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SIMONE: LARGE SCALE TRAIN NETWORK SIMULATIONS

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ABSTRACT

This paper describes the architecture and potentials of Simone. Simone is a simulation environment to generate, simulate and analyze complex and large scale train networks. The purpose of Simone is to (1) assess the robustness of timetables; (2) determine the stability of the network; analyze causes and effects of delays; (3) improve timetables, by determining the relations between design standards and robustness of the timetable; (4) detect and quantify bottlenecks in a train network and (5) quantify delays for different lay-outs of railway infrastructures

A strong feature of Simone is the ability to automatically generate ready-to-use network simulation models from databases. First, the concepts are described, then two case studies are presented. Last, the paper ends with a short evaluation of the use up till now and forthcoming developments for Simone.

1 INTRODUCTION

1.1 Rail Networks

The Dutch rail network system is among the world's most heavily loaded and highly interconnected train networks. There are many dependencies in the network, many correspondences and capacity is scarce. The network-wide timetable changes yearly, due to a variable market demand of freight and passenger transport. Furthermore, the network is continuously subject to changes in order to cope with the increasing market demand. To support the decision making where to develop new railway infrastructure and how and to allocate network capacity to train operating companies, Incontrol and Railned have developed a simulation tool for large scale rail networks, called Simone.

Railned is the organization, which performs capacity management of the Dutch rail infrastructure for the Dutch government. Incontrol Enterprise Dynamics is a worldwide simulation consultancy firm and developer of the simulation package Taylor Enterprise Dynamics.

1.2 Stability of Timetables and Networks

Railned uses the system DONS (Hooghiemstra 1996) for making hourly patterns of a timetable and to generate a number of timetables for different scenarios. By this possibility, the need to compare the quality of timetables on a set of criteria arises. One of the criteria is the stability of the timetable. Due to the complexity of large scale train networks, relations between design standards and robustness are not available in an objective method.

1.3 Network View

In general, to the best of our knowledge, most train simulation models developed so far, are limited to a detailed set of elements of a train network, for instance one station, a rail section or a line (Huisman et al. 1998). It is difficult to define the right assumptions on the boundaries of one location. Quality depends on network properties, such as correspondences between trains and use of shared capacity. It would be better to look at the whole network. When needed zooming in on smaller "local" networks is possible. Inspired by studies with FASTA (Noordeen 1996), Simone also operates at network-level and uses a higher abstraction level of detail.

When the entire network is taken into account, it is possible to compare simulation models with different problem boundaries. Hence, is it possible to answer the question how much of the entire network must be taken into account to be able to grasp the essentials of local problems.

2 CONCEPTS

Central in a Simone Simulation Model is the timetable, which drives the activities that trains perform. Trains arrive at stations, depart from stations and pass stations at a given time and use connecting tracks to travel between stations. When there are no disturbances in a Simone Simulation Model, all trains will run according to the timetable, there are no conflicts between trains and no slack is used. Delays are propagated by defined correspondences or by sharing infrastructure capacity.

Disturbances act on either running times or dwell times and are said to introduce primary delays. The user has total freedom in specifying the characteristics of the disturbance level and where (which part of the network and what kind of trains) and when (in time) the disturbance(s) act on. To reduce the delays the processes in the timetable contain slack. When a train is delayed it deviates from its schedule and starts having conflicts with other trains. Because of these conflicts, others trains are delayed as well. When the cause of a delay is a conflict with another train, it's said that this is a secondary delay. In Simone there are seven different causes of secondary delay. Mainly those causes are due to conflicts of sharing infrastructure capacity or due to specified correspondences.

3 ARCHITECTURE AND FUNCTIONALITY

Figure 1 shows the Simone component architecture. Simone is a simulation environment that consist of an integrated set of applications that all work seamlessly together:

- Incontrol Center
- Simulation Library
- Infra and Timetable Database Interface
- Automatic Model Generator
- Simulation Models
- Scenario Manager
- Output Generator
- Output Analyzer and Manager

