Validation of a train simulation model with train detection data

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Abstract

Rail traffic simulation tools are used for timetable design and for the analysis of existing timetables. For these models, correct data for infrastructure and rolling stock are needed. Parameters are often estimated, but this can lead to differences with real train operation, especially when these models are used for timetable designs of lines or networks with larger distances. Important in this respect is the validation of the running times, speed profiles and track occupation times.

In this paper, the validation of a simulation model is described. The running times in this model are based on the calculation of traction force and resistance of Dutch trains. Acceleration and braking rates are determined from measured data. Validation takes place on the basis of train detection data of an Intercity and an Interregional train on the line from Rotterdam to The Hague HS (The Netherlands).

In the case of the Intercity, standard trains are operated. The result is a running time, calculated by the simulation model RailSys, which is 5.7 % larger than the minimum running time measured by train detection data. This small difference is rather acceptable.

The validation of the Interregional train shows a large difference between the model calculation and the train detection data: 11.9 %. There were serious problems with the disposition of trains. Due to lack of data of actual train disposition, it was impossible to either select the appropriate trains or to calculate the appropriate running times.

1 Introduction

Simulation models of rail traffic are often used for timetable design and for the analysis of existing timetables. For these models, correct data for infrastructure
and rolling stock are needed. Important parameters are the traction characteristics, including train resistance and the acceleration and deceleration rates. These and other parameters are often estimated, but this can lead to differences with real train operation, especially when these models are used for timetable designs of lines or networks with larger distances. These differences may be not so important at the time level of minutes. For a thorough analysis of delays and conflicts - especially for headways and buffer times - a time scale of seconds is needed.

For analysis of train movements the planned situation has to be compared with the realized train movements. Especially conflicts points, such as level crossings and merging locations near stations are of interest. For these conflict points, no planned passing times are available: only the departure and arrival times of trains at the stop location at the platform are known, in roundup minutes. For this reason, simulations tools can be used to estimate the planned passing times of trains at conflict points. The realized train movements are determined with available train detection data. These data are processed with computer tools to determine occupation and clearing times of track sections, and the signal and switch status, connected to train numbers. The time level is in seconds.

For a correct comparison between the planned and the realized train processes the validation of the running times, speed profiles and track occupation times of the simulation tool is important. After validation the comparison shall render a solid base for correction of timetables and for analysis of train delays.

2 Rail simulation models

Rail simulation models are used for determination of the operability of the timetable, the effects of disturbances, the capacity and the effects of changes in infrastructure. There are two kinds of simulation models: the a-synchronous and the synchronous models. In the a-synchronous model the train with the highest priority is first simulated and then the other trains at priority order, till conflicts arise. In the synchronous models all trains are simulated at the same time, according to priority rules and dispatching measures. Conflict solving is interactive, not automatic [7]. For our research the (synchronous) tool RailSys was chosen [1]. In this tool a graphic and statistic presentation of blocking and buffer times is available, which is very important for analysis purposes. The used version is RailSys 1.25.

RailSys consist of three parts: The track layout, the simulation tool and the performance evaluator. The track layout consists of nodes and links: the nodes represent switches and signals, speed changes and stop locations; the links are attributed with length, speed and gradient. In the track layout the characteristics and parameters of the signalling system can be chosen, for instance distant-main signal systems and moving block systems, with route setting and releasing times and safety margins.

In the simulation part the input consists of the timetable and the characteristics of the rolling stock to calculate running times. Timetable input is:
train types, routes, stations, arrival, dwell and departure times, and running time margins.

Data of rolling stock to calculate running times are: acceleration, deceleration, train resistance (running, rolling and air resistance), initial friction coefficient, length, mass, supplement of rotating parts, and maximum speed.

Outputs of the RailSys simulation are graphics, for instance speed - distance and time - distance diagrams, and statistics, for instance data of train runs, blocking and buffer times, occupation times and delays.

3 Train detection data

The tracks and yards of the Dutch railway network are divided in sections: parts of track, insulated from each other and having a unique code. In general, these sections are subparts of blocks. At yards, sections are mostly identical to switches, platform and parking tracks. The status of the sections: occupied or clear, is always determined automatically.

Dutch Traffic Control uses the Train Describer System (TNV: Trein Nummer Volgsysteem) for the localization of trains. For this purpose the network is divided in TNV-positions (sequence of sections). The train numbers and entrance times of each train at each TNV-position are stored in TNV-logfiles. Status changes of sections, switches and signals are also stored. No data are available about exact stopping locations and dwell times at the platform, because there are only TNV-positions before and after the platform. Furthermore, the distance between the TNV position before the platform and the stopping location at the platform is often several hundreds of meters. The program ‘TNV-Prepare’ assists in determining from the TNV-logfiles the route of each train through a station [4]. The program TNV-Filter makes precise estimations of arrival and departure times, including dwell times and delays [5]. Output is tables with occupation and release times of each train at every section over the whole train route.

