Train Mounted Laser Survey of Birmingham New Street Area Resignalling Phase 7

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Executive Summary
The case study sets out how the use of a Multi Purpose Vehicle (MPV), installed with a laser scanner compatible with OmniSurveyor3D was used to undertake a survey in order to produce a model of the Birmingham New Street Station area for signal sighting purposes.

Background
As part of the Signalling National Innovations Portfolio (SNIP) Signalling Innovations Group undertook an upgrade of the systems installed on MPV (DR98008). The MPV provides Network Rail (NR) with a second survey platform for Automatic Mapping of the Railway (AMR) surveys to meet the demands of IP Signalling Project Teams.

Figure 1: MPV (DR98008)

The upgrade consisted of:

- Installation of an OmniSurveyor3D® (OS3D) specification Ring Laser Gyroscope (RLG) and logging system on to the MPV.
- Installation of additional tachometer inputs and distribution to run the S&C Inspection System, track geometry systems, and OS3D, simultaneously.

- Timecode distribution between OS3D and Real Time Positioning System (RTPS) such that an OS3D survey does not affect normal operation and media can be shared between systems.
- Installation of a survey-grade Global Navigation Satellite System (GNSS) antenna, receiver and cabling.
- Development of the OS3D data processing system to integrate the S&C Inspection System with panoramic video and associated data streams.
- Development of OS3D desktop kiosk software to enable the system to interpret and view both linescan (rail, track and 4-foot) and areascan (panoramic) imagery.
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- Figure 2 and 3: GPS Antenna and RLG installed on MPV

Prior to the use for IP Signalling Surveys, the MPV is used for S&C inspection, with the existing inspection system comprising of a Real Time Positioning System (RTPS), forward facing and rear facing cameras, 4-foot cameras (areascan) and 3 cameras per rail head (linescan), along with a canopy between driving cabs for the MPV itself.

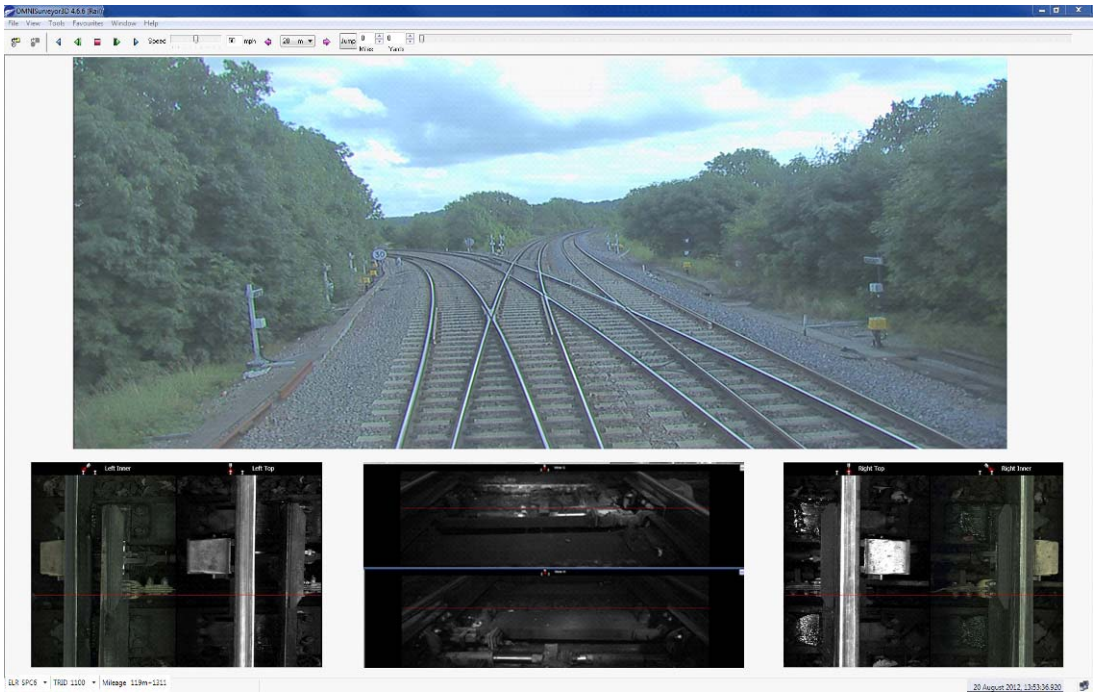

Figure 4: Imagery captured from MPV, displayed in OS3D software

Birmingham Signalling Design Group (SDG) reported the requirement to undertake a survey of the station and surrounding areas for signal sighting purposes.

