planning constructed with the presented methodology reduces the passenger travel time in practice with up to 17%.

However, not only the timetable determines the quality, but also the line plan and the network restrictions do. This PhD thesis also proposes a heuristic method that integrates line planning and timetabling in order to improve the service offered to the passengers. The line plan and timetable are constructed from scratch and mathematical statements are presented and proven on why some line plans do not allow a feasible timetable. The focus is here both on the operator cost and on the passenger travel time in practice. This approach was successfully applied on the S-tog network of Copenhagen.