

# A Rail Model Calibration Methodology

Brooke Markewicz

Email for correspondence: [brookemarkewicz@yahoo.com.au](mailto:brookemarkewicz@yahoo.com.au)

## Abstract

Railway simulation tools can model a railway operation before construction and investigate a wide range of scenarios, such as the optimal timetable for a corridor or the location of new passing loops on single track lines. Rail modelling can produce outputs such as on-time reliability, travel times and infrastructure requirements which can input into the economic and service planning analysis.

In order to ensure accurate project outcomes, rail models need to be calibrated. A well-calibrated model outputs results that closely reflect historical figures, and, importantly, faithfully simulates the railway operations.

The shortage of a methodology for rail model calibration has led to a lack of standardisation, ad-hoc analysis and no base to consider calibration concerns. This motivated the author to write a master's thesis, *A RailSys Calibration Methodology* (Markewicz 2013), to address these issues. This paper summarises the thesis and broadly applies the methodology to general rail operations modelling.

The methodology summarises the fourteen steps to complete a calibration. These steps fall into three general work areas: calibration set up, calibration process and documentation/finalisation.

Finally, a RailSys calibration case study is described. RailSys is a computer program which uses information about infrastructure, timetables, rolling stock and delays to simulate rail operations. RailSys modelling has been used to evaluate multi-billion dollar projects in Australia such as Regional Rail Link (currently under construction for completion in 2015), Melbourne Metro and Cross River Rail.

*Opinions in this paper are my own and not necessarily those of Public Transport Victoria or the Victorian Government.*

## 1. Introduction

A number of factors have led to an increased use of railway computer modelling to complement the 'expert opinion' relied upon in the past. Three of these factors are computer advances, the ageing railway workforce and the need for modelling as part of business case development.

Computer improvements have allowed complex simulations to be performed on relatively affordable standard desktop computers (Chung 2004, p. 20; Hellinga 1998, n.p.). As well, software programs can now offer graphical user interfaces, enabling users without expert programming skills to complete analysis (Chung 2004, p. 20).

The ageing railway workforce will see industry knowledge drain through retirement and resignation (Australian Railway Association 2008, p. 14; Parliament of Victoria 2010, p. 41). The median age of an Australian railway worker is 44 years compared with the 39 years median age of all Australian workers (Australian Railway Association 2008, p. 5). This loss of experienced employees will lead decision makers to have an increased reliance on modelling results.

Business cases need to include quantitative results and a thorough technical examination of railway complexities, for example, Infrastructure Australia’s *Reform and Investment Framework* (Infrastructure Australia 2013). Railway simulation tools can model a railway operation before construction and investigate a wide range of options, such as interactions between trains from different lines and passing locations on single track sections. Railway modelling can produce results such as on-time reliability, travel times and capacity which input into the economic analysis. Business cases have a greater chance of funding success when modelling can produce quantifiable data.

**2. Background**

Chung (2004, p. 16) defines simulation modelling and analysis as a process of creating and investigating a computerised mathematical model of a physical system. Simulation modelling covers a wide range of activities in many different fields such as medicine, weather forecasting and finance. Different modelling associated with railways can be undertaken, such as patronage forecasting, pedestrian flows at stations and on-time reliability estimates. This paper will focus on the timetabling and operations area.

Two examples of rail operations modelling tools are RailSys, a program developed by the University of Hannover and Rail Management Consultants (RMCon) in Germany and OpenTrack, produced by OpenTrack Technology in Switzerland.

Simulating rail operations can be complex and railways difficult to model (Koutsopoulos and Wang 2007.) A number of inputs are required into the model, such as infrastructure data (grades, track, signalling, station), rolling stock data (mass, maximum speed, acceleration/deceleration) and timetable data (stopping patterns, travel times, dwell times, connections).

Analysis can be static (time is not progressed) or dynamic (time is progressed to study the interactions of trains). Static analysis requires infrastructure, rolling stock and timetable data whereas dynamic analysis requires delay data. Dynamic analysis can involve running multiple simulations of the railway usually to determine the on-time reliability of a future timetable and infrastructure. Dynamic analysis is more complex as more data and a greater understanding of how the model operates are required.

Some example dynamic and static railway operation tasks are shown in Table 1.

**Table 1: Possible rail modelling tasks**

Static task	Dynamic task
Travel time estimates for a new alignment or extension	The reliability of a greenfield timetable
Designing a new timetable to reduce overcrowding	Assessing delays when operating additional trains during the morning peak
Assessing the headway improvements of high capacity signalling	A comparison of reliability before and after a passing loop is built

### 3. Calibration and on-time reliability

Before dynamic simulations are undertaken for a project, the model must be calibrated. The purpose of calibration is to obtain an accurate operational representation of the actual rail network. The model can then be used to investigate a future project, such as the reliability of a timetable when additional peak trains are operational.

