Railroad capacity and traffic analysis using SIMON
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Abstract

A capacity and traffic flow analysis for trains has been performed using the simulation software tool SIMON. The study comprised a contiguous railroad net in central Sweden. First, bottlenecks in the present traffic flow were found. In the second part, SIMON was used to calibrate two different train schedules for the year 2005. These future train schedules are used as input data for socio-economic studies.

Some facts regarding computing speed: The track length was approximately 900 km, with around 220 trains per day, resulting in an average of 24000 train-kilometres per day. On an ordinary Sun Sparc IPX, one day was simulated in 9 minutes, 160 times real time.

1 Introduction

The simulation software tool SIMON was developed by ÅF-Industriteknik for the Swedish National Rail Administration (Banverket), starting in 1990. It has been in use at ÅF-Industriteknik since 1991 and at Banverket since 1993, and new releases of the programme come out on a regular basis. SIMON has been used by ÅF-Industriteknik for various analysis, including almost all the commuter lines in Stockholm, several mass transit systems in the Far East as well as studies for Banverket. This paper covers one of these analysis.
2 SIMON

SIMON was described in detail at COMPRAIL 92 in Washington DC, USA [1]. Here follows a short description of the discrete event simulation tool, developed in Simula/Simulation and C. (See also the paper by Magnus Wahlborg, Banverket [2].)

The user supplies different input data:
1. Default values (crawl speed, signal type, warning distance etc. These values can be altered at specific locations, if necessary.)
2. Track (branches, stations, number of parallel tracks, signals etc.)
3. Train types (acceleration, retardation, maximum speeds etc.)
4. Timetable (stations, departure times, dwell times, trains to wait for etc.)
5. Delays and disturbances (distributions, patterns for trains affected etc.)
6. Traffic control (additional rules to alter the decision making.)

All this information is put into one single input file. SIMON carries out a number of different tests on the input, to ensure that the user has given correct data. When the input data has passed this control, the simulation may begin. The user is presented with a schematical graph depicting the track layout as well as a map showing a map of the area studied. An example from the Network analysis in Bergslagen described below:

![Image of SIMON interface]

Figure 1: Using SIMON, it is possible to follow each individual train on the screen as it moves towards its final destination. Signals and track reservations are displayed. In future versions it might be possible for the user to make the decisions!
The user can follow each individual train as it moves across the screen, study each individual decision made by the traffic control and study the present speed of every train.

The runtime kernel (RTK) calculates the running times. It takes into account the gradients, train characteristics, maximum speeds etc, and return the corresponding time. This part of SIMON is described in the paper by Magnus Wahlborg, Banverket, [2] and is not discussed further here.

The decision-making is, in short, using the priorities of the individual trains as well as their respective timetables when deciding which trains goes first. SIMON uses a pressure-calculation logic, where the train considered looks at the closest train ahead and behind it. Depending on these two other trains’ priorities and timetables, it can decide to:

- Continue
- Stop (if there is a scheduled stop at this station)
- Stop (and avoid a certain track)
- Stop (and wait for another train).

The logic presently **never** takes into account later decisions that will be made by the model, a restriction which could be changed in order to further improve traffic throughput.

In order not to cause the trains to block each other indefinitely, the algorithm presented by Peterson & Taylor [3] was used, more specifically the simple meetability criteria.

After the simulation is finished, there is an enormous amount of information to analyse. It is possible to study each train, how well it ran according to the timetable, and if it was delayed, where the delays occurred. The information can also be seen from the track point of view, if that is the objective. The results can be aggregated in a number of ways, from the obvious summary of identical trains running the same stretch, to comparing for example high speed trains (X2000). At times, the simulated time is divide into several intervals, in order to give the user an idea of how the results are distributed, not only getting an average value.

In order to get usable results, we have found that it is desirable to compare different alternatives, getting a relative description of the alternatives, rather than just studying one alternative, trying to obtain an absolute result.
3 Network analysis - Bergslagen

Located roughly 150 km NNW of Stockholm, Bergslagen is an old industrial region in Sweden. The track layout is typical of Sweden, with a large share of single-track and some parallel track. The gradients are large at points, another common aspect of the Swedish railroads. The rail network carries traffic in several directions, and there is a diverse mixture of trains. Statistics showed that disturbances occurred quite often, and that the trains were delayed on arrival. The first part of the study aimed at finding the bottlenecks, which parts of the track network that caused the delays. In the second part, SIMON was used to calibrate two different train schedules for the year 2005.

A map showing the simulated rail net:

![Figure 2: Where are the bottlenecks? SIMON was used to analyse the 900 km railroad net with 220 daily trains, resulting in decreased delays and running times. Most of the delays occurred along the stretch between Gävle (Ga), Borlänge (Blg) and Frövi (Fv), the long circular track from the coast to the south. Stockholm is located at the bottom right corner of the map.

For a detailed view of the train traffic, the presentation windows displays the complete situation including trains, track reservation and signals:

Some facts regarding computing speed: The track length was approximately 900 km, with around 220 trains per day, resulting in an average of 24000 train-
kilometres per day. On an ordinary Sun Sparc IPX, one day was simulated in 9 minutes, 160 times real time.

Additional statistics: The 220 trains averaged 73 km/h and stayed in the model for 1.5 h. This resulted in an average load of 14 simultaneous trains. During this time, around 36000 discrete events occurred, an average of 166 per train, and an average of 1.5 per km. The events are reaching a distant or main signal or releasing a track. They also include the decision-making done by the dispatcher logic. This means that SIMON uses an average of about 15 ms per discrete event. On a faster computer this time would naturally be decreased.