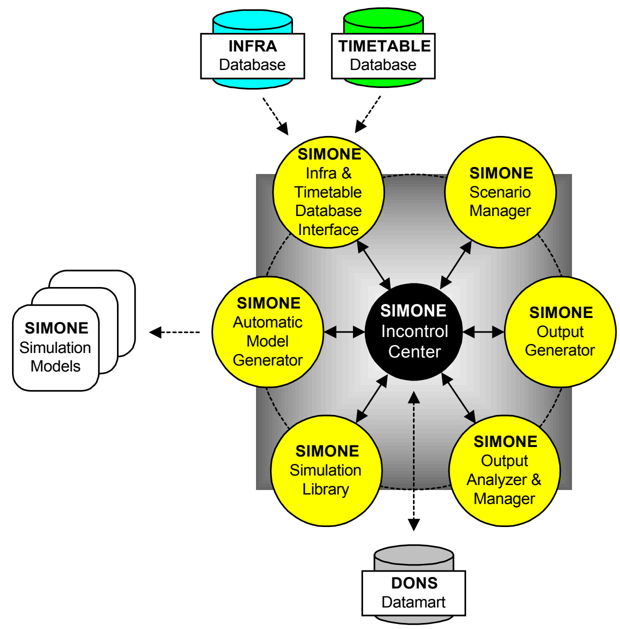

Figure 1: Simone Incontrol Center

Together with the Simone Architecture, a specific Simone methodology has been developed for conducting studies with Simone.

3.1 Simone Incontrol Center

The Simone Incontrol Center (see Figure 2) is the core of Simone simulation environment from where everything is controlled. Information is stored in the Oracle database of the Railned DONS system for later retrieval. This information ranges from experiment setups, to user annotations and to the output of experiments.

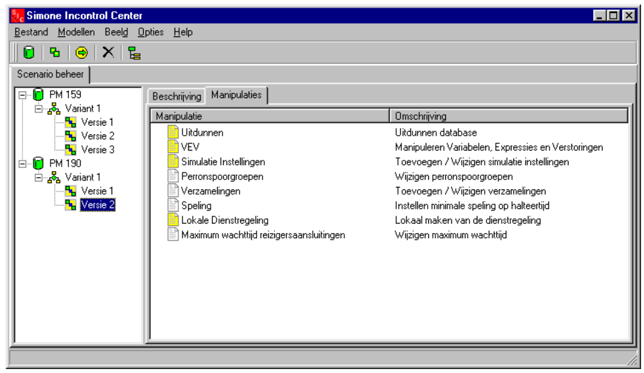

Figure 2: Simone Incontrol Center

3.2 Simone Simulation Library

The Simone Simulation Library is a collection of six simulation building blocks or so called modules. The Simone Simulation Library is used to construct a Simone Simulation Model. See Figures 3, 4 and 5.

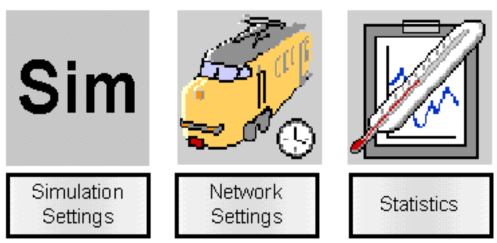

Figure 3: Simone Simulation Library: Simulation Settings, Network Settings, Statistics

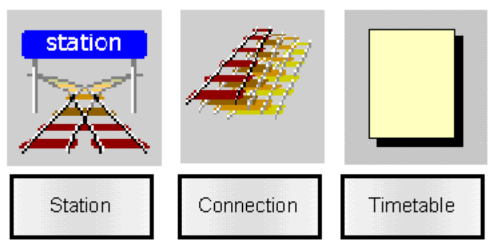

Figure 4: Simone Simulation Library: Station, Connection and Timetable

Module	Purpose
Simulation Settings	Simulation Specific Parameters
Network Settings	Network-wide properties, disturbances, etc.
Statistics	Specification of the performance indicators for the output
Timetable	Train activities including available slack
Station	Stations, junctions and other point relevant to the timetable
Connection	User definable number of free tracks connecting two stations

Figure 5: Simone Simulation Library

Two of these modules, the Stations Module and the Connection Module are used for constructing the infrastructure network. Almost always the modules are automatically filled with data from the DONS system without user input. When needed, modules allow for detailed extra input . Examples are different types of capacity constraints, possible conflicts between trains at a station, the correspondences between trains (either passengers or rolling stock), the bi-directional use of tracks, etc. The specification of this information can be done from a high level of abstraction down to a low level of abstraction.