For rail operational modelling, a calibrated model comprises of a timetable, supporting infrastructure and perturbations. The reliability outputs of the calibrated model should produce results as close as possible to historical figures. The aim is to minimise the difference between the simulated on-time reliability and the actual on-time reliability.

On-time reliability (sometimes called punctuality) is measured as the percentage of trains which arrive at a given location on-time (usually the destination station). The definition of 'on-time' can vary between rail operators and government organisations. For metropolitan Melbourne, it is no later than four minutes 59 seconds after the scheduled arrival time (Public Transport Victoria 2012). Similarly, Queensland Rail, operating Brisbane's trains, generally define a train as 'on-time' if it arrives less than four minutes late at its destination (Queensland Rail 2012). Sydney's CityRail on-time benchmark is for trains to arrive within five minutes of their scheduled time (CityRail 2012).

On-time reliability is a good guide to the robustness of a timetable. A very robust timetable will have a high on-time reliability, while an unstable timetable operation will have a low on-time reliability. A 'high' reliability can be different for each city, as shown in Table 2. The reliability benchmark is dependent on local conditions, for example the mixture of trains on the railway and conditions of the infrastructure and rolling stock.

**Table 2: Comparison of on-time reliability benchmarks**

City	Reliability benchmark
Melbourne	87% at 4:59 minutes <sup>1</sup>
Brisbane	94.53% at 4 minutes <sup>2</sup>
Sydney	92% at 5 minutes <sup>3</sup>
South West Trains, United Kingdom	89% at 5 minutes <sup>4</sup>
Hong Kong	99.7% at 5 minutes <sup>5</sup>

<sup>1</sup> Public Transport Victoria, *Performance monitoring*, <http://ptv.vic.gov.au/about-ptv/victoria-s-pt-network/performance-monitoring/>

<sup>2</sup> Queensland Rail, *Your Time*, <http://www.queenslandrail.com.au/AboutUs/CustomerCharter/Pages/Yourtime.aspx>

<sup>3</sup> CityRail, *Our Performance*, [http://www.cityrail.info/about/our\\_performance/#](http://www.cityrail.info/about/our_performance/#)

<sup>4</sup> South West Trains, *Our performance*, <http://www.southwesttrains.co.uk/our-performance.aspx>

<sup>5</sup> MTR, *MTR Performance Achievements*, <http://www.mtr.com.hk/chi/publications/images/performance.pdf>

## 4. Literature limitations

In a discussion of a framework for the application of rail simulation, Koutsopoulos and Wang (2006) point out calibration literature is inadequate and the current methods for rail model calibration are not advanced.

Rakha et al. (1996, n.p.) highlight that further research is required to develop a methodology which can allow an analyst to calibrate a traffic simulation model. Rakha et al. (1996, n.p.) also recommended a standard calibration framework be developed to assist modellers. It is suggested the framework contains strategies to address calibration issues and be broad enough to be used to calibrate any traffic model (Rakha et al. 1996, n.p.). Although this paper discusses traffic modelling, the same sentiment applies to rail modelling as well. There is a lack of calibration documentation for railway modelling in the industry and with practitioners.

Lindfeldt (2010, p. 27-29) discusses a RailSys calibration methodology conducted in order to investigate rail capacity. However, this description is short, is not generalised and lacks detail. Lindfeldt's thesis focussed on models for analysis of railway operations and therefore only a small section was devoted to calibration.

## 5. Calibration methodology

This section summarises the calibration methodology in the author's thesis, *A RailSys Calibration Methodology* (Markewicz 2013).

The aim of calibration is to produce a model that outputs reliability results which closely reflect historical reliability figures, and to model the operations of the railway accurately. The analyst should produce an appropriately calibrated model and thoroughly understand how the model works. A model which outputs reliability close to historical but does not represent rail operations accurately is not calibrated.

A well-calibrated rail model can then be used to investigate rail projects such as the reliability when a single line section is duplicated or delays when a new timetable is implemented. The project model uses the calibration model as a base to ensure the future operations replicate historical operations. However, sometimes there is no historical data available, such as when modelling a new alignment, and future operations must be predicted.

The calibrated model will simulate a 'normal day' (defined as when a timetable can recover from small delays) of a rail network (or parts of it). It is not recommended rail operations software be used to simulate large delays (for example a broken down train). This should be considered for each calibration project as there is no rule on how this measure is chosen, however delays greater than ten minutes is a good guide. The number and length of delays will impact on this figure, as may other considerations. Delays greater than this number are exceptional events where the timetable will not recover and reliability will be poor. These incidents should be excluded from calibration.

The analyst may calibrate a model from the start, or have the infrastructure and timetable model already available, or have a previously calibrated model to use as a base. A model which has been previously calibrated should be assessed whether it is suitable for the particular project to be analysed. For example, if the aim of the project is to analyse a new rolling stock type, the calibrated model should very accurately represent the current rolling stock on the network. If there is no suitable model available, calibration must be completed before project modelling commences.

