Using simulation to predict the impact of upgrades

ERIC COSANDEY
CEO
SMA and Partners Ltd

PASCAL JORIS
Expert Operations
SMA and Partners Ltd

Sophisticated modelling is a useful tool to assess the impact of upgrades on complex and busy metro networks.

Services on sections of the London Underground share track with services run by other operators.

High-frequency metro services are increasingly confronted with rising demand, forcing operators to provide additional capacity. There are two basic options to achieve this: new infrastructure, which requires high levels of investment, or operational optimisation, which costs less. Automation presents new traffic control options, but these bring their own challenges, and operators are still building up experience with CBTC and ETCS.

Choosing between different modernisation paths requires dependable information about possible performance gains. A sophisticated simulation model can assist in predicting how a network will perform as traffic increases and the number of services is stepped up. The operator can evaluate the impacts of these trends on a network where upgrading work of various kinds is a continuous process. Using a train service simulation model enables operators to assess the results of future upgrades and the outcome of proposed operating strategies in a virtual environment.

Taking into account each network's peculiarities, and considering key performance indicators such as reliability and punctuality, a microscopic synchronous simulation model is an interesting option. SMA and Partners Ltd has built and exploited models of this kind using OpenTrack software.

Such a model allows simulation of realistic operating situations such as the impact of train delays on the rest of the network. It enables rules to be specified during the simulation to reproduce dispatching and traffic management decisions taken during real operations. These rules include simple train priorities, as well as more complex procedures

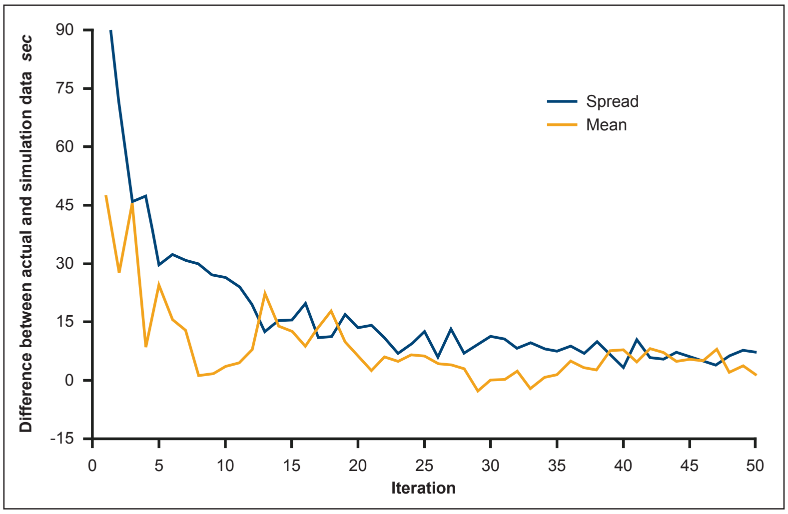

Fig 1. The average difference between actual and simulation data is not sufficient to calibrate the model. The spread of the differences gives a better idea of the calibration progress.

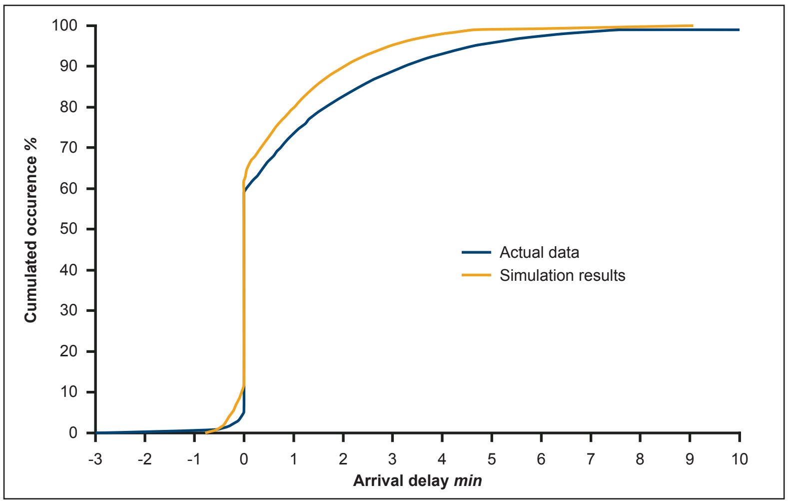

Fig 2. The distribution of delays is a good tool to evaluate a simulation model. Differences in behaviour of the model and the real operations have a direct impact on the curves and hint at the corrective input needed.

Table I. Incident classes used for simulation

Delay *min*	Type of incident	Measures	Simulation type
Less than 3	Marginal	Minor or self-recovering	Purely stochastic
3 to 10	Average	Corrective traffic management	Test of intervention strategies
More than 10	Disruptive	On-site intervention plans	Test of alternative operation programmes

designed to optimise particular system behaviours. In essence, the model attempts to replicate good dispatching decisions for metro and commuter rail systems.

Challenges of calibration

The main challenges lie in calibrating the model. Questions regarding reliability, punctuality and on-time performance for specific delay cases can only be assessed in a perfectly calibrated model, which acts as a form of operations laboratory. The model has to be able to handle the different signalling systems and operational patterns on the network, and the simulation tool needs to be flexible enough to adapt or match the behaviour of different system elements to real operations.

Dense metro and commuter rail networks generally focus on planning and traffic management based on journey times and frequencies. The operating plan or timetable acts as a guide for a synchronous dynamic simulation, and it needs to be calibrated to reflect the changes in operating patterns that occur when services switch from off-peak to peak-hour frequencies and back again.

The model also needs to allow for numerous minor deviations from planned operations, which happen continuously over the course of a day. Examples include slow passenger exchange at a station or a train being held to regulate the service. These deviations are covered by the simulation through stochastic events following a given random distribution.

Real-time traffic data has to be compared with the output of the simulation, with the distribution model then adjusted in an iterative process to ensure calibration. Supplementary variables including the actual performance of the trains and the reaction times of the signalling and train control need to be fine-tuned during these iterations. In order to manage the calibration process, a standardised iterative procedure using a data analysis tool serves as interface between the operator's traffic data and the simulation software.

Typically, the calibration is tested with chosen representative incidents (Table I). The most interesting cases usually occur with incident durations that lie in the 3 to 10 min range, for which light corrective traffic management measures are engaged. Below this range, the need for intervention is expected to be minimal and the system designed to recover without external intervention. For delays of more than 10 min, more complex handling measures — including partial or full cancellation of train services, or even withdrawal of services over part of a route — may be required.

Cost and effort versus precision

In such a project, the collection and processing of the input data is a critical task. Data usually exists in different formats at a varied level of detail, often from several signalling and rolling stock suppliers, ranging over several decades. Interpretation of the documents requires strong expertise and proficiency.

The process raises the question of trade-offs between cost and effort on the one hand and precision on the other. Calibration of the model is a major factor in the time needed. The acceptance criteria dictate the precision needed, starting with the modelling of the infrastructure and the vehicles. Just as important is the way in which traffic is modelled: entire days or shorter periods; all movements or just commercial services. Finally, between introducing disturbances with a single distribution for the entire simulation or defining individual events for each train at each station, the range of calibration options is almost infinite.

Such approaches make it possible for operators of highly complex networks to assess future upgrades and new operating strategies. They can then perform partly or fully automated simulations to test diverse service strategies, stopping patterns, and infrastructure and equipment enhancements. Even in the most complex networks running high-frequency services, there is always room for optimisation. ■

Complex networks with varied service patterns such as the New York Subway can benefit from operations modelling.