3.1 Capacity analysis

In order to find the bottlenecks, four different traffic loads were used. Traffic load 1 corresponded to today’s traffic, while traffic load 4 corresponded to an increase in traffic by 30%. After each traffic load was analysed, a number of changes to the track layout were suggested. Possible changes included adding meeting stations, allowing trains to enter the station from two directions simultaneously, increased speed for freight trains and adding double-track, especially close to the larger stations.

In order not to analyse the timetable but the track layout, the trains were heavily delayed as they entered the model. The simulations normally ran for 9-10 days (simulated time), after which the results were collected and studied.

After studying traffic load 1, some areas with larger-than-normal delays were found, mostly along the Gâ-Blg-Fv stretch. Before continuing with traffic load 2, the following changes were made along that stretch:

- New and moved signals (2+2)
- Simultaneous entrance to stations (9)
- New meeting stations (2)
- Double-track (3+6 km)

No other tracks were changed.

By gradually increasing the traffic, it is possible to take care of the disturbances as they occur. Should all extra trains be added at once, the traffic would not work at all, making it impossible to find the most effective areas for changes. One simple and extremely expensive solution would be to do all the available changes at once. The gradual approach also give an indication of where to start the upgrading of the rail network, as in this case the total time span was around 10 years.
3.2 Comparing two track layouts

This part of the study aimed at determining the potential of the track layout by comparing two alternatives. Alternative 1 is basically today’s situation, while alternative 2 requires a massive investment in infrastructure. The question is how much more traffic the system can handle after the investments have been done.

In order for the two alternatives to be comparable, some results have to match. In this study, we used recovery rate, defined as

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\text{recovery rate} = \frac{\text{initial delay} - \text{final delay}}{\text{initial delay}}
\]

The goal was to reach 0% for all train types for both alternatives. The method used could in short be described as:

1. Calculating running times.
2. Constructing a timetable.
3. Simulating the traffic.
4. Analysing the results.

3.2.1 Calculating running times  For each type of train, the running times in both direction were calculated, as these times could differ considerably. At this stage, it is vital that the trains run without disturbing each other, or with constraints caused by the timetable.

3.2.2 Constructing a timetable  The first timetable had no slack, that is extra time at a certain part of the layout, where a delay could be diminished. The high-priority trains had the first pick, and the empty slots were then filled by the rest of the trains. As this part had to be done several times, several UNIX scripts were used to speed up the process. An example of a timetable and the outcome:
Figure 3: Do the trains run on time? In order to make sure that the timetable was feasible, slack time had to be added, and departure times moved. In the end, the trains ran according to schedule.

3.2.3 Simulating the traffic The track layout and the timetable was then simulated for around 9-10 days (in around 1.5 h). The simulation could be studied during this time, but the results were the primary goal.

3.2.4 Analysing the results The recovery rate was calculated for each train type (high speed, normal, freight). In some cases it was impossible to achieve 0%, as a small initial delay can result in a large % value. If the recovery rate differed from 0%, additional slack was added or subtracted, and the departure times were moved. If a recovery rate of 0% was not achieved, the process is repeated from step 2.
3.3 Conclusions

To date, this is the largest railroad net analysis done using SIMON. It is not the length of the track that makes it complex, but rather the timetable, and how they are constructed. The UNIX scripts developed for this purpose have been invaluable.

One conclusion is that there are a number of advantages in studying a network instead of separate lines, as has been the method used up to now. If the lines are analysed separately, the disturbances caused by merging traffic is completely lost, and the solutions might be sub-optimal.

General results from this study:

- The block sections have to be studied. By moving signals or shortening the block sections, the overall performance of the system is improved.
- Simultaneous entrance can improve the capacity.
- Parallel track should be built around the connection points.

4 Final words

SIMON has been used for a variety of analysis by both Banverket and ÅF-Industriteknik, and has shown its flexibility as it can cope with both station and line simulations. As the confidence in SIMON has increased, larger railroad networks and more complex stations have been studied. As computer speed constantly improves, this development will probably continue.

Future developments include different signalling systems (presently ATP 1, ATP 2 and ZUB123 are acknowledged), improved presentation of tracks and signals. As mentioned above, one obvious development would be to use SIMON as a tool to teach dispatchers and others to control train traffic.

One area in need of improvement is editing the timetable. In a large model like this, with around 220 daily trains, with different priorities and speeds, it is difficult to put together the input data. The track layout is often quite stable, with perhaps a few different alternatives. The timetable however, is often in need of constant revision, and keeping track of all the trains and departure times becomes a problem. Sometimes a whole group of trains need to be moved, or slack put into a number of trains at a specific location.

With a graphical tool, this is a lot easier than maintaining a number of tables or raw input files. Perhaps this layout could also be used to view the simulation, as a presentation package. In order to properly study the simulation, it is necessary to keep track of the timetable, which is difficult in the present package. The trains change colour in three steps depending on how late they are, but that’s about it.
Can SIMON be used for other signalling systems? Great care has been taken to make a modular design. The dispatcher logic, implemented as a procedure, can easily be replaced by a new procedure. The parameters to the procedure is only the train, which in turn keep track of all the needed parameters. This concept means that it is rather straight forward to exchange the signalling systems, should the need arise. To this date, we have strived at having only one version of SIMON, and use the standard values to inform the package of which signalling system to use. In the future this may be revised, as the code would be almost impossible to maintain.

In the March 1994 issue of the Railway Gazette International [4], further information on SIMON can be found.

References