It is recommended a model be recalibrated after a major timetable or infrastructure change. This ensures the model contains a recent timetable and infrastructure, is accurate and is ready for project work. Significant changes to the software, patronage or identified improvements to the calibration technique may also trigger a need for recalibration.

A calibrated model has five main inputs which are shown in Table 3.

**Table 3: Potential inputs into a rail operations model**

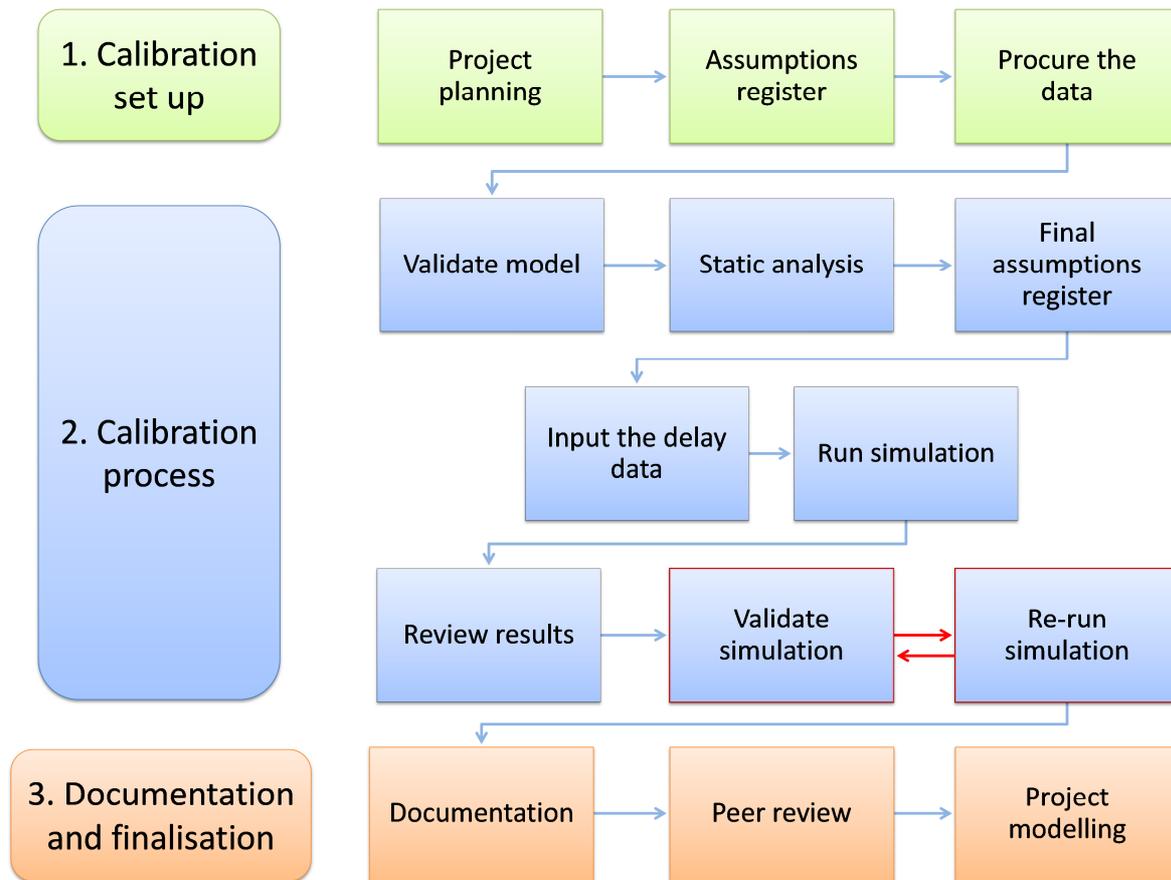
Input	Example of components
1. Track infrastructure	<ul style="list-style-type: none"> <li>• Track data</li> <li>• Maximum speed</li> <li>• Signalling</li> <li>• Stations</li> <li>• Interlocking</li> </ul>
2. Working timetable	<ul style="list-style-type: none"> <li>• Departure times</li> <li>• Arrival times</li> <li>• Connections</li> <li>• Dwell times</li> <li>• Track/platform usage</li> <li>• Rolling stock type</li> </ul>
3. Rolling stock characteristics	<ul style="list-style-type: none"> <li>• Maximum velocity</li> <li>• Length</li> <li>• Mass</li> <li>• Acceleration curves</li> <li>• Rolling resistance curves</li> </ul>
4. Perturbations	<ul style="list-style-type: none"> <li>• Dwell distribution</li> <li>• Incident distribution</li> <li>• Departure distribution</li> <li>• Entry delay distribution</li> </ul>
5. Parameters	<ul style="list-style-type: none"> <li>• Routing/dispatching settings</li> <li>• Train priority</li> <li>• Alternative tracks</li> <li>• Minimum connection times</li> </ul>

The calibration comprises of three broad work areas (broken into fourteen steps):

1. Calibration set up – project planning and data collection.
2. Calibration process – the calibration process from validating the model to validating simulation results.
3. Documentation and finalisation – documentation, peer review and project modelling.

