

SSG Case Study



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Sector: Light Rail
Asset owner: Transport for Greater Manchester - Manchester Metrolink

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Introduction

Description of assets in study

Manchester Metrolink is Britain’s largest tramway system, owned by the public body Transport for Greater Manchester (TfGM). In 2017 Keolis Amey was awarded the contract to operate and maintain the system for up to 10 years. Metrolink comprises of

- 103km of double track (59km ballasted, 24km embedded and 20km direct fix),
- electrified at 750V DC overhead line,
- supplied by 49 traction substations.
- 147 light rail vehicles
- operating from two depots

The system is integral to Manchester’s public transport network carrying 120,000 passengers each day and approximately 44 million passenger per annum.

The assets that were considered as part of the project were:

- 105 km of track,
- 750V DC overhead line electrification
- 147 trams – each with 1 pantograph and 12 wheels
- 2 tram depots

When was the activity carried out?

The acquisition and installation of the Remote Condition Monitoring equipment took place between 2019 to 2022. The outputs of the RCM will be used until the end of the Keolis Amey Metrolink (KAM) contract in 2027 and beyond.

Why was the activity carried out?

The operations and maintenance of Manchester Metrolink is the responsibility of KAM.

As part of KAM’s contract with TfGM there is a requirement not only to maintain the network but also to monitor, report on and extend asset life.

Accurate data collection is essential for assessing asset conditions and informing the maintenance and renewal strategies of KAM and TfGM. While manual data collection is possible, this process can be time-consuming, less accurate, may lack consistency and traceability, and could place staff at risk.

To address the challenges, KAM, with the support of Amey Consulting, implemented a variety of Remote Condition Monitoring (RCM) initiatives to automate data collection across various assets, including:

- Tram wheel profile measurement
- Monitoring of in-service pantographs
- Measurement of the overhead contact wire – height, stagger, wear, thermal imaging, video
- Track measurement – gauge, rail wear, geometry, corrugation, alignment, video
- Vehicle ride

Terminology

Abbreviation	Definition
TfGM	Transport for Greater Manchester

KAM	Keolis Amey Metrolink
RCM	Remote Condition Monitoring
RfP	Request for Proposal
EAM	Enterprise Asset Management
RFID	Radio Frequency Identification
OLE	Overhead Line Equipment
EAMS	Enterprise Asset Management System

Description of activity

Methodology

Amey's approach to selecting and installing the RCM equipment included:

- **Survey of data collection hardware market**

A survey was conducted to identify potential suppliers and products that could meet Metrolink's requirements. The survey revealed that while there are a range of suppliers, the varying range of measurements makes it unlikely that a single supplier can provide all the necessary equipment.

- **Supplier Meetings**

Investigatory meetings were held, without prejudice, with several suppliers to ascertain that technology capable of automatically capturing the required data existed.

- **Collation of Measurement Costs**

Amey determined the internal costs of collecting this data using the current 'manual' methods and identified the potential value benefits and cost savings to inform the business case.

- **Request for Proposal**

A Request for Proposal (RfP) was developed in conjunction with KAM procurement and engineers and issued to invite proposals from a range of suppliers.

Suppliers were invited to a supplier day, which included a presentation on Metrolink and the project, an opportunity to view the tram, the location of wheel monitoring equipment, and a session to address initial technical queries.

- **Evaluation of the proposals**

Submitted proposals underwent a thorough and independent evaluation process by two distinct groups: the finance team, which focused on quantitative aspects, and the technical team, which concentrated on qualitative factors. During this phase, clarifications were requested from the suppliers to ensure a comprehensive understanding of their proposals. The technical evaluations were then carefully reviewed and moderated in a dedicated meeting to ensure consistency and fairness. Following this moderation, the final scores and recommendations were compiled and subsequently endorsed by the project sponsor, ensuring that the decision-making process was both rigorous and transparent.

The qualitative benefits were captured, and the costs of procurement, implementation, training and longer-term operations and maintenance costs of the RCM equipment were included in the final business case for each initiative.

- **Due Diligence**
Due diligence was meticulously conducted on the preferred suppliers. This process included issuing comprehensive questionnaires to each of the references provided by the suppliers and organising site visits to evaluate their operations firsthand. Additionally, suppliers were invited to present their products to Metrolink engineers, including those who participated in the technical evaluation. These presentations provided an overview of the products' features and capabilities. This was followed by an in-depth Q&A session on each of the systems being provided.
- **Negotiations**
A short period of Negotiation followed to finalise costs including any optional extras and minor enhancements.
- **Installation, Testing and Commissioning, Staff Training**
After placing the orders, Amey took charge of project management, overseeing the integration, design review, installation, and adherence to internal change control requirements. Once the equipment was installed on the infrastructure or tram, it underwent rigorous testing and commissioning, followed by a period of fine-tuning the measurement parameters. Subsequently, staff received training on the equipment and visualisation software.