A review was undertaken of the methodologies and technologies available to the team. The Birmingham New Street (BNS) Station presented a number of difficulties, in that the: -

- High density of tunnel areas, rendering HD video too dark for use.
- GPS Coverage is poor for positional systems.
- Volume of traffic results in possessions very difficult to obtain.

On the 30th June, Signalling Innovations Group presented the outcome from a pre-feasibility study to the Project Team. The summary of the presentation included: -

- Discussions with Data Collection Service (DCS) and BNS Local Operations Manager offered a potential survey plan.
- MPV would be the ideal survey platform, subject to fitment of a rotating Laser Scanner to survey the tunnel areas.
- Laser trials with a Land Rover had proved successful in demonstrating Combined Laser/Video surveys for use with the Signal Sighting.
- Demonstration of the use of 3D rendered models in OS3D met the requirements of the Signal Sighting Engineer. The 3D models would also be compliant with the use of the Signal Sighting Image Models developed by the SNIP project for use by Signal Sighting Engineers (SSE)
- Undertaking the Sighting in a rendered model generated from the laser point cloud in the tunnel and station areas would also meet the requirements of the Sighting Engineers and Chairperson.

Subsequent discussions with the Area Director, Network Operations, for LNW and the Project Manager for BNSAR, SDG decided to utilise the MPV with the laser scanner to undertake the Sighting Survey for BNSAR Phase 7.

Laser Scanner Installation
In order to expedite the project, SIG issued a variation to the contract for the MPV Systems Upgrade to install a Z&F 9012 Laser Scanner.

The scope of the variation covered:-

- Production of manufacturing and installation drawings, a Material Inventory List, and Method Statements for the laser installation.
- Undertake Hazard ID and Detailed Design Reviews.
- Manufacture and Installation of all bracketry.
- Supply of Logging and Control Pod.
- Source Vehicle Acceptance Board (VAB) Approval.
- Undertake Static and Dynamic Commissioning and Test runs.

The laser protrudes beyond the vehicle buffers and is therefore removed after the survey has been completed.

Figure 5: Laser Scanner Install on MPV

The Survey

The survey extents were defined by the Project Operations Interface Specialist and SDG Design Manager. These were conveyed to DCS, to Omnicom and the Shift Signalling Manager.

Meetings were held with DCS, the SSM and Omnicom to develop the run profile through the station. Traditional AMR surveys are delivered in video clips identified by ELR, TRID and Mileage. For BNS, it was agreed to deliver the data to the corresponding train run through the station, which met the requirements placed on the project by the Signal Sighting Specialist. (SSS) It was also agreed with the SSS which of the runs would need joining to adjacent run, to create a longer clip. Joining multiple clips together was required to minimise the total running time in the station. With traditional AMR surveys, joining two adjacent clips together is not straightforward if the system accuracies are to be maintained. With the improvements afforded by the MPV recording architecture and the laser point cloud data, this is now feasible.

Detailed train plans were generated and briefed to all stakeholders, for 42 train paths through the station area, which contained each approach to every signal. During routine operation of New Street Station, at least one platform is out of use at any one time. During the survey Platform 1 and East Dock Road were unavailable, resulting in 3 runs being missed.

Due to operational constraints, it would not be possible to allow 5 minutes for the static alignments for the RLG and GPS systems every time the train changes direction. To mitigate for this, Omnicom contracted with Offset Services Limited to layout visible targets around New Street Station. These were situated on each end of each platform and were located using a theodolite survey. These known 3D locations are then

captured using the onboard camera and laser systems and utilised by Omnicom software to provide further camera calibration.

Figure 6: Laser Target 5009 visible on the end of 'Welcome to Birmingham New Street Sign'

On the approach of the survey, weekly conference calls were held with the stakeholders involved in the Engineering aspects and the Operational aspects of the survey. These provided an excellent forum to raise and close issues within each distinct stakeholder group, which also ensured that the survey work was planned along side the maintenance requirements of the vehicle. The weekly forum also provided a means of communication between the two groups of stakeholders who often had competing requirements.

A revised survey template was generated by the Work Package Manager (WPM), which formed the basis of the survey contract for Omnicom and will also support the use of the MPV for future surveys.