Figure 1 shows the calibration work areas. Green represents the calibration set up, blue represents the calibration process and orange represents the documentation and finalisation. Note the cyclic process from *Validate simulation* to *Re-run simulation*. This is an iterative process until the model is calibrated.

**Figure 1: The calibration process**



Each step is discussed in greater detail below.

### **Step 1. Project planning**

The first step of the calibration process is to plan the project. Setting up files and holding inception meetings are part of the project planning. Depending on the specific project, this step can include:

- Clarification of the objectives of the project modelling and to clearly define what the calibration will achieve.
- Administration tasks such as setting up folders and preparing documentation.
- Discussions with stakeholders. A number of people and organisations may have an input into the calibration. Stakeholders may include the client of the final project, the train operating company, data sources, management and colleagues.
- Producing a project plan and timeline to estimate the time required for each task, deliverables and the due date of the project.
- Site visits are advisable for the analyst to gain an understanding of the operation, infrastructure and geography of the rail line or group.
- Preparing a proposed methodology, ideally similar to the methodology described in this paper.
- An examination of the model (if it is available) should be made to gain an understanding of how closely the model aligns with the calibration requirements.

- Commence the procurement of data as it may take weeks to receive all of the data.
- The time period of the calibration should be determined at this stage.
- The version of the software must be chosen carefully as outputs may change when different versions are used.
- Project modelling risks should be analysed. Potential risks include an inability to get quality data, difficulty obtaining data, problems calibrating the model and the project running over budget (time/cost).

## **Step 2. Assumptions register**

The second step is to begin an assumptions register. This will be a dynamic document which will be updated regularly until step 6 when the assumptions register will need to be finalised. Some examples of assumptions are:

- General assumptions such as time period, minute mark/s where the model will be calibrated, locations where the reliability will be measured and a definition of when the model will be calibrated.
- Infrastructure assumptions such as parameters and interlocking types.
- Data assumptions such as the number of perturbations.
- Static analysis assumptions such as how trains are grouped, whether other trains will be included and parameter settings.
- Dynamic analysis assumptions such as the time period the simulation will run, how the reliability will be reported (by line, individual trains, groups etc.) and the number of days to be simulated (250 to 500 is recommended).

## **Step 3. Procure the data**

Data should be collected and analysed early in the project as it may take some time to collect all of the required data. A checklist is recommended to allow the analyst to keep track of the data required. As well, this allows the analyst to check off what data has been obtained and make notes. Five main types of data are required for a rail operations calibrated model:

1. Timetable and infrastructure information.
2. Rolling stock data.
3. Dwell data.
4. Incident data.
5. Reliability data.

The rail operator or government rail organisation usually collects this data to monitor performance. After receiving the raw data, it is likely manipulation is required for the data to be in a format readable by the software.

## **Step 4. Validate model**

An important step is to validate the model. In some instances the infrastructure and timetable will need to be built from the beginning, which will require validation as part of the construction process. However, in most cases the infrastructure and timetable will be supplied. It is not satisfactory to assume the model is accurate. The responsibility is for the analyst to ensure, to a reasonable degree, the model is accurate. The analyst must demonstrate they made a sufficient effort to check the model.

## **Step 5. Static analysis**

This step consists of checking the timetable for problems other than what was discussed in the validation of the timetable. An important part of this step is to run a nominal simulation. This is a simulation without any perturbations (all trains run according to the timetable). This provides an opportunity to check for deadlocks and timetable errors, which can emerge when the nominal simulation is run. Deadlocks occur when the software incorrectly routes two trains to move towards one another on the same section of track – this does not happen on the actual railway due to the actions of train controllers.

There will always be small conflicts in a timetable, especially during the peak period when a high number of trains are operational. Small delays under one minute can generally be accepted.

## **Step 6. Final assumptions register**

By this stage the data will be procured and the model thoroughly checked, providing the analyst with an excellent idea of the overall project. Data difficulties, model problems and other issues will be known, allowing the assumptions register to be completed. Stakeholders should understand the assumptions and sign off the register. Further changes to the key assumptions should be communicated with stakeholders.

## **Step 7. Input the delay data**

This step is inputting the delay data into the software. This can be done manually (the analyst typing the data into the software) or by some kind of automation. The latter could be simply cutting and pasting the data if the software allows this process or by a more sophisticated program.

## **Step 8. Run simulation**

It is now time to run the simulation. The input delays have been entered into the software and checked for errors. Now the multi-simulations can be generated by the software, however the user must decide how many simulations to create. It is generally recommended 250-500 simulations be run to allow the reliability to converge and therefore be accurate. It is worthwhile running a series of simulations (for example four sets of 250 simulations) to check the difference between simulation sets. The variability between the simulation sets should ideally be less than +/-1%. If the variability is larger than +/-1%, more simulations should be run.

