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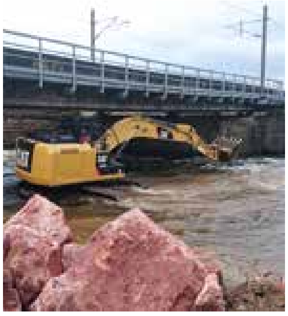

ASSET MANAGEMENT
Decision support
Research seeks to help infrastructure managers make better spending choices
PAGE 31

SOUTHEAST ASIA
State Railway of Thailand
After multiple false starts, SRT is making headway with a double-tracking programme
PAGE 45

ANALYSIS
Time to change
Spinetta report recommends tough choices to prepare SNCF for competition
PAGE 25

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Towards better asset understanding

Dynamic **clearance analysis** paves way for **automated fleet**

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High-precision 3D measurement of the Glasgow Subway network has formed the basis for accurate clearance simulation ahead of the introduction of Stadler rolling stock on the Glasgow Subway.

Automation is the watchword of the transport sector in 2018, yet in the urban rail market automation is not new. Nevertheless, as legacy metro and light rail networks age and demands for more capacity increase, more operators and network owners are looking to automate their trains.

The older the metro, the greater the challenge, and the modernisation of Glasgow's 10·5 km Subway is a case in point. Known colloquially as 'the clockwork orange', this orbital line opened in 1896 and is considered to be the third oldest underground metro in the world, after London and Budapest. As a result, it has some relatively unusual characteristics, including a track gauge of 1 220 mm and a tunnel diameter of just 3 400 mm.

Some years ago, Strathclyde Partnership for Transport, which manages the network, and the Scottish Government concluded that the Subway was overdue for major renewal, allocating a budget of £288m for this work. While plans to extend it were ruled out, the authorities decided to resignal the network and order a new fleet of trains with a view to reducing headways and increasing passenger throughput. In March 2016 SPT awarded a £200m contract to a consortium of Ansaldo STS and Stadler Bussnang to supply a fleet of 17 driverless trains and signalling systems for automated operation (RG 4.16 p14).

The four-car trainsets with walk-through gangways will replace the existing fleet of three-car sets, but will otherwise be built to the same dimensions. They will have space for wheelchairs, and some stations are being rebuilt to provide step-free access. The trains will be 39 m long with a maximum design speed of 58 km/h. Each set will have 104 standard seats, six folding seats and 200 standing spaces. Half-height platform edge doors will be fitted to all 15 stations.

High-precision 3D measurement of the Glasgow Subway was undertaken using the IMS 5000 surveying tool.

The new trains are expected to enter service from 2020, and the new control system is being designed for a minimum headway of 90 sec. According to SPT, operations will switch from the current ATO (GoA2) to UTO (GoA4) 'over time', once the signalling and control systems have been fully tested.

During the transition period, the first

AMBERG IMS

The Inertial Measuring System

IMU technology is at the core of inertial navigation systems. Initially developed for flight navigation, today it is well established as a sensor technology for railway surveying. Amberg has adapted the technology to support surveying at walking speed.

The Amberg IMS 5000 used in Glasgow contains a high-precision IMU (Amberg AMU 1030) consisting of three gyroscopes, three accelerometers and an onboard processor. It has a measuring frequency of up to 1 000 Hz and extremely low drift over time.

The IMU sensor is used to measure and record the 3D space curve of the track, which previously was undertaken using a theodolite or GPS. During the processing of the results, the survey data are converted into higher-order co-ordinates supported by multiple reference points. ■

MONITORING Great Britain

The 17 new Stadler trainsets for the Glasgow Subway must match the dimensions of the existing fleet.

Principal features of the Amberg IMS 5000 measuring system

Laser scanner performance	200 profiles/1 million points/sec
AMU 1030 Inertial Measuring Unit	
Odometer	
Gauge sensor	
Additional cant sensor	
Maximum measuring speed *km/h*	4
System accuracy	
Track geometry *mm*, 30 m chord	0·7 (2 sigma)
Track geometry *mm*, 300 m chord	3·0 (2 sigma)
Gauge *mm*	0·3
Superelevation *mm*	0·5
Profile accuracy relative to track axis *mm*	3·0

Stadler trainsets will be employed in mixed operation alongside the existing rolling stock, and will have drivers on board.