During the survey weekend, 3D Visual Simulations Limited, the company that will undertake the rendering of the 3D model, captured a number of photographs, in order to assist them through their work. These included the approach to East Dock and Platform 1 where the model would be created from a combination of the Point cloud (on approach to the route), the track layout diagram, imagery from adjacent lines and the photographs. Fortunately the signal for East Dock Road remains in place and it's location was captured in the video and laser footage.

Figure 7: East Dock Road.

The train was pathed from its stabling yard in Rugby to Birmingham International. At Birmingham International the laser was installed and a 20 minute static alignment was undertaken. The train then remained under local control of the BNS Signallers for the duration of the survey. 31 runs through New Street were undertaken, running to the maximum extents of Soho on RBS2, Kings Norton on BAG1, Grand Junction on DBP before heading back to Birmingham International for the end static alignment and the removal of the laser.

OmniSurveyor3D®

OS3D is a system based upon high resolution digital images and an augmented positioning system that includes differential GPS (DGPS) and a high grade Inertial Measurement Unit (IMU) and quadrature phase tachometer. The OS3D application will enable Network Rail to undertake accurate three-dimensional measurements and acquire and validate accurate asset information. The application will also be used for basic signal sighting, using the Signal Sighting Image Models (SSIM) developed by SIG. The software also allows the user to undertake design verification, route familiarisation and pre-planning of possessions or site excursions.

The OS3D system has been successfully applied to many signalling scheme design projects with the use of accurate asset data captured from the OS3D system together with the Automatic Mapping of the Railway tools will make scheme plan design more efficient. The provision of both OS3D asset inventory and track centreline data form the basis of 'as is' CAD diagrams used in the early planning stages of a re-signalling scheme design project.

The addition of high speed laser scanning capability enables the OS3D system to create 3D model of the areas being surveyed. The 3D model is then rendered back into OS3D. This provides particular benefits in areas such as tunnels where due to the low lighting it is difficult to determine the location of assets in these areas.

Video Data Processing - Positioning

Data from the GPS and Inertial Measurement Unit are augmented to establish an accurate position trace of the route traversed by the vehicle. GPS is differentially

corrected against static base station data. The inertial data is relied upon through the complex area of New Street where GPS availability is non-existent or sparse and subject to multipath. Precise orbit ephemeris data is also used to improve the solution accuracy.

Image data is processed from its raw captured format into an indexed JPEG based proprietary format required by OS3D. The imagery is time corrected against the positioning solution to allow each frame to receive a position and playback in synchronisation.

The laser scan data along with calibration data for the lead cameras is used to generate a set of frames for a virtual forward facing camera view for the sections of tunnel. This provides a view of sections that are usually not visible within the tunnel areas from standard video. These frames are then spliced into the video clips to provide a seamless clip of data combining the camera and laser data for signal sighting purposes. Details on the processing of the laser data specifically is covered in the next section.

The data is edited into the desired paths for signal sighting in order to allow the end user a single clip to traverse the routes from a sighting perspective and provided as OS3D clips.

Data Processing - Point Cloud Data Modelling
During the processing stages, the point cloud data is modelled in two ways.

- Firstly, the video data is superimposed with the point cloud rendered on top and exported in a format for viewing in OS3D.
- Secondly, the 3D Point Cloud Model is amended where required and provided for viewing in its raw format.

OS3D Format
An example of the raw data captured from the scanner is given below. The 'as-captured' data requires processing to improve the visualisation and usability of the data. Data cleansing on the raw data is undertaken to remove and shadow points and reflections.