## **Step 9. Review results**

After the simulations have been completed the results can be viewed. Note the results can be checked while the simulation is still running in some software programs, for example RailSys. This can be useful to check if there is a major fault. This can save valuable time as the simulation can be stopped and the timetable/infrastructure checked instead of waiting until the entire simulation set has run, potentially saving hours of time. RailSys has a performance evaluator providing generic outputs and the ability to export for more detailed measures or illustration.

## **Step 10. Validate simulation**

This part is checking the model output against the historical reliability. Preferably this would be performed in a spread sheet which can automatically calculate the difference between the historical and model reliability. It is desirable to minimise the difference between the historical reliability and the model generated reliability. This can be expressed mathematically as:

$$|R_m - R_H| \leq E$$

where

$R_m$  = Model produced reliability.

$R_H$  = Historical reliability.

$E$  = Calibration error described in the assumptions.

A perfect calibration is unlikely, therefore a calibration error range needs to be determined. The definition of a 'good' calibration and 'poor' calibration will vary for each project. One highly dependent factor is the amount of time available to complete the project. A sufficient amount of time will enable fine-tuning of the reliability, allowing a better calibration. Conversely, a small amount of time may result in a 'rough' calibration with a greater number of 'poor' and 'close' calibrations.

There may be times, especially during a rapid calibration, when some points cannot be calibrated within the 'good' range. Usually there are a number of points to calibrate, such as a mixture of minute marks, groups of trains and locations, so a small percentage of 'poor' or 'close' calibrations may not be a concern. A high percentage of 'good' calibration errors can enable the model to be declared calibrated. Of course, if time is available any 'close' or 'poor' errors should be rectified if possible.

### **Step 11. Re-run simulation**

It is extremely unlikely the model will calibrate the first time it is run. Many iterations of running the simulation, checking the model and re-running the simulation will need to be performed. This will probably be the longest step of the calibration process. If the model is not calibrated during the first run (and this is unlikely to happen), a number of actions can be taken to improve the calibration:

- Adjustment of parameters such as:
  - Routing/dispatching methods.
  - Routing/dispatching settings.
  - Train priority.
  - Threshold for catching up with timetable if late.
  - Alternative tracks.
  - Minimum connection-times.
- Checking the timetable or infrastructure for errors.
- Check for other errors, such as perturbation errors.
- Investigating whether the appropriate perturbations were applied.
- Considering potential issues which may have affected historical on-time reliability during the calibration period. This could include track speed restrictions or occupations.
- Additional perturbations may be needed. However, this will need to be analysed and justified satisfactorily.
- As a last resort the perturbations can be adjusted. This is not the preferred option to calibrate a model and it is strongly recommended all other options be exhausted before this step is taken. The reason for the adjustments must be explained clearly and rationalised in the documentation.

### **Step 12. Documentation**

The calibration needs to be well documented. The final document will clearly discuss the assumptions, the calibration methodology, the results and an interpretation of the results.

The documentation should contain enough information for someone else to replicate the outcomes.

The documentation can either be written progressively throughout the calibration process or at the end. The preferred method is to continually update the documentation throughout the calibration rather than at the end. This enables any inconsistencies to be recognised early and enables the analyst to 'step back' and review the project. The writing and formatting do not have to be perfect, as this can be finalised during the formal writing phase.

Graphs are useful to show calibration outcomes and other data. A line graph can clearly show the difference between the software generated reliability and the historical reliability, for example. Distributions can also be shown in a line graph format. Tables are useful to show exact figures if this is required.

It is unlikely the model will be perfectly calibrated. The report may conclude by suggesting improvements to the model. Due to complexities in the model and the likelihood of inaccuracies, a continuous improvement process could be suggested. This could include improvements to data, further refinement of parameters or deadlock reductions.

### **Step 13. Peer review**

A peer review can be defined as a critical appraisal of a piece of work by a qualified person or group of people. The purpose of a peer review is to ensure a task has been completed correctly, to maintain a high standard and to provide credibility (Bain 2010, p. 9).

Peer reviews occur for a number of disciplines such as academia, scientific publishing, accounting and law (Bain 2010, p. 9). However, they can also be applied to modelling. In this case, the calibrated model and documentation can be reviewed by a suitably qualified person or organisation.

Bain (2010, p. 10) suggests four ways which a modelling peer review can occur, in order from the least intensive to the most intensive:

- **General desktop review**

These tend to be short projects which require the review of modelling reports and technical documentation. A spread sheet can be used to quickly check results instead of detailed modelling. There is usually no interaction with the original modelling team.

- **Specific desktop review**

The specific desktop review is similar to a general desktop review but an examination of more specific questions.

- **Desktop review**

This peer review includes site inspections and interactions with the original modelling team.

- **The 'embedded' peer reviewer**

This comprises of the reviewer being involved in the modelling process by attending meetings, reviewing documents and approving assumptions.