Risk types

Implementing an RCM initiative for the Metrolink system involved multiple risks. These risks had to be carefully evaluated and managed to ensure the successful deployment and operation of the RCM equipment. The key risks associated with this initiative were:

- **Availability Risk:** This involved the potential for the RCM equipment to be unavailable when needed, which could lead to reverting to manual methods or potential service disruptions.
- **Economic Risk:** Each RCM initiative must be supported by a robust business case. This included assessing the financial viability, cost-benefit analysis, and potential economic impacts such as changes in operational costs, return on investment, and funding availability.
- **Business Risk:** This assessed whether the initiative would benefit the business quantitatively in terms of cost reduction and was evidenced by the business case for each initiative and an acceptable breakeven point. Qualitative benefits might include improved customer satisfaction, improved staff safety and increased operational efficiency.
- **Design Risk:** This included the risk of design flaws, inadequate specifications, and the need for redesigns, which could impact performance and integration with existing systems.
- **Construction Risk:** This involved the challenges and uncertainties associated with installing the RCM equipment onto the Metrolink system and trams. It included risks related to project delays, cost overruns, technical difficulties, and compliance with regulatory standards.
- **Safety Risk:** This focused on the risks related to equipment malfunction, improper use, and adherence to safety protocols and standards.
- **Maintenance Risk:** This involved the potential challenges in maintaining the RCM equipment. It considered the complexity of maintenance procedures, the need for specialised skills, and the impact of maintenance activities on service continuity.

Risk management process

Implementing an RCM initiative for the Metrolink system involved risk management to ensure successful deployment and operation. The following outlines key actions taken to manage and mitigate risks associated with the RCM initiatives:

- A quantified risk register was produced for each RCM initiative to ensure each risk was mitigated. The risk register served as a comprehensive tool to document all identified risks, their potential impacts, and the mitigation strategies implemented to address them. This proactive approach ensured that all foreseeable risks were managed effectively, minimising the likelihood of adverse outcomes.
- External third-party experts were engaged to validate the installation designs of critical RCM equipment e.g. pantograph monitoring mounted on a bridge and equipment mounted on the tram. The third-party validation provided an independent assessment, ensuring that the designs met all regulatory requirements and industry best practices, thereby enhancing the overall integrity and performance of the system.
- The installation was managed via the KAM Engineering change control process including the client's approval as asset owner. The change control process ensured that all modifications and installations were thoroughly reviewed, documented, and approved, maintaining alignment with the client's requirements and ensuring seamless integration into the existing infrastructure.

Tools used

- SSG Insight Agility EAM software – Used to effectively manage assets and maintenance.
- Microsoft Office packages – Excel for creating the risk assessment and business case, Word for various reports, and PowerPoint for the project presentations.

RCM Equipment

Wheel monitoring

Equipment to automatically, measure digitally, record and display the tyre profile have been installed in the sand plant at Old Trafford Depot. The equipment supplied by SelectraVision comprises of high-speed cameras and lasers mounted in 4 track boxes either side of the rails. These are installed in the sand plant building at Trafford Depot. Sensors detect the approach of a tram wheelset initialising the system, and sensors then open the laser window doors for the milliseconds required to scan the tram tyre. RFID sensors identify the tram and its orientation via RFID tags fitted to the trams. In this way the tram profile can be associated with the correct tram and tyre.

The wheel measuring system is composed of the following elements:

- 4 boxes installed on the tracks that contain cameras and lasers
- Sensors that detect the arrival of the tram
- RFID reader for tram identification
- Rack cabinet installed on wall of sand plant equipped with:
 - Computer and electronics for acquiring the images and managing the measuring system
 - Electrical panel of the measuring equipment and the other sensors
 - Compressor unit for compressed air production to guarantee the automatic cleaning of the windows of the system

- Wi-Fi antenna or cabled connection to transfer data to the server



Figure 1 Wheel Measurement Equipment installed within the sand plant at Trafford Depot

Pantograph Monitoring

Pantograph Monitoring equipment Panobot 3D™ supplied by CAMLIN Rail has been installed onto the 'birdcage viaduct' south of Deansgate Castlefield tram stop. The equipment is mounted on a 'goalpost arrangement' fixed to the bridge structure locating the equipment above the outbound track. As the pantograph head passes beneath the Panobot equipment an eye safe laser triggers the LED light arrays, and the digital camera to capture high resolution 3D images of the pantograph head.

Machine learning software is utilised to analyse the images to identify defects such as incorrect alignment, wear, carbon damage and missing components. RFID sensors identify the tram and its orientation via RFID tags fitted to the trams. In this way tram images can be associated with the correct pantograph on the tram or trams.