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The timetable contains a collection of running-times, dwell-times, slack and the track allocation for the connecting tracks. When simulating, the timetable headway times are taken into account.

3.3 Simone Infra and Timetable Interface

Simone is capable of generating simulation models based on information in databases containing information about infrastructure and timetables. Currently, Simone is designed for interfacing with the databases of Dutch Railways, the so-called DONS system. The DONS system contains production models. Based on a model description of both the railway network infrastructure and the traffic demand, a cyclic timetable is generated.

3.4 Simone Automatic Model Generator

A strong feature of Simone is the possibility to generate simulation models without user intervention. The only task that the user has to do, is go through some screens to specify model settings. A Simone Simulation Model consists of instances of the modules of the Simone Simulation Template. Using the Simone database interface, information is extracted from infra and timetables databases and is used to construct a Simone Simulation Model. After that, the model is ready to use.

3.5 Simone Simulation Models

A Simone Simulation Model contains a graphical representation of a train network. Each station and each connection of the network is a separate module in the simulation model. A running Simone Simulation Model shows trains running on the network. The color of each train represents is type (Inter city, Freight Train, High Speed Train, etc.) and its delay. Both Railned and NS Reizigers use Simone Simulation Models of the whole of the Netherlands' rail network. This means almost 600 stations (including junctions) and about 1100 tracks. About 350 trains are running during a regular hourly timetable. These simulation models are big in size by any standard. See Figure 6 and 7 for screen dumps.

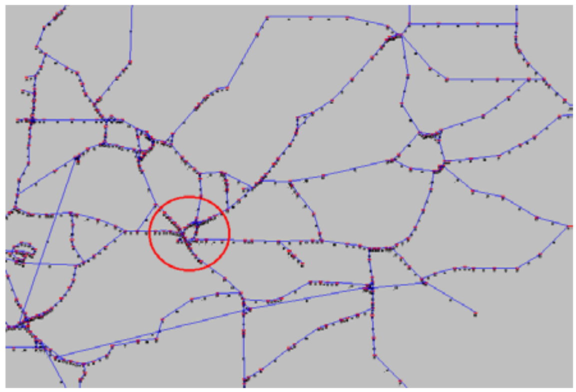

Figure 6: This is a Screen Dump of a typical Simone Simulation Model. The Re Circle marks an Area around Utrecht Central Station; one of the busiest Stations in The Netherlands. This Area is enlarged in the next Picture.

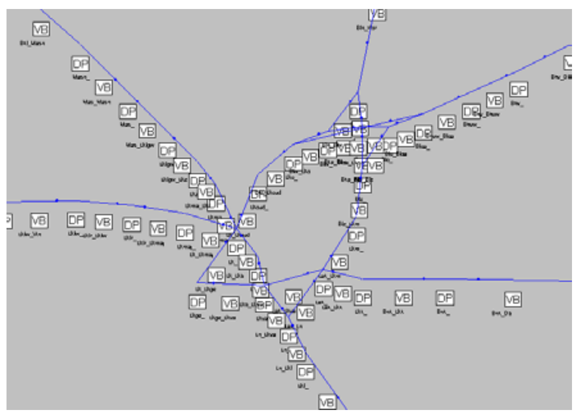

Figure 7: This picture shows the Red Circled Area of the previous Picture. The Stations (DP) and the Connections (VB) Modules are clearly visible.

3.6 Simone Output Generator

An important feature of Simone, is that statistics can be gathered of any selection of infrastructure and trains in the model. This can range from the whole model + all trains, down to a specific station and a specific train. In this way, it is possible to get insight on a very aggregated level down to a very detailed level. The Simone Output Generator collects all output of simulation runs and automatically creates reports. A few examples of performance indicators are:

3.6.1 Network Diagrams

A key feature is the possibility to make so-called network diagrams, as shown in Figure 8. The performance of a network as a whole or a comparison between two variants can be displayed in one single diagram. Figure 9 demonstrates this in terms of the punctuality. Other types of network diagrams showing other forms of output are also possible, such as the amount of broken correspondences, the use of slack, etc.

