Simulation models: important aids for Banverket’s planning process

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Abstract

When making decisions in infrastructure investments the Swedish National Railway Administration (Banverket = BV) perform socio-economic calculations. Input for the calculation consists of forecasts concerning future travel demand and traffic simulation for evaluating different alternative investments. Because of that BV in cooperation with ÅF-IndustriTeknik has developed a package of Simulation programs RTP (Running Time Program) and SIMON. RTP is used for train simulation (profits of reduced running time) and SIMON for traffic simulation (profits of extra capacity). The following briefly describes the simulation models and their use in Banverket’s planning work.

1. Introduction

BV has developed as well as initiated development of several simulation models. The models communicate with the Track Information System, BIS.

BIS => SIMON => SIMTRAC

BIS => RTP

RTP is developed to be used in investment planning and management and the main tasks are:
- to calculate theoretical running time for a specified train and route,
- to calculate reduced running time for a specific track investment,
- to show the profile of the track and speed of the train graphically.

RTP is an easy tool to use. Today the system has 80 users, who are in the headquarter (1/3) and in the 5 Regions (2/3) of BV. RTP is run on a VAX-
computer and graphical environment is X-Windows. The database for the system is Ingres.

SIMON has been developed to analyse traffic and capacity in the Railway system. So far the system has primarily been used for evaluating track and signal systems. The connection to SIMTRAC (system for simulation of train traffic - power system) makes it possible to study the power supply. Besides analysing investments in infrastructure SIMON is good for evaluating timetables.

SIMON has a complex model and education is necessary to perform analyses. In March 1996 SIMON has 5 - 10 users in BV and the same amount externally. In BV every Region performs analyses. Externally analyses are made, for example, for traffic operators, suppliers of trains and infrastructure, and the industry. SIMON is run on a Unix Workstation (Sun) and graphical environment is X-Windows. The database for the system is Ingres.

2 Running Time Program (RTP)

RTP model
The calculations of the driving profile is performed in the Running Time Kernel. The calculations are based on basic mechanics formulas, and the result consists of theoretical running time and mechanical energy consumption divided into acceleration and deceleration.

The characteristics of the model are:
- Every train has one traction bend, how the power supply affects the traction is not modelled.
- The adhesion control is made in Running Time Kernel, which makes it possible to vary the adhesion along the track.
- The train is modelled with length when calculating permitted speed, but the weight is in the center when calculating the resistance of incline.

The Running Time Kernel is a common module for RTP and SIMON. Input to the Running Time Kernel, the model of track and train, are also common for RTP and SIMON. The algorithms are so called discrete event simulation. A train is under acceleration, deceleration or drives with permitted speed.

The Track information is transferred from BIS (the Track Information System) and consists of:
* speed-signs
* bends
* inclines
* station stops
* kilometer signs
The trains are stored in a train database. Every train has data for weight, length, maximum speed, excess speed in bends, etc. The performance of the train are defined by traction, friction and speed resistance as functions of speed. The driving behavior is modelled by the parameters percentage of acceleration, percentage of deceleration and maximum speed margin.

The running times are defined as theoretical. In the train database for acceleration the maximum tractive effort has been chosen. The adhesion formula is given as input for a runtime calculation. For motorcars and high speed trains running resistance defined of the train producer is used. For locomotive trains general formulas are used which are a function of numbers of cars and type of cars [1].

**RTP in management (the track of today)**

The track data is transferred from BIS to the track database of RTP. The user chooses if he wants to work graphically in BIS, or if he from RTP wants to specify start and end station. Other data to specify are train from the database, driving behavior, adhesion and which station to stop at.

The speed restrictions are represented logically in BIS and RTP. A speed restriction can be constrained or bend depending. A constrained speed restriction gives the same permitted speed for every train, and a curve depending speed restriction is multiplied with the excess speed in bends. The excess speed of the train varies between different parts of the track. When the train has good dynamic behavior 10 - 15 % excess is normal for trains with good dynamic behavior and active body tilting 30 % excess is normal.

![Figure 1: Stockholm - Göteborg, speed profile X2000, speed limits excess speed 0 % and 30%.

Figure 1: Stockholm - Göteborg, speed profile X2000, speed limits excess speed 0 % and 30%.
The permitted speed is for X12 160 km/h and for X2000 200 km/h. The distance Falun - Gävle is 90,5 km and the distance Stockholm - Göteborg is 454,0 km. For information about data quality in BIS we refer to [2].

**Falun - Gävle**  
Excess speed | Theoretical running time | Profit excess  
--- | --- | ---  
Motorcar X12, 160 | 15 % | 0:50:19 | 3:39 (-6,8%)  

**Stockholm - Göteborg**  
Excess speed | Theoretical running time | Profit excess  
--- | --- | ---  
High speed X2000 | 30 % | 2:38:58 | 31:39(-16,6%)  

**RTP in investment planning (future track)**  
When studying investment in infrastructure the planner works directly in the database of RTP. The task is often to study the reduction in running time when increasing permitted speed or projecting a new line. This work is mainly performed at the region level and it gives each region an own library of future tracks. If track data is not classified it is available to all RTP users by the function copy. There are functions to prepare data such as cut, paste and turn.