Facilitating a new fleet

Clearly, the development of a new train design for the Subway would be dependent on understanding the precise characteristics of the infrastructure as well as the dimensions of the existing fleet. Because the current motor and trailer cars are physically identical, there was no extensive data on the clearance envelope nor a comprehensive policy for data handling. As Stadler was required to provide proof that the new trains could operate on the existing infrastructure, it became necessary to source comprehensive geometric data on track and structures.

Stadler Rail appointed Amberg Technologies to undertake the required surveying and carry out customer-specific clearance testing. To achieve full-coverage capture and recording of an extremely precise geometric baseline, Amberg had to:

- document the current condition of the infrastructure;
- conduct dynamic clearance analyses for testing and optimising the car models;
- verify the profile clearance of the defined model.

A total of 21 track-km had to be surveyed, covering the two concentric unidirectional running lines, depot access tracks and sidings, and other non-revenue track.

Because of the restrictive dimensions of the tunnel bores, the new vehicle design must make best use of space. As a result, calculation reserves had to be kept to a minimum, and very stringent requirements were issued for data accuracy and density. The 3D geometry of both the track and the tunnel walls had to be determined very accurately. To ensure that every asset relevant to the clearance calculation could be surveyed, including wayside signs, structural supports and other fixed installations, a data density of 5 mm was specified.

Precise recording of the track parameters has a direct influence on the resulting clearance envelope. Inconsistent track geometry, either horizontally or vertically, can affect the dynamic behaviour of the rolling stock and the resulting clearance requirements. Track gauge and cant will also affect the clearance calculations.

Surveying tools

Access to the tracks was limited to brief overnight possessions, already used for routine infrastructure maintenance. The need to fit around other work required a particularly flexible surveying methodology.

The Amberg IMS 5000 measuring system was selected for the work (p41). This tool pairs an Amberg Profiler 6012 laser scanner with an Inertial Measuring Unit, which allowed the track parameters and the 3D geometry of the tunnel to be captured in a single pass. As a result, only four overnight possessions were needed to complete the measurement of the entire network, including sidings. The IMS 5000 tool achieved approximately four times higher performance than Amberg's previous equivalent surveying tool.

By using a mobile and modular measuring tool, late-notice changes to the overnight maintenance regime could also