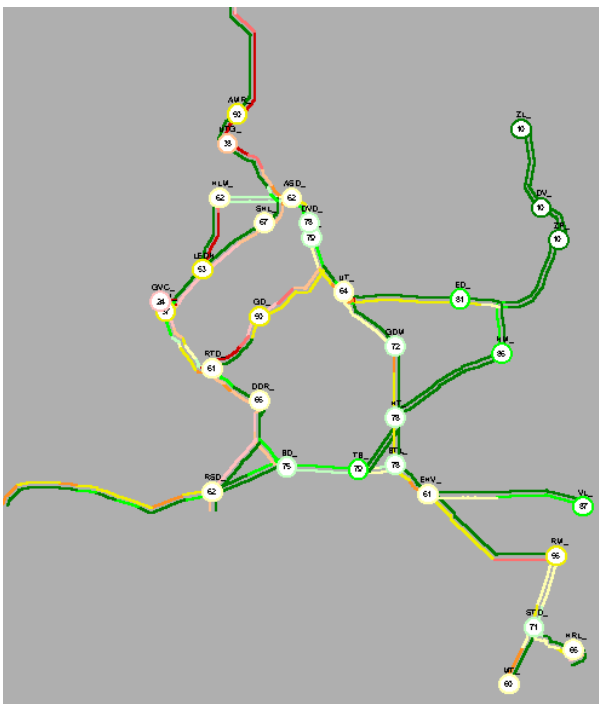

Figure 8: A Network Diagram. The Colors denote the Amount of Delay on that Part of the Network

3.6.2 Punctuality

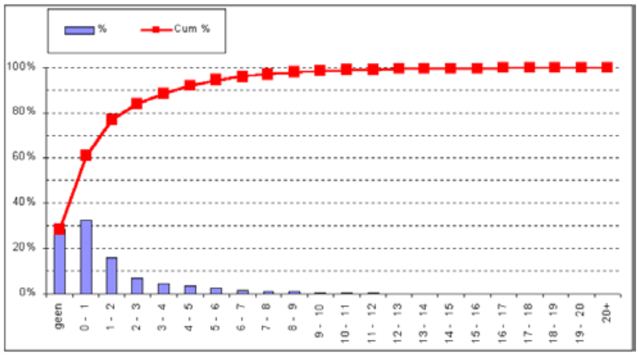

Figure 9a: The output of a Single Experiment showing the Punctuality of Trains on a Selected Part of the Network. The x-axis shows the Amount of Delay. The first Category represents Trains having no Delay at all.

3.6.3 Relationships Between Various Output Parameters

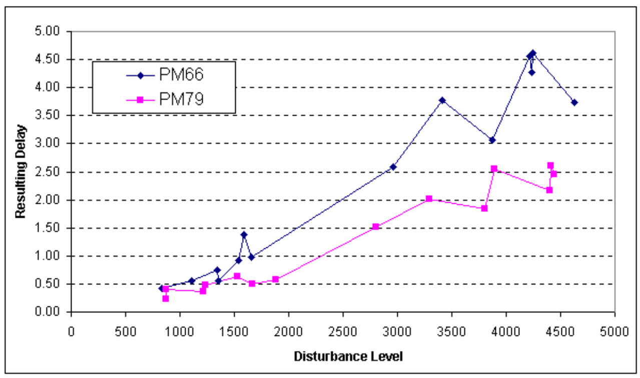

Figure 9b: This picture shows the Robustness of two timetables for different Disturbance Levels and is a Combination of several Experiments.

3.7 Simone Output Analyzer and Manager

The Simone Output Analyzer and Manager is a tool for the analysis of the output of Simone Simulation Models. With this tool it is possible to compare the performance of several scenarios, assess the relationship between causes and effects, and so on.

3.8 Case Study 1: Strategic Planning

Each year, A new train timetable for the whole country is designed and implemented. Actually, the design of a new timetable can take place years in advance of the actual implementation of the timetable. Such a strategic study takes into account future transportation needs in terms of train service and future infrastructure.

Currently, Simone is used in a special project of the Ministry of Transport, on the effects of investments in rail infrastructure in the past and in the future. Simone is used to assess the stability and robustness of different network configurations and to compare different configurations on a network-scale. See Figure 10. The obtained results enlarged the insight of planners in the properties of the different configurations.