The future tracks BV produce is also available for train producers and traffic operators. Because of that a function has been developed for transferring data to pc EXCEL. In the train database there are also a few trains of the future. These have been specified in dialogue with train producers and train operators.

**Purpose of RTP in the future**  
Besides planners there are people using the model for other purposes, such as:  
- when projecting signal systems and speed profiles,  
- when constructing stations with steep inclination profile, e.g. stations in tunnels,  
- when studying what the maximum train weight is,  
- when studying energy consumption.

In the future BV intends to spread the use of RTP, and to produce documentation for these purposes. That work is made in cooperation with The Swedish State Railways (SJ) and the Royal Institute of Technology, Stockholm (KTH). The projects consist of gathering and analysing of empirical data of: driving profile, true adhesion and energy consumption. Empirical data is used for calibration and validation of existing and future models.

During 1992 - 94 full scale tests of running resistance for passenger and freight trains was made by KTH [1]. The result was lower running resistance than was used before.
3 SIMON, Train Traffic Simulation

SIMON model
SIMON the BV system for train traffic simulation consists of Train Traffic Simulator (TTS), which is the model. In TTS the calculations of running time is made, the train is guided by train dispatcher and signal system, and the train movements are shown graphically. Besides TTS there are systems handling input data and presentation of output data.

Input | Train Traffic Simulator | Output

<table>
<thead>
<tr>
<th>Track</th>
<th>Traffic control</th>
<th>Disturbances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timetable</td>
<td>=&gt;</td>
<td>=&gt;</td>
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</tbody>
</table>

Figure 2: SIMON System Structure

Input The data system for input data consists of a number of modules where the user specifies data in dialogue windows. The data is stored in an Ingres database.

* The track model is more detailed than RTP with data about track layout and signal system. Common data with RTP are speed limit notices, bends, inclines, station stops and distance notices.

* The timetable stores data about the traffic. It is possible to give conditions for connecting trains.

* The databases for train and driving behavior are the same as RTP.

* Disturbances can be specified either as a delay or as a work on the track. A delay gives an extra time for a specific train. A work on the track is specified for a part of the track and affects all trains that pass/wants to pass.

* In Traffic control every train gives a fixed priority. More over it is possible to make rules for what stations meeting and overtaking won’t be allowed, for a selected set of trains.
TTS In TTS runtime calculations are made for all trains continuously. The train dispatcher of SIMON decides when a train should drive by reserving blocks. A train drives until a signal shows stop. The dispatching logic is based on rules and consists of line block prevention, a pressure algorithm (next meeting and next overtaking), dispatching rules given as input and an algorithm for choosing track in a station. During a simulation the user follow the trains movements in the system and the decisions of the dispatcher. If there are problems they are shown in a specific window.

Output Output data is presented as:

- Timetable graphs with timetables and the traffic movements they produce,

- Finished reports of the results,

- Output as Ingres tables. They can be used for SQL queries and the results can then be shown graphically in Excel.

SIMON connection to other systems

SIMON is connected to the systems BIS and SIMTRAC. BIS is BV system for storing information about the track. SIMTRAC is a simulation program to study how the power supply affects the train traffic. SIMTRAC is owned by ADtranz and is developed in cooperation with BV. SIMTRAC was released in January 1996.

BIS The user works in BIS-reference system, where the track layout is shown graphically. The user creates a query and the result is stored in a file. The records used in a query are: station stops, switches, (speed-signs), bends, inclines and kilometer signs. The file is then transferred to the database SIMON Track. There the user selects switches to model and then construct the track layout of the stations.

SIMTRAC SIMON produces input data to SIMTRAC via intermediate files. In SIMTRAC the power supply system is included and a new simulation is performed. SIMTRAC uses SIMPOW, a well established package for power systems analyses (developed by ABB Power System), for stationary and dynamic calculations. Output from SIMTRAC is new running times for the traffic, and data over how the power supply has behaved.

The data transferred to SIMTRAC are track, train and traffic. The track data consists of: network SIMON, station stops, bends, inclines and catenary. Train data is the train model of SIMON and the electrical behavior of the train. Traffic data consists of the trains path, allowed speed and time information. In that way SIMTRAC uses the detailed model of SIMON with track layout, signal system, dispatching e.t.c.
4 Conclusions

The simulation programs RTP and SIMON are important tools for BV in investment planning and management. RTP calculates the theoretical running time and SIMON is used to analyse train traffic and infra-capacity. For the future there are plans to spread the use of RTP and SIMON within BV. RTP will be used for different kinds of analyses and in projecting. Because of that there is a project for calibration and validation of RTP with empirical data. SIMON has a newly developed connection to SIMTRAC which makes it possible to study how the power supply affects the train traffic.

Moreover the model, structure and connections to other systems have been briefly described for RTP and SIMON.

References
