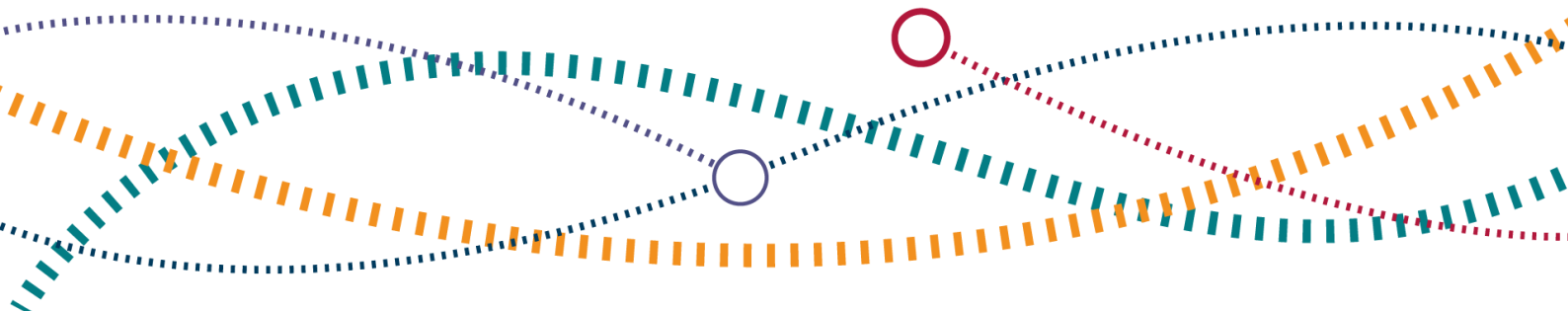# Electrification & Power Asset Condition Monitoring Capability to implement Predict and Prevent Maintenance

Targeted Assurance Review

18 February 2021

Contents

Table 1.1   Document history

Version	Description	Created	Reviewed	Authorised	Dated
v 1.0	Draft for NR Review	MG	IM	SF	05 Nov 20

Acronyms and Abbreviations

E&P Electrical and Power

CP5 - Control Period 5

CP6 - Control Period 6

CP7- Control Period 7

DEAM – Director of Engineering and Asset Management

STE – Safety, Technical & Engineering Group (now known as Technical Authority)

ORR – Office of Rail and Road

P&P –Predict and Prevent

RAM – Route Asset Manager

RCM – Remote Condition Monitoring

RSSB – Railway Safety and Standards Board

PPF – Putting Passengers First

TA - Technical Authority

Glossary

Asset Life the expected time an asset will run before failure based on manufacturers claims and historic data

Condition Based Maintenance a maintenance scheme based on the condition of an asset rather other factors such as time.

Control Period (CP5, CP6,CP7) a 5 year rolling policy programme

Intelligent Infrastructure is Network Rail's programme, using technology to turn data into intelligent information to improve asset management across Network Rail; eliminating failures through product and maintenance regime design and capturing, analysing and exploiting asset data to make better planning decisions about investment in the asset

Maintenance Strategies

- **Predict and Prevent** having sufficient asset knowledge that failures can be predicted and preventative actions taken to prevent failure

- **Risk Based maintenance** activities are based on use, environment and time but not on the condition of an asset

- **Fix on Failure** for non-critical assets, for instance office lights it may be acceptable to allow the light to fail before repair

MENTOR an instrumented train that can monitor and benchmark the position of the overhead line

Putting Passengers First a policy to ensures passengers are at the heart of every decision Network Rail makes.

Red Zone Working when person are working on or near the track while train movements are unconstrained risking workers being struck by a train

Regions - Network Rail's five operating regions – Eastern, North West and Central, Scotland's Railway, Southern and Wales & Western.

1. Executive Summary

Network Rail are moving from a time and standards based maintenance regime to a risk based strategy based on the condition of the asset. There are many benefits to such an approach in targeting maintenance activities where they are most needed, reducing unnecessary maintenance activities and enabling assets service lives to be extended beyond their original asset design life. Most importantly it enables effective trend analysis to enable preventative action to be taken before equipment failure.

Successful predict and prevent strategies require accurate, comprehensive and timely asset knowledge in order for them to be implemented successfully. Network Rail are aware that their current level of asset knowledge does not currently meet the required standard for implementation. Network Rail are currently working to develop sufficient asset knowledge to inform their maintenance decision-making.

With sufficient asset knowledge, a mix of maintenance strategies will be required. These include predict and prevent, risk based and fix on failure dependent on the asset class, its criticality and consequence of failure.

This assurance review has identified that the regions have made progress on improving their condition monitoring capability with several initiatives currently on trial or being proposed. However, these are not supported by a formal documented transformation strategy or a programme at this time. The application of appropriate governance and resourcing would help to support a successful implementation.

The involvement of the train operating companies will be critical to any overhead line predict and prevent strategy, with equipment needing to be placed on their rolling stock. The retrieval and timely analysis of data collected will also require close cooperation. Progress is being made with a general industry recognition that Network Rail adopting a more condition-based maintenance approach would bring wider benefits to customers and freight operators. On the basis of this review, ORR is broadly satisfied that the actions being proposed or currently undertaken are appropriate at this stage. To assure continuance of commitment