Testing the stability of the rail network

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Abstract

The Dutch rail network system is one of the busiest networks in the world. Small delays can have large implications elsewhere. Railned, the Dutch capacity manager for rail infrastructure, uses timetables for the specification, development and allocation of the capacity of rail infrastructure. For a number of scenarios different timetables or timetable-structures are compared on a set of criteria. One of those criteria is the stability of the network. To measure the stability and the sensitivity for disturbances, Railned has developed the network simulation tool SIMONE, in co-operation with Incontrol. The tool is used in a number of studies. This article describes some case studies to demonstrate the kind of problems that are investigated. The cases are used to determine the use of SIMONE in the Railned Capacity Allocation department. The first case investigates the influence of a local correspondence in Weesp. The waiting time for a departing train in this station was varied, both positive and negative effects could be demonstrated. The second case shows the effects of introducing extra freight trains using the triangle Den Bosch-Tilburg-Eindhoven. Most trains routed from the harbour of Rotterdam to Germany pass this triangle. The results show expected and unexpected bottlenecks in the network. The third case evaluates the introduction of a switch in the station Hengelo. With this new switch a change of the timetable is possible to solve a bottleneck in a neighbour station. With SIMONE it could be demonstrated where in the network benefits and disadvantages occurred.

The results were reason to investigate future extensions and development of SIMONE.
Railned is the capacity manager for the Dutch railway network and advisor of the Dutch government in this matter. Railned employs the DONS system[1] to decide where to develop new railway infrastructure and to allocate network capacity to train operating companies in the form of timetables. SIMONE was designed and realized in cooperation with Dutch simulation consulting firm Incontrol Enterprise Dynamics.

1 Introduction

Railned is the organisation which performs capacity management of the Dutch rail infrastructure for the Dutch government. Two of its departments assess this capacity for the nearby and the far future. Railned Capacity Planning advises where to develop more capacity by building new infrastructure or by using better control systems. Railned Capacity Allocation decides how to divide the available capacity between different operators for the coming year. When executing these tasks both the departments need to compare and judge two or more timetables on stability. In the Dutch situation a timetable is a regular interval timetable for a heavily loaded and interconnected network. To investigate the stability Railned has constructed a method and, in co-operation with Incontrol Enterprise Dynamics, a simulation tool (SIMONE) to test and compare different timetables on stability. First the tool is used in strategic studies for the Capacity Planning department. To demonstrate the possible use of SIMONE for the Capacity Allocation department, three case studies were conducted. These studies are described in this article. Besides the application within Railned, SIMONE is also used by the Product Development Department of the Dutch railways.

2 Stability test

In strategical and tactical capacity studies different variants of a combination of rail infrastructure and a timetable are compared on a set of criteria. These criteria are transport size, travel times, safety and environment issues, costs and quality. The judgement of quality is mostly based on expert knowledge and experience. Planners have the need to support their judgement with an objective and transparent method. One of the issues playing a role in the quality is the stability of the timetable.

2.1 Timetable stability

A timetable consists of a set of planned processes, all described by process times, for instance the running times and dwell times for trains. Trains are dependent of each other by shared use of infrastructure, passenger correspondences or turnaround times. These dependencies are a potential source of delay propagation. To make a robust timetable recovery times are added to
and between the planned processes. These recovery times make it possible that a timetable can handle minor disturbances. Minor in this context means that no interventions of the traffic control, i.e. rerouting or cancelling of trains, are needed to prevent the plan from falling into chaos. The robustness or stability can be measured with a set of performance indicators:
- delayed trains (by different causes)
- punctuality
- used recovery-time (slack in running- and dwell-times)
- the ratio of introduced disturbances related to resulting delays
- broken connections
- delay absorption

Figure 1: Example network performance (punctuality)

Also we want to know how elements of the networks score on selected indicators like in the figure above.

To test the stability there are different kinds of disturbances which can be added to the timetable. One can vary the size, the probability, the time period
and the place(s) of a disturbance. To introduce daily variation a so-called noise disturbance is used. All planned processes are affected by a disturbance. For examining a bottleneck more specific disturbances, eventually combined with a noise-disturbance, are introduced. Delay propagation can take place by defined dependencies between trains.

2.2 Simulation tool

To conduct the stability test for a network-wide timetable, SIMONE was made, a Simulation Model for Networks. It supports a rough-to-fine approach According to this approach, the network is viewed from a high abstraction level. The results on the network level could be the starting point for conducting locally oriented studies.

After the construction of the timetable, the definition of disturbances and simulation run parameters, simulation models are built automatically. Users can focus on defining the right experiments and analyzing the results. Having the possibility of simulating the network-wide timetable planners are supported in:

- development and improvement of objective design requirements
- determination of the relation between design standards and stability
- the comparison of timetable quality and the evaluation of a timetable
- tracing bottlenecks in the infrastructure and the timetable
- obtaining more knowledge and learn to understand more of the complexity of the network-wide timetable

SIMONE [see also 2] is connected to the DONS-system [1], which generates regular hourly timetables on a country- or network wide scale. Recently the tool is updated completely with a new simulation engine and user interface.