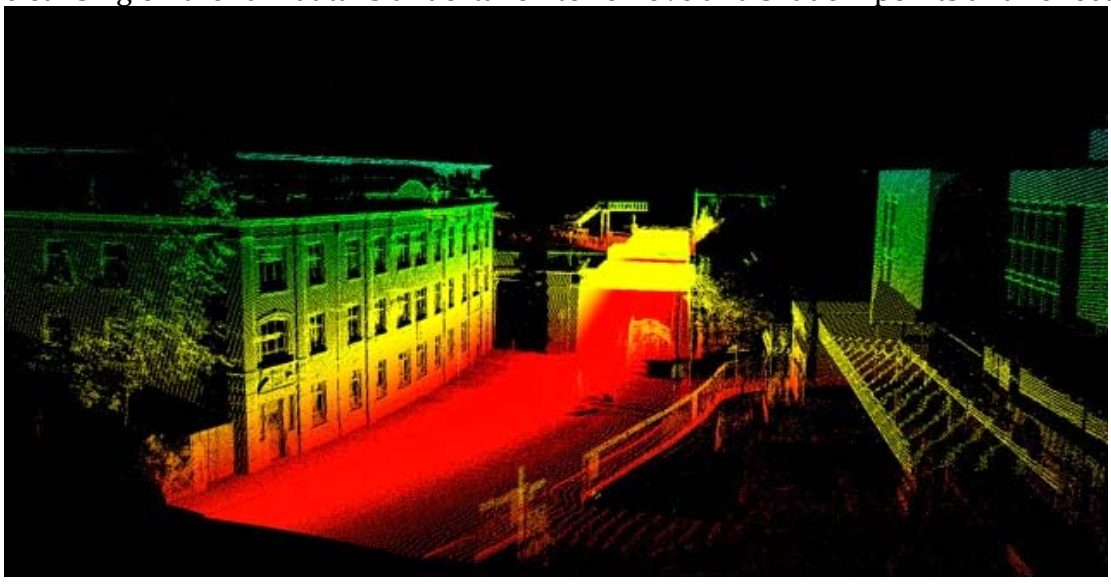

Figure 8: Raw Point Cloud Data

The data is re-sampled to equalise the point density, as the track below the data will be densely sampled. Visualisation enhancement processes are applied to the data to identify flat surfaces and edges within the data.