4 Validation

The validation consists of a comparison between the running time calculated by the tool 'RailSys' and the minimum running time from train detection data, as derived from TNV-Prepare. Validation is for rush-hour conditions: maximum train length and full occupation. Two train series are examined: an Intercity train and an Interregional train from the station Rotterdam CS to the station The Hague HS; the line length is 23 km. The IC train has no intermediate stops, the IR train stops at Schiedam en Delft (figure 1).

The smallest track curve of the line is situated at Delft and has a minimum radius of 380 m and an allowed speed of 100 km per hour; the maximum grade is 1.1 % (tunnel at Rijswijk). This line - one of the oldest lines in the Netherlands - is also one of the most crowded: in 1999 15 passenger trains per hour passed in each direction. Goods trains also use this line, but only during off-peaks hours.
4.1 Data of infrastructure and trains

The data used for the infrastructure are derived from the so-called OBE and OKT maps of the Dutch railways: these maps contain data of location and names of sections, switches, signals and platforms. From these data, section and block lengths are calculated. Also, typical parameters of the Dutch signalling system were used.

Most data of Dutch rolling stock - including the acceleration and deceleration rates derived from measurements in practice - are from Gijsen and van den Brink [3]. No data of train resistance of Dutch trains were available in the public domain. Further more, most formulas for train resistance are based on measurements of rolling stock from the sixties or even older. Therefore, train resistance is calculated by means of formulas from measurements of relative modern Swedish trains [6].

For this validation the standard rush hour loading is used: passenger occupation is estimated at 1.2 times the number of seating places (all seats occupied; 1 passenger standing on 5 seating); the length of trains is the maximum used in the service. According to the planned situation, the Intercity train 1900 is made up of a locomotive and nine coaches; the train composition is not changed during the day. The Interregional train 2200 consist of two four-unit train sets IRM4 during rush hours and one train set IRM4 during off-peak hours, but in practice other train sets were used too. Detailed information is given in Appendix 1.

4.2 Train detection data

Train detection data were derived from logfiles of the TNV-system with the program TNV-Prepare. The used data are from September 1999. For both trains TNV-tables of Rotterdam, Schiedam, Delft and the Hague HS were generated and combined. The precise estimation of arrival and departure times from TNV-Filter was only applied for the station The Hague HS. Departure times at Rotterdam and arrival and departure times at Schiedam and Delft are estimated. Departure time estimation is equal the occupation time of the first section after the platform track section, minus an offset based on TNV-Filter data per train series and a correction for the distance between the stopping location and the section border. Arrival time estimation is equal the clearance time of the section
before the platform track section, plus an offset based on TNV-Filter data per train series and a correction term for the distance between stopping location and section border. Correction terms were in the order of 25 s.

For arrival the train length is of influence (only train IR 2200): a long train has a short running time over the distance between section border and stopping location, a short train a longer running time. Therefore, only data of long trains in the rush hour are used. An estimation of train length is derived from occupation and clearing times at an appropriate section border.

4.3 Results

**Intercity train 1900**

The calculated running time of the train IC 1900 from Rotterdam CS (track 9) to The Hague CS (track 5) is 833 s at an initial acceleration of $a = 0.48 \text{ m/s}^2$. At a passenger occupation of 0.5 the calculated running time is only 4 s shorter. The running time margin is set at 0 %.

The dataset from TNV consists of 75 trains during the rush hour (7:00 to 9:00 h and 16:30 to 18:30 h, figure 2). The minimum recorded running time is 784 s and the average running time is 937 s, with a standard deviation of 86.0 s. Therefore, the running time calculated by RailSys is 5.7 % longer than the minimum running time derived from the TNV-data but very close to the left side of the distribution (short running times).

These trains IC 1900 had an average departure delay at Rotterdam CS of 102 s with a standard deviation of 99.4 s; the average arrival delay at The Hague HS was 20 s with a standard deviation of 80.9 s. The scheduled running time is 17 minutes = 1020 s. Compared to the recorded minimum running time of 784 s, this corresponds to a margin of 30 %!

![Figure 2: Distribution of running times IC 1900 Rotterdam - The Hague HS (TNV data September 1999; ■ = calculated running time by RailSys).](image-url)
Interregional train 2200
The calculated running time of the train IR 2200 from Rotterdam CS (track 8) to The Hague CS (track 6) is 987 s at an initial acceleration of $a = 0.51 \text{ m/s}^2$. With a passenger occupation of 0.5 the running time is 10 s shorter. The running time margin is set at 0 %.

The dataset from TNV consist of 62 trains at rush hour (7:00 tot 9:00 h and 16:30 tot 18:30 h, figure 3). The minimum running time is 882 s and the average running time is 995 s, with a standard deviation of 74.0 s. Therefore, the running time calculated by RailSys is 11.9 % longer than the minimum running time from the TNV-data and very near the average running time.

These trains IR 2200 had an average departure delay at Rotterdam CS of 50 s with a standard deviation of 91.6 s; the average arrival delay at The Hague HS was - 6 s with a standard deviation of 90 s. The scheduled running time is 18 min 48 s = 1128 s.