3 Case studies

The Capacity Allocation department has two sections who use and judge timetables. One is the section which judges the timetable for the coming year. This section also integrates transport demands, train paths for transporting passengers, freight or maintenance activities. The other section judges small-scale changes in the timetable and the infrastructure capacity, coming from known bottlenecks or building activities. They test the impact these changes have on the timetable. One of the criteria used is the quality of the timetable. Nowadays potential bottlenecks are identified based on planners experience and performance data of realised timetables. There is a need to support the planners judgement with a method which is transparent and objective. This support could be given by conducting a stability test with SIMONE. In a pilot the use of SIMONE is demonstrated for three case studies. These cases represent typical problems for this department. In short the three cases are described. In all cases all trains who pass the investigated infrastructure are taken into account. Other parts of the network are moved (automatically) from the model.
3.1 Case 1 Correspondences in Weesp

3.1.1 Situation
The first case is a study which investigates the variation of the waiting time for a passengers correspondence in Weesp. A correspondence means that the difference between the arrival time of the first train and the departure time of the second train has to be no more than 3 minutes. In case of disturbances the correspondences are a potential source of delay propagation. For a situation with disturbances there is a waiting time for the departing train. In this study the objective was to determine the influence of the waiting time on the network performance. The waiting time is varied, there is a variant with no waiting time and one with a waiting time of three minutes is defined.

The station Weesp is part of one of the busiest parts of the Dutch rail network. The correspondences are defined each half hour between trains which run from the direction of Amsterdam to Lelystad and from the direction of Schiphol to Amersfoort (v.v.), see figure 2. Fifteen minutes later they are defined between trainlines Amsterdam-Amersfoort and Schiphol-Lelystad.

Besides the train lines which act in the correspondences there are 4 intercity trains and two regional trains passing Weesp in both directions in the timetable.

3.1.2 Experiments
In all cases first an experiment without disturbances is made to determine that the model does not generate delays due to input or model failures. In following experiments disturbances are added in three different ways based on the planners experience.
- To all running- and dwell times in the network (noise-disturbances) continuously.
- to all running times and dwell times or for two train lines heading west continuously.
- as above but for a period of two hours

3.1.3 Results
After simulation of both variants the results showed that the network was partially sensitive for variation of the waiting time. In case there is no waiting time the positive effect is an increase of the punctuality. A negative effect is a decrease of reached correspondences. Both these effects could be made clear and weighted.

3.2 Case 2 Triangle Tilburg-Eindhoven-Den Bosch

3.2.1 Situation
The second case handles a situation where 6 freight train paths are added to the timetable. The paths are needed between Kijfhoek, the main marshalling yard, and Germany. On their route they pass on of the sides of the triangle between the stations Tilburg, Eindhoven and Den Bosch. For the situation with and without these extra paths the stability of the network is examined.

3.2.2 Experiments
For this case a set of increasing so-called noise disturbances was defined. Noise means that all running and dwell times are affected with a certain chance.

3.2.3 Results
The adding of the 6 extra trainpaths causes a 10% higher average delay in the network. Punctuality was decreased, mainly caused by smaller headway times on the tracks. By showing a network representation differences between the two variants and potential bottlenecks could be shown. Some could be accounted for directly from the knowledge of the network, others were more surprising.

3.3 Case 3 Extra switch in Hengelo

3.3.1 Situation
In the third case there is a proposal to build an extra switch in the station of Hengelo. In Hengelo a correspondence is defined between two trainlines. One of the trains has a short turnaround time in Oldenzaal without recovery time, in fact it is too short. In the opposite direction the train acts again in a correspondence with the other trainline. In the current situation the trains use the same switch at their departure in Hengelo, therefore the departures of the trains have to follow each other with a difference of 2 minutes. The new switch makes it possible that the two trainlines exit the station Hengelo simultaneously. A small timetable...
change, the earlier departure in Hengelo, makes it possible to introduce recovery time in the turnaround station Oldenzaal.

3.3.2 Experiments
The timetable was disturbed by increasing dwell times with values drawn from an exponential distribution. Running times were lengthened for different probabilities by adding a relative part of their value.

3.3.3 Results
The results, illustrated by figures 3 and 4, show that the train with the earlier departure passes on more delays through Hengelo (fig. 3) and also that less correspondences are realised (fig. 4). This is caused by the change of the dwell time in Hengelo. In Oldenzaal, the turnaround point, there was an increase of punctuality. This benefit is caused by the ‘shifted’ recovery time in the timetable.

Figure 3: Delay propagation in Hengelo.

Figure 4: Broken correspondences in Hengelo.
In the overall results the differences were very small. The new switch does not bring better performance other than on a very local scale. The (new) insight in the local differences must be weighted with other criteria (like the number of passengers affected by delays in the different stations) to make the right decision.

4 Conclusion

The case studies show that application of the stability test and SIMONE can be a useful tool for the Capacity Allocation of Railned. The judgement on timetable stability can be made in objective and transparent way. Positive and negative effects and potential bottlenecks are made clear. The results contain both expected effects and unexpected effects. The shown effects can be declared with the planners knowledge of the timetable and the network. With the development of SIMONE Railned has introduced a way to support the decisions made for new infrastructure plans and integration of timetables. The results were reason to start a study on how the tools can be integrated in the capacity allocation process and which extensions and modifications are needed.

References