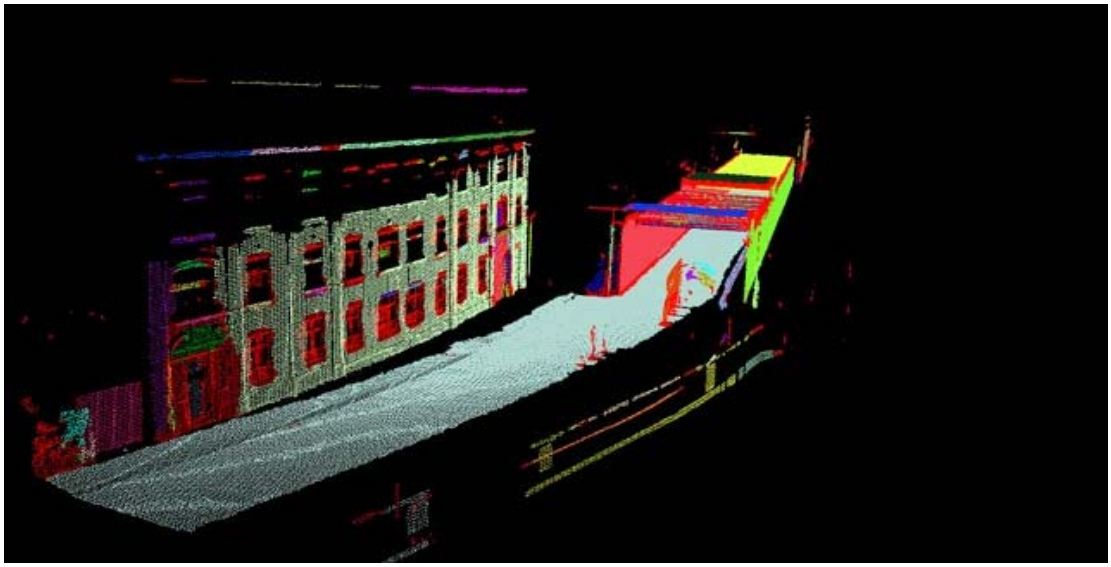

Figure 9; Cleansed Data processed with surfaces identified and visualised

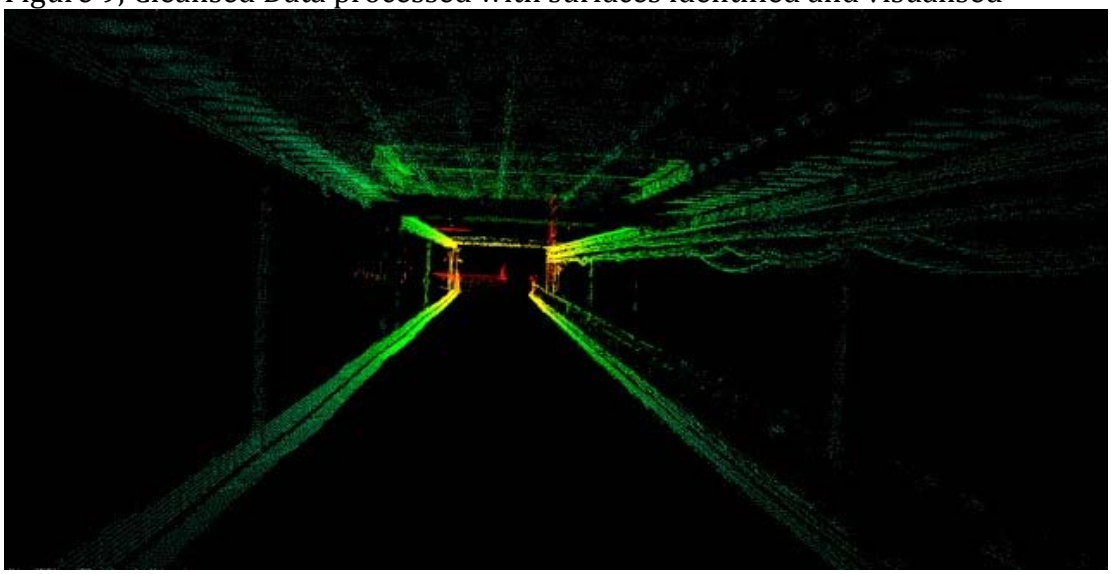

Figure 10; Cleansed Data processed with edges identified and visualised

Once processing is completed, the laser points are rendered on to each respective video frame and images are exported in an OS3D compatible format. This is the principal view that the Signal Sighting Specialist uses for presentation to the committee.

Scheme Point Cloud Model

The Scheme Point Cloud Model takes each of the individual laser point files from the stage above, prior to rendering on the video, to create a single dataset. For BNS a number of project specific tasks were undertaken, namely:-

- Removal of stabled trains from the point cloud.

- Removal of any works sites from the point cloud. For BNS, boarding was removed from Platform 1 and the approach to East Dock.
- The 3D model for East Dock was created from the Track Layout plan, photographs and manual measurements.
- Creating a virtual train path through East Dock and Platform 1, for Sighting purposes.

More generic processes are also applied at this stage such as re-sampling the data to remove any duplicate scans that were captured in more than one run. Any holes in the data can be filled. These can occur on Platform surfaces, as the laser scanner is mounted on the train at platform level, therefore the individual laser points can be sparsely populated thus creating the illusion of holes in the data.

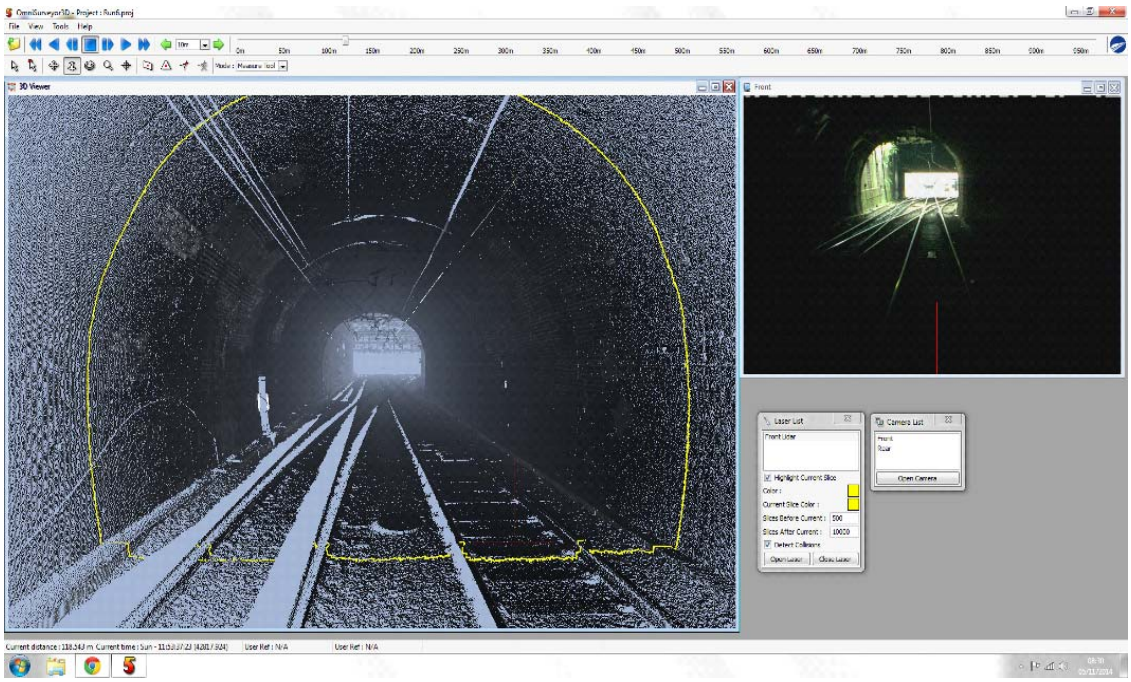

Figure 11; Synchronised video and laser data

Signal Sighting Process

The Network Rail company specification on signal sighting (NR/L2/SIG/10157) states that 'a Signal Sighting Committee (SSC), shall verify the proposed position and form of all new, modified and repositioned signals...'