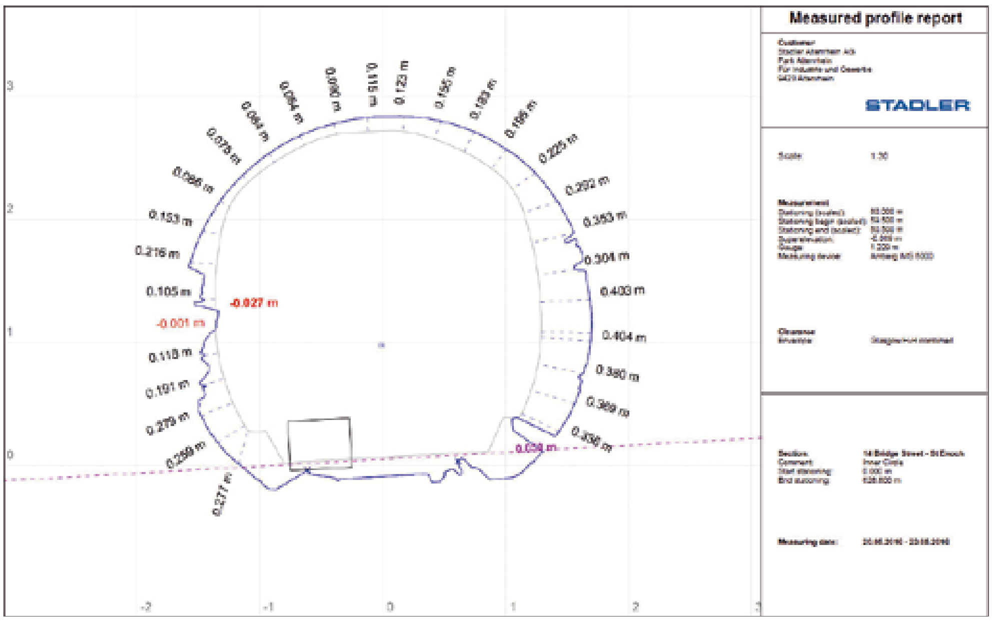

Fig 1. Creation of cross-sectional reports to show areas of restricted clearance.

be accommodated. Access to the tracks was obtained through the stations, and the live conductor rail was switched off for the duration of the surveying work.

Finding extra space

The full-coverage point cloud and track data were evaluated using Amberg Rail 3.0 software (Fig 1). The 3D data primarily serve as the basis for the clearance tests required by Stadler, indicating whether the proposed design could match the dynamic envelope of the existing fleet, and what extra adjustment to the dimensions might be necessary.

The greatest challenge lay in determining accurately the dynamic behaviour of the train under normal running conditions and in a series of possible alternative scenarios. Stadler engineers and Amberg staff held a series of meetings to identify these scenarios as well as assessing in detail the engineering and safety features of the proposed trainset. This process went beyond conventional clearance tests, which show whether the vehicle would fit through the tunnel, to include an assessment of potential 'problem areas'.

The full-coverage survey data showed potential infringement risks caused by signals, signage, cable brackets or station platforms, and highlighted where extra space might be found using cross-sectional profiles (Fig 2). This analysis was then fed back both to Stadler and SPT so that decisions could be taken about either adjusting the dimensions of the vehicle design, or modifying the infrastructure, for example by moving a lineside asset.

These clearance analyses were carried out in several iterations, informing Stadler's final decisions about the carbody design and the location of key components.

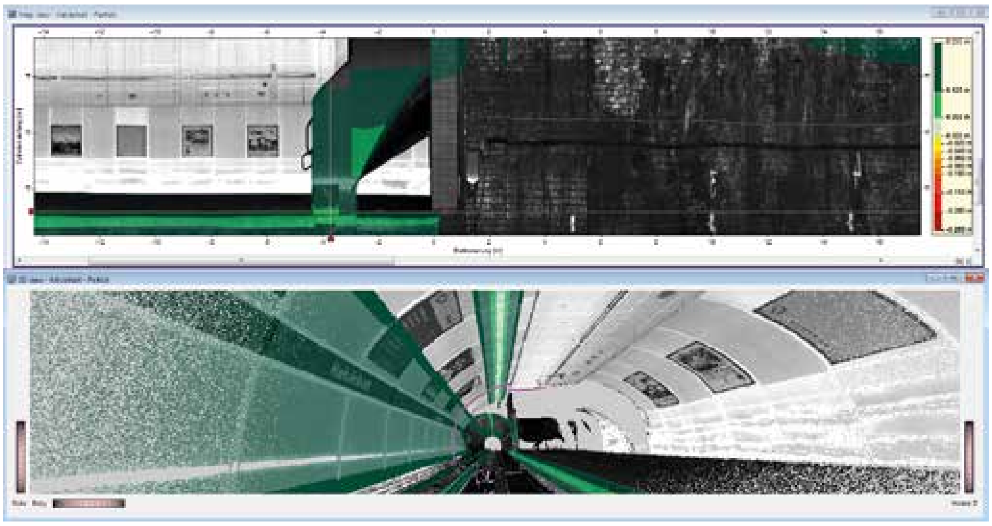

Fig 2. Full-coverage dynamic clearance models are created using Amberg Rail 3.0 software.

A basis for BIM

The high-resolution 3D data obtained from the surveys can also be used to support wider objectives in the Subway upgrading programme. Because known control points along the track were measured as well, the 3D point cloud can be georeferenced and provided with absolute co-ordinates. This can be used to support construction activity taking place around or close to the metro, and as the basis for the network owner to use Building Information Modelling in the future. ■