Studying robustness by simulation in DSB S-tog. Two case studies

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1 Abstract

Two independent studies of robustness in plans of DSB S-tog are presented. They are of a very different level of detail and they differentiate in their main goals. First a simulation model of low detail is presented. This model concentrate only on train circuits and is ideal for quick inclusion of e.g. various recovery methods. The second model presented is a work in progress. This model is very large and it is not suited for making quick adjustments. It qualifies in beeing suited for making overall robustness evaluations of both crew and timetable plans on future scenarios.

1.1 Robustness of timetables

The first case study is the study of the effect on robustness when covering the S-tog network with various timetables with different characteristics. The main characteristic of the model is that rolling stock is simulated as it circulates according to the timetable. Drivers are assumed available for all departures. Delay distributions are constructed from historical data and applied to the simulation on station level. Buffer times in the model are present only on terminals, i.e. lost time can be gained only when trains arrive at their terminals. The test setups are worst case scenario of driving peak hour demand all day. It is therefore possible to assume that no changes of train composition occur and as a consequence this is not included in the simulation model.

The first case study also investigates the effect of a variety of recovery method when employed individually on a disrupted operation. Specifically the recovery methods implemented in the simulation model are *Insertion of On-time Trains from the Central Depot*, *Early Turn-around* and *Cancelling Train Lines*. These methods were chosen because of their different characteristics w.r.t the direct decreasing of delays or the increase of headways.

The timetables tested are mainly timetables used in operation on the S-tog network. However, also timetables that might be interesting for operation in the future were tested. Finally, two timetables were included in the tests that represent entirely new suggestions for covering the S-tog network.

Results show that the necessary size of buffer times on terminals seen with respect to the benefit on robustness is limited. Tests with different sizes of delays show that small delays have a significant negative effect on robustness when occurring together with large delays as opposed to the small delays contributing with almost no effect on robustness when they occur alone. Results on comparing the different timetables with and without the recovery methods are also presented. The expected results in this case were that a high number of train lines in the network would result in a decreased regularity. This is confirmed in most cases. For a few timetables, inserted time buffers makes the number of lines less important to the value of regularity. The recovery methods are compared on their stand-alone efficiency seen with respect to regularity and reliability.

1.2 Robustness of Crew plan vs. timetable

The second case study is work in progress on the simulation tool SiMS - Simulation of Crew at S-tog. The simulation tool simulates the trains in circuit according to the timetable where trains are covered by the drivers. The combined effect of simulating over both timetable and crew plan enables a more detailed evaluation of the effect of planning on the robustness of operation. In the simulation model delays occur on both trains and drivers. All delay distributions are based historical data.

SiMS simulates the circuits of trains without marshalling and the process of covering each departure with drivers. Drivers are available at crew depots only. SiMS is basically run on the tasks given by the crew plan. The trains are running in circuits according to the train sequence file as transporters picking up drivers. In that way the departures given by the timetable is covered.

As a train can only run in operation when a driver is present, simulation of the covering train-tasks is included. For this purpose, reserve drivers are available in a predefined schedule over the day. Tasks are covered by employing a set of dispatching rules that prioritize the use of vacant scheduled drivers or reserve drivers. One dispatching rule could be the swapping of tasks among drivers to cover more tasks in total. If no possible solution is found, an imaginary driver is used for covering the task. An imaginary driver is equivalent to an extra reserve. In reality, when no vacant scheduled driver or reserve driver can be found, the train is cancelled.

All of the S-tog network is included in SiMS. Hence the amount of data necessary is excessive. First of all, the crew plan with tasks of each single driver must be available. Also, the timetable at the detailed level of all departures during the day is necessary. In the timetable data the minimum driving times must also be included. For connecting the train numbers and the tasks of drivers the train sequences are included. For each station, information is given on the dwell time, minimum dwell time, number of available platforms, the probability of delay and a delay distribution variating across the day. A list of the working hours of reserve drivers is also included.

SiMS will make it possible to quantify robustness of the crew plan when analysing the results on e.g. regularity, employed reserve and imaginary drivers and violations of work rules. Furthermore, it will make evaluation possible on future timetable or crew scenarios.