Figure 3: Distribution of running times IR 2200 Rotterdam - The Hague HS (TNV data September 1999; □ = calculated running time by RailSys).

Interpretation
A persistent problem of this validation is the lack of data concerning the disposition of the actual trains with respect to train length and weight. For the train series IC 1900 the similarity of the RailSys calculated running time to the realization of running times is quite acceptable. It is apparent that the trains are running fast because of delays. Due to problems with the axles of some ICR coaches in 1999, sometimes trains with only 8 or 7 coaches were used [2]. Furthermore, the acceleration can be faster in good weather conditions, due to
higher friction coefficient between wheels and rails. These effects could explain partly the shorter realized running times.

For the train series IR 2200 the similarity of the calculated minimum-running time to the realization of running times is not satisfactory. In 1999-2000 a structural shortage of 10 train sets IRM - due to mechanical problems - made disposition very problematic [2]. Other train sets were used, like probably the older and slower train types Plan V and T.

Short trains were used often, which influence the real times of arrival at Schiedam and Delft: the running time, derived from TNV data, can be shorter than the real running time. Due to lack of data of actual train disposition, a validation for the IR 2200 train series is not possible. Furthermore, the simulation tool identified very small buffer times upon arrival in Schiedam.

Differences in the calculated running times due to passenger occupation and the influence of wind on train resistance \( V_{\text{wind}} = 10 \, \text{m/s}^2 \) proved negligible.

## 5 Conclusions

Validation of simulation models is important for longer running distances and for a correct analysis of train conflicts. In ideal conditions, validation should take place by means of data from specially arranged trains runs under specified and measured conditions.

Next best alternative is the use of available train detection data. Problem here is the lack of data of the actual train disposition and the actual rates of acceleration and deceleration, depending on driver behaviour and weather. In the case of the Intercity 1900 standard trains are operated; because there are no intermediate stops, the influence of variations in acceleration and deceleration is less then with intermediate stops. Result is a RailSys calculated running time, which is 5.7 % larger then the minimum running time measured by train detection data. This small difference is rather acceptable.

The validation of the Interregional train series 2200 shows a very large difference between the calculation and the train detection data: 11.9 %. There were serious problems with the disposition of trains. Due to lack of data of actual train disposition, it was impossible to either select the appropriate trains or to calculate the appropriate running times.

The validation of running times can be very helpful for correct interpretation of the results of time table and operations analysis. It is recommended to add data of the actual train type and the train length and weight to the train numbers of TNV. Especially with goods trains the actual train disposition can differ considerably from the planned disposition, with a large influence on the track occupation and clearance times. Validation has also to be done for real track occupation times and train speeds.
Appendix 1: train data

Traintype: locomotive 1800 and 9 coaches ICR:

<table>
<thead>
<tr>
<th>Train data</th>
<th>Lok1800</th>
<th>ICR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of carriages</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Seats</td>
<td>-</td>
<td>80</td>
</tr>
<tr>
<td>Max velocity [km/h]</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Continuous power [kW]</td>
<td>4540</td>
<td>-</td>
</tr>
<tr>
<td>Efficiency</td>
<td>87%</td>
<td>-</td>
</tr>
<tr>
<td>Mass [ton]</td>
<td>83</td>
<td>41</td>
</tr>
<tr>
<td>Supplement rotating parts</td>
<td>20%</td>
<td>8%</td>
</tr>
<tr>
<td>Length</td>
<td>17,6</td>
<td>26,4</td>
</tr>
<tr>
<td>Number of axles</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Powered axles</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Passenger occupancy</td>
<td>-</td>
<td>1.2</td>
</tr>
<tr>
<td>Adhesion weight</td>
<td>83</td>
<td>-</td>
</tr>
</tbody>
</table>

Mean initial acceleration \( a_{avg, v=0} = 0.48 \text{ m/s}^2 \) with initial friction coefficient \( \mu = 0.33 \);

Traintype: two train sets IRM4

<table>
<thead>
<tr>
<th>Train data</th>
<th>2xIRM4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of train sets</td>
<td>2</td>
</tr>
<tr>
<td>Seats</td>
<td>744</td>
</tr>
<tr>
<td>Max velocity [km/h]</td>
<td>160</td>
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<tr>
<td>Continuous power [kW]</td>
<td>3216</td>
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<tr>
<td>Efficiency</td>
<td>87%</td>
</tr>
<tr>
<td>Total mass [ton]</td>
<td>458</td>
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<tr>
<td>Supplement rotating parts</td>
<td>11%</td>
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<tr>
<td>Length</td>
<td>214</td>
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<tr>
<td>Number of axles</td>
<td>32</td>
</tr>
<tr>
<td>Powered axles</td>
<td>8</td>
</tr>
<tr>
<td>Passenger occupancy</td>
<td>1.2</td>
</tr>
<tr>
<td>Adhesion weight</td>
<td>120</td>
</tr>
</tbody>
</table>

Mean initial acceleration \( a_{avg, v=0} = 0.51 \text{ m/s}^2 \) with initial friction coefficient \( \mu = 0.25 \).
References