Figure 2 Camlin Panobot Equipment installed at Bridge 49 Deansgate Castlefield

OLE Measurement

OLE RCM equipment supplied by SelectraVision has been fitted on a tram roof. The contactless equipment uses a light source and high-speed image processing of the overhead line wires contact surfaces to measure OLE height, stagger, wear, video of the interaction between the pantograph and the OLE contact wire and video of the surrounding area to orient the tram position when video images are replayed. In addition, a thermal imaging camera is provided monitoring the temperature of the pantograph and surrounding overhead line elements. All measurements and video are synchronised and located by GPS. Compensation

for movement of the vehicle body with respect to the track is achieved by the installation of transducers between the bogie and the car body.

Equipment mounted on the roof weighing less than 15 Kg includes:

- Height / stagger / wear measuring box
- GPS antenna
- Camera for Overhead Line (OHL) and pantograph video inspection
- Camera for panoramic view
- Thermal camera



- Sub-systems
 - Rotating Laser (lateral and vertical position)
 - Light reflection (lateral position and wear)
 - Video – pantograph and side view
 - Thermal camera

Figure 3 OLE measurement equipment installed on the roof of tram 3071

Track Measurement

Track RCM equipment supplied by SelectraVision has been fitted to a tram mounted above the rails on each side of the centre bogie. Equipment mounted on one side of the bogie measures track corrugation taking measurements along each rail and the other side measures track geometry and rail wear taking measurements across the track. The equipment utilises lasers to scan the railhead to capture the rail profile of grooved and Vignole rail, and the surface corrugations that occur longitudinally. The corrugation laser heads are mounted on the bogie independently from each other because they measure longitudinally. Conversely the rail profile laser heads are mounted on a calibrated beam because in addition to capturing the rail profile and therefore head and side wear, they are also used to provide measurement of track geometry e.g. gauge, cant etc.

The system is comprised of the following elements mounted on the tram as indicated:

On the Roof of the Vehicle:

- GPS antenna – shared with OLE equipment
- Camera for panoramic view - shared with OLE equipment

Under the vehicle:

- track measuring system for measuring track geometry, corrugation and rail profile/wear
- cameras for video of tracks
- microprocessor cabinet
- signal from tram odometer

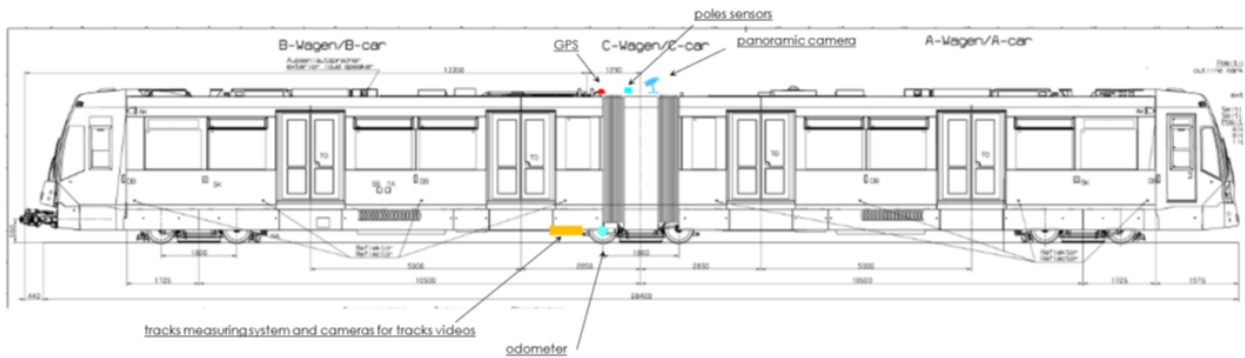


Figure 4 Track Measurement equipment location

Ride Monitoring

Tram ride monitoring of individual vehicles is achieved using the Macminder system “G” Model – supplied by Donfabs and Consilia.

The Macminder system comprises of a small, battery powered, and rugged self-contained enclosure providing an unattended method of monitoring vehicle ride performance, and track conditions on board in-service trams.

Evaluation

What was the main output of the activity?