If a peer review is not possible, a detailed calibration report should be produced which clearly shows the reasoning behind the assumptions and the validity of the results. It should enable the results to be reproduced at a later date if required.

### **Step 14. Project modelling**

When the calibrated model and documentation is finalised, it can be used as a base for projects such as new timetables and additional infrastructure. It is advantageous for the

model to be calibrated for a particular project to ensure the assumptions are aligned. However, given the effort required to calibrate a model, it is likely the model will also be used for other projects. Careful consideration must be given to the project's assumptions and whether the calibrated model is relevant.

Calibration must be completed when a future on-time reliability figure needs to be predicted or reliability comparisons must be made between different options. However, the quantitative value must be used with caution, as it is very difficult to predict the future on-time reliability due to the possibility of operational, timetable and infrastructure changes occurring. The confidence in the modelling decreases when the project significantly differs from the calibrated model and when the project is operational in the longer term.

An additional train or small infrastructure changes to the calibrated model should yield accurate results as only minor variations have been made. However, a major project such as a new alignment will be a significantly different operation, with new stations, routes and service plans compared with the calibrated model. It would be conservative in this instance to compare various alignment options rather than provide a predictive reliability for, most likely, many years in the future.

The project documentation should make clear whether a quantitative future reliability figure or a comparative reliability figure will be used.

Calibrated rail operation models have been used to evaluate city-shaping projects such as Regional Rail Link in Victoria, Melbourne Metro and Brisbane's Cross River Rail. These projects will aid the development of contemporary urban environments by building stations in areas which previously had no rail access. Regional Rail Link will include two new stations in Melbourne's west at Wyndham Vale and Tarneit, providing rail services for the first time to the many people in these rapidly growing suburbs. Melbourne Metro proposes a station at Arden to support urban renewal in the precinct, which is currently an industrial and low density inner city area of North Melbourne. Finally, Cross River Rail will provide a station at Albert Street in the heart of Brisbane's CBD, increasing rail access to government, financial, retail and education precincts.

## **6. Case study: A RailSys calibration**

The Rail Simulation and Analysis team at the Victorian Department of Transport (now part of Public Transport Victoria) completed a calibration of Melbourne's Northern Group using RailSys modelling software. The Northern Group consisted of the Broadmeadows, Upfield, Sydenham, Werribee and Williamstown lines.

The Northern Group also serves four regional V/Line routes: Geelong on the Werribee line, Ballarat and Bendigo on the Sydenham line and Seymour on the Broadmeadows line.

The Northern Group was calibrated for the morning peak between 7:00 and 9:00, measured when services are scheduled to arrive at Flinders Street. There are 42 metropolitan trains and 27 V/Line trains during this peak period.

The model was set up with a Connex timetable (Connex operated the metropolitan network at the time) and V/Line timetable on an up-to-date metropolitan and regional infrastructure. Perturbations from twelve sample days were applied to the model in the form of dwell and incident delays:

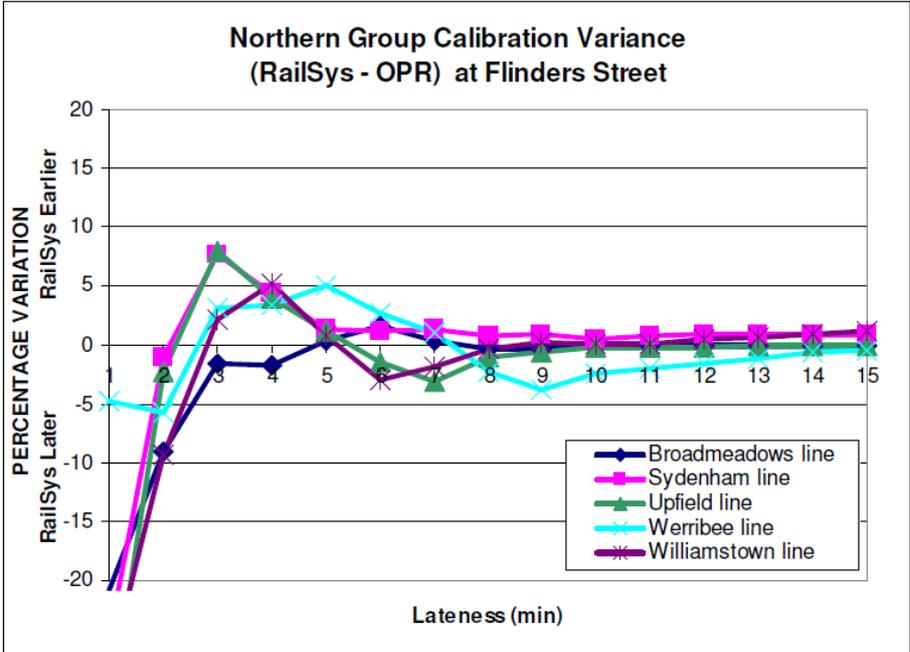
- Stations received a delay based on previous dwell surveys.
- Incident delays were applied to account for a number of delays across the group. These included delays because of passenger loading, train faults, police operations and short consists (during this period some trains operated as 3-car sets).
- V/Line services received a delay prior to entering the metropolitan area and dwell delays when stopping in the metropolitan area.