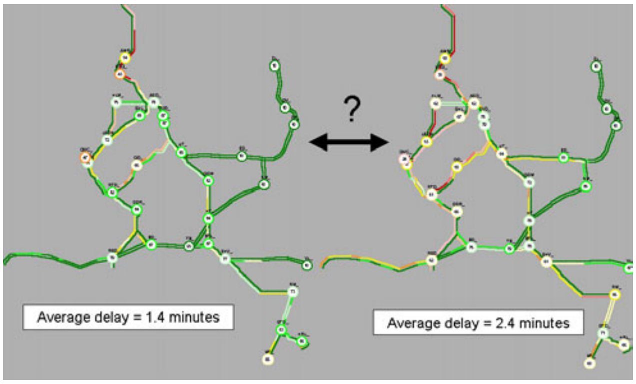

Figure 10: This Picture Shows the Comparison of Two Different Configurations of the Network

3.9 Case Study 2: Hengelo Station

Hengelo is a station that is located in the east of the Netherlands. In the current timetable, there is a potential conflict at Hengelo station for two specific trains when they try to leave the platform for the main line. To the experience of planners at Railned, this potential conflict leads to many problems in the area surrounding Hengelo.

Simone was used to asses the effects on Hengelo station and the surrounding network when the conflict was eliminated. Using Simone's automatic model generation feature, model construction took place in a couple of hours.

A large number of experiments was conducted to get the required information. Examples of output are shown in Figure 11 and Figure 12. Besides a confirmation of expected results also an unexpected effect became clear.

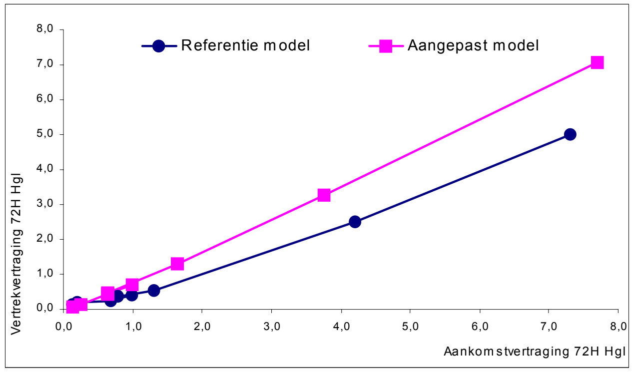

Figure 11: This picture shows the Amount of Delay a Train leaves from Hengelo station (y-axis) given the amount of Delay when it enters Hengelo Station (x-axis) for the two situations: with the conflict at Hengelo station (lower) and without the conflict at Hengelo station (upper).

This unexpected effect is about the number of broken correspondences. In the end, the conclusion was that Simone made it possible to support the decision making of the planners in a relatively short time period.

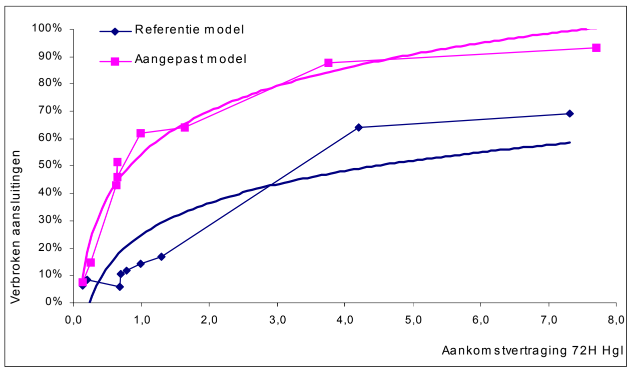

Figure 12: This picture shows the Percentage of Broken Correspondences in the model (y-axis) given the Amount of Delay Trains arrive at Hengelo station (x-axis) for the two Situations: the Conflict at Hengelo station (upper) and without the Conflict at Hengelo station (lower).

3.10 Evaluation of the Use So Far

Until now, Simone is used in a number of different studies. These studies prove that Simone is a successful research tool. It provides insights about the performance of a timetable-infrastructure combination, by simulating an entire railway network. The early conclusion is that the concept of Simone is working very well.

Currently, we are still learning more about defining the appropriate experiments and obtaining valuable results to judge network performance.

3.11 Upcoming Developments

The use of Simone has led to a great deal of suggestions, initiatives and plans to enhance the concept and to let more interested parties use it. Some of the upcoming developments are:

- More integration with the DONS system
- Faster simulation runtimes
- More functionality in the Simone Incontrol Center
- New concepts in the Simone Simulation Library
- More widespread use
- User group meetings

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