- **Presentations at various stages:** Throughout the project, presentations were delivered at key milestones to update stakeholders on progress, challenges, and next steps. These presentations provided a platform for transparent communication, ensuring that all parties were well-informed and actively engaged in the decision-making process.
- **Quantified Risk Register:** A detailed and quantified risk register was developed for each RCM initiative. This register identified potential risks, evaluated their likelihood and impact, and outlined mitigation strategies. This enabled the team to prioritise actions and allocate resources effectively to manage and reduce potential threats.
- **Business Case Spreadsheet:** A detailed business case spreadsheet was developed for each RCM initiative. This document included financial analyses and cost-benefit evaluations. It served as an essential tool for justifying investments and illustrating the value of the initiatives to stakeholders.
- **Board Paper with Recommendations:** A board paper was prepared, outlining the recommendations for the RCM initiatives. This document provided a thorough analysis of the options considered, the rationale for the chosen approach, and the expected benefits. It was used to secure approval and support from the board of directors.
- **RCM Equipment and Process Document:** A detailed document was compiled, describing the RCM equipment and the processes involved in its implementation. This document produced at handover was intended to be used by KAM and stakeholders as a reference guide. It ensured everyone involved in the project, and in future had a clear understanding of the equipment specifications, installation procedures, and operational protocols.

- **Successful Installation of RCM Equipment, Testing, Commissioning, and Training:** The project culminated in the successful installation of the RCM equipment. This phase involved thorough testing and commissioning to ensure the equipment was fully operational and met all performance standards. Additionally, training sessions were conducted for staff, ensuring they were proficient in using and maintaining the new systems.

Validation

- **Testing and commissioning was carried out once installed:** To ensure all systems were functioning as intended and met the required performance standards, an extensive testing and commissioning phase was undertaken following the installation of the RCM equipment.
- **Measured parameters were validated against measurements carried out manually to provide verification:** To ensure the accuracy and reliability of the RCM equipment, the measured parameters were validated through manual measurements. This verification process involved comparing the data collected by the RCM systems with manual readings taken by technicians. By cross-referencing these measurements, the team could confirm the precision and consistency of the RCM equipment, ensuring its effectiveness and reliability.

Outcome

The project wasn't without problems. Initially, there were setbacks due to restrictions on using the equipment in bad weather conditions, owing to rain affecting laser measurements. However, after making necessary adjustments during the testing and fine-tuning phase and understanding the acceptable operating conditions the project successfully delivered the desired results.

The project faced significant challenges due to the COVID-19 pandemic, which made the installation process and face-to-face meetings almost impossible. Strict lockdown measures, social distancing requirements, and travel restrictions severely impacted the ability to conduct on-site work and in-person collaboration. As a result, the project experienced delays and the project timeline was extended.

Benefits

RCM data provides a source of data to the Enterprise Asset Management System (EAMS). By leveraging this data, the delivery of maintenance and renewals is optimised, leading to substantial time savings and cost reductions. Additionally, the use of RCM data improves safety by removing staff from a position of danger e.g. trackside and providing accurate and timely information, which also helps in making informed decisions. The integration of RCM data into EAMS not only streamlines operations but also contributes to a safer and more cost-effective maintenance strategy.

The benefits include:

- Optimisation of life cycle costs
- Accurate and repeatable data quickly obtained.
- Providing better insights and improved resilience and reliability
- Safety benefits - fewer people walking the route and putting themselves in harm's way preventing safety concerns and incidents.
- Automated acquisition, unattended operation freeing up staff to carry out more value-added work as opposed to manual data collection, input and analysis of data activity.

- Business efficiencies - better utilisation of staff - added value. e.g. an anticipated saving of approximately 6726 man hours measuring tyres / OLE / track
- Health check of in-service pantographs and SMS alerts of defective pantographs.
- Quality data for TfGM to inform renewals and for KAM to support maintenance.
- Reduced requirement for isolation/possessions and disruptions

Two key examples of the RCM equipment providing benefit to Manchester Metrolink are:

1. The Pantobot™ pantograph monitoring system was installed near Deansgate Castlefield, a key point on the network passed by over 85% of the Metrolink services, to provide real-time monitoring of pantograph condition. This remote monitoring provides system resilience by alerting the operator to any abnormalities enabling proactive tram withdrawal, preventing major overhead line damage and reducing disruptions. The Pantobot has so far detected damage in eight vehicles, preventing service disruptions and saving at least £60,000 per incident, replacing time-consuming manual checks.
2. A tram was installed with RCM equipment to measure OLE contact wire wear, height, stagger, video pantograph interactions and thermal imaging. This equipment has reduced the requirement for overhead line patrols and provided inspection data to inform maintenance and renewals. Its introduction has improved safety and accuracy, as well as our ability to forecast OLE renewals. The introduction of the measurement tram incorporating RCM is expected to save £250,000 per year, providing a payback on the original capital outlay in less than three years.

Testimonial

With regards to the pantograph monitoring system:

“Since installing Pantobot 3D, Metrolink have already seen the positive impact by already identifying trams that need to be withdrawn from service with issues. The effectiveness of Camlin’s technology has already been proven, and we are now in the stages of fine-tuning the project details”.

Bilal Mohamed Engineering Director KAM