The on-time reliability was taken at Flinders Street and North Melbourne for inbound trains for the twelve survey days. Reliability was also taken for outbound trains at their destination, giving a three-point calibration. The benchmark percentage on-time running was at the two and six minute marks. The calibration target aimed to have a difference of between +/-10% at two minutes between RailSys and historical and between +/-5% at six minutes.

A number of parameters were tuned to achieve the required target. One parameter adjusted was *conflict identification look-ahead range* which determines the length of time into the future RailSys looks to identify conflicts. Another parameter adjusted was *threshold for catching up with timetable if late* which tells a train to increase to maximum allowed speed when a delay is above the setting.

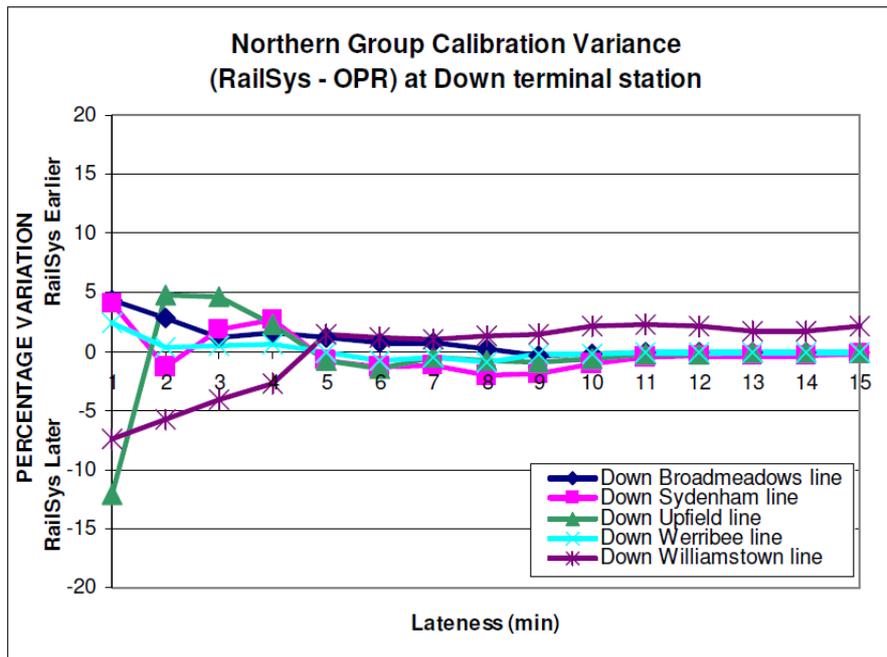
Figure 2 below shows the percentage difference between RailSys modelled reliability and real franchisee reliability expressed as Operational Performance Regime (OPR) for inbound (Up direction) metropolitan trains. The difference at the two mark is within +/-10% and at the six minute marks is within +/-5% target. So these would be deemed within the acceptable calibration targets.

**Figure 2: Up direction AM Peak RailSys calibration variance of each of the Northern group lines at Flinders Street station.**



The difference between RailSys reliability and OPR reliability for outbound (Down direction) trains at their destination station is shown in Figure 3. The differences are also within the targets described above.

**Figure 3: Down direction AM Peak RailSys calibration variance of each of the Northern group lines at their terminal station.**



The results were within the target at North Melbourne as well, therefore the model was declared calibrated and fit for purpose.

The calibration steps generally followed the steps in this paper. Significant project planning and data procurement was completed and the model thoroughly validated before simulations were run. The results were documented clearly and the general methodology was peer-reviewed by RMCon, the developers of RailSys.

This calibrated model was subsequently used to analyse a number of important projects such as Craigieburn electrification (completed in 2007), Sunbury electrification (completed in 2012), Regional Rail Link (currently under construction at a cost of \$4.807 billion (State Government of Victoria 2013)), Grovedale station (\$16.5 million was funded in this year's budget by the Victorian government (Premier of Victoria 2013)) and Melbourne Metro.

## 7. Conclusion

The shortage of rail operations calibration methodology has led to a lack of standardisation, ad-hoc analysis and no base to consider calibration issues. Therefore, this paper summarised a rail calibration methodology aimed at modellers to address this shortage of documentation.

A well-calibrated model outputs reliability results that closely reflect historical reliability figures, and simulates railway operations accurately. A model which outputs reliability near to historical but does not represent rail operations accurately is not calibrated.

The benefits of a calibration methodology are:

- A uniform base which enables comparison between different calibrated models.
- A more accurately calibrated model as the methodology provides suggestions to improve results and recommends standards.
- Decreases cost and effort required to calibrate a rail operations model by providing a step-by-step methodology which covers all calibration requirements.