New signalling schemes involve the use of a scheme plan being used, which is produced by a Signal Designer. This scheme plan is used by the SSC in both video and site based discussions throughout the sighting process.

The SSC is generally led by a Signal Engineer from the Design Group, who is competent to Chairperson level.

Agreement or otherwise on the proposals are documented and when satisfied that all considerations are acceptable, each member signs the Signal Sighting Form (SSF) to

indicate their agreement. Until all members have signed the SSF, the RAM will not sign off to approve the proposed signal recommendations.

Signal sighting documentation now includes more than just the SSF, as was the case 10 or so years ago, and there is in fact a 'pack' of documentation relevant to each signal.

It can be considered that pre SSC assessments are undertaken by Engineering Staff only, as they result in the actual SSC work being less time consuming. Design & Signal Sighting staff used the rendered jpg images in OS3D to undertake the pre-SSC assessments successfully, and sighted the signals in the tunnels, without the need for site visits. Also, the laser data was used to identify any obscuration and provides additional modelling capabilities.

In simple terms the SSC aims to achieve the following;

'Ensure the driver has the optimum reading time and receives a clear and unambiguous message relating to the relevant signal aspect displayed'

Conclusions

During the BNS survey a number of firsts were achieved, namely :

- First time the MPV was used for Signal Sighting and Automatic Mapping of the Railway Surveys.
- A Survey was undertaken under local control.
- Laser Point Cloud captured from a rail vehicle.
- Multiple data sets have been integrated for the Sighting Process.
- Modelling of adjacent roads.

The planning and communication between the Train Crew and the Signallers ensured the survey went smoothly and maximised the survey extents covered.

The additional flexibility in surveying provided by the MPVs recording hardware allows the following benefits to be realised:-

- The use of the SSIM Models within OS3D Video/Rendered Model is an extremely cost effective and efficient Signal Sighting process. One Survey can be undertaken for Asset Inventory, Signal Sighting and inclusion into the BIM model.
- The downstream uses of the Model, the TCL data and the Video data provide benefits through both the Design and Construction Phases on any project.

The vehicle and the modelling process have subsequently been used for an Asset Inventory Survey for Euston Station, where once again, vehicle access is very difficult during daylight hours.

Data from both surveys has also been provided to Asset Information, for use in the management of the map model for the Geo-RINM viewer.

Business Case

Referring back to the review of methodologies available to Birmingham SDG, the options included:-
1) Boots on Ballast
2) Computer modelling using combined laser and video modelling.

If we take each option in turn:-

Boots on Ballast - For the 64 signals, SDG has estimated that 10 possessions would be needed for setting out the sighting and taking measurements. For each of those possessions, the planning, setting up safe system of work, COSS, and Lookouts (if required), would be in the region of £5,000.

In addition to the setting out, the review by the Signal Sighting Committee would require an estimated additional 20 possessions. There are a number of difficulties in convening the committee as possessions would only be available on a Saturday night shift, when potentially committee members would not be available.

Typically, the TOC representatives change NR up to £700 per man day for attendance. Including the committee costs this would be in the region of £10,000 for each possession.

Thus the total estimated costs for option 1 would be in the range of £250,000 - £260,000.

For the computer modelling option, the costs of the survey and the train hire charges were £118,000.

For the committee review, it is estimated 3 shifts would be required at a cost of up to £7,000 per shift. Using the video tools, up to 25 signals can be reviewed in one committee review.

Thus the total estimated costs for option 2 would be in the region of £139,000.

The safety benefits obtained by undertaking the sighting measurements and committee review from the office instead of the track should not be underestimated.

In addition, to the cost and safety benefits the difficulties encountered sighting signals in tunnels are also valid when sighting on track. The video modelling techniques deployed provided repeatable measurements, providing the committee with a clear view of the surrounding area inside the tunnels.

The MPV is now available for deployment on future SDG projects.

Project Team
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