- A wider acceptance of the model by clients and colleagues as the methodology is based on consultation with rail calibration experts.
- Provides modellers and other interested people with general information and a calibration philosophy.

Calibrated rail models have been used as a base to evaluate city-shaping projects such as Regional Rail Link in Victoria, Brisbane's Cross River Rail and Melbourne Metro.

## 8. References

Australian Railway Association (2008) *A Rail Revolution: Future Capability Identification and Skills Development for the Australian Rail Industry*,  
<http://www.ara.net.au/UserFiles/file/Publications/Rail%20Revolution%20report%20TEXT%20PAGES%20170608.pdf>

Bain, R (2010) *Modelling Best Practice: The Benefits of Peer Reviews*, Data & Modelling: Winter 2010, Local Transport Today, December 2010, pp. 9-10,  
[http://www.robbain.com/Modelling%20Best%20Practice\\_The%20Benefits%20of%20Peer%20Reviews.pdf](http://www.robbain.com/Modelling%20Best%20Practice_The%20Benefits%20of%20Peer%20Reviews.pdf)

Chung, CA (2004) *Simulation Modeling Handbook: A Practical Approach*, CRC Press, Florida.

CityRail (2012) *Our Performance*, viewed 2 November 2012,  
[http://www.cityrail.info/about/our\\_performance/](http://www.cityrail.info/about/our_performance/)

Hellinga, B (1998) *Requirements for the Calibration of Traffic Simulation Models*, Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada,  
<http://www.civil.uwaterloo.ca/bhellinga/publications/Publications/CSCE-1998-Calibration.PDF>

Infrastructure Australia (2013), *Reform and Investment Framework*,  
[http://www.infrastructureaustralia.gov.au/priority\\_list/files/Infrastructure\\_Priority\\_List\\_Submission\\_Guidance\\_August\\_2013.pdf](http://www.infrastructureaustralia.gov.au/priority_list/files/Infrastructure_Priority_List_Submission_Guidance_August_2013.pdf)

Koutsopoulos, H & Wang, Z (2006) *Simulation of Urban Rail Operations: Models and Calibration Methodology*, International Symposium on Transport Simulation, 2006, Lausanne, Switzerland, <http://www.crcnetbase.com/doi/abs/10.1201/9781439808016-c10>

Koutsopoulos, H & Wang, Z (2007) *Simulation of Urban Rail Operations: Application Framework*, Transportation Research Record: Journal of the Transportation Research Board, Volume 2006 / 2007, <http://trb.metapress.com/content/W8WX5Q2XL9101680>

Landex, A (2012) *Reliability of Railway Operation*, Proceedings from the Annual Transport Conference at Aalborg University, [http://www.trafikdage.dk/papers\\_2012/87\\_AlexLandex.pdf](http://www.trafikdage.dk/papers_2012/87_AlexLandex.pdf)

Lindfeldt, O (2010) *Railway Operation Analysis*,  
<http://kth.divaportal.org/smash/get/diva2:318296/FULLTEXT01>

Markewicz, B (2013) *A RailSys Calibration Methodology*.

MTR (2013) *MTR Performance Achievements*,  
<http://www.mtr.com.hk/chi/publications/images/performance.pdf>

Parliament of Victoria (2010) *Inquiry into Skills Shortages in the Rail Industry*,  
[http://www.parliament.vic.gov.au/images/stories/committees/etc/full\\_report.pdf](http://www.parliament.vic.gov.au/images/stories/committees/etc/full_report.pdf)

Premier of Victoria (2013) *New \$26 million Grovedale station a boost for public transport in Geelong*, viewed 28 May 2013, <http://www.premier.vic.gov.au/media-centre/media-releases/6593-new-26-million-grovedale-station-a-boost-for-public-transport-in-geelong.html>

Public Transport Victoria (2012) *Performance Monitoring*, viewed 2 November 2012,  
<http://ptv.vic.gov.au/about-ptv/victoria-s-pt-network/performance-monitoring/>

Queensland Rail (2012) *Your time*, viewed 2 November 2012,  
<http://www.queenslandrail.com.au/AboutUs/CustomerCharter/Pages/Yourtime.aspx>

Rakha, H, Hellinga, B, Van Aerde, M, & Perez, W (1996) *Systematic Verification, Validation and Calibration of Traffic Simulation Models*, 1996 Transportation Research Board Annual Meeting,  
<http://www.civil.uwaterloo.ca/bhellinga/publications/Publications/TRB%201996%20Validation.pdf>

South West Trains (2013) *Our performance*, viewed 13 June 2013,  
<http://www.southwesttrains.co.uk/our-performance.aspx>

State Government of Victoria (2013) *FAQ about the project*, viewed 28 May 2013,  
<http://www.regionalrailink.vic.gov.au/about/faqs/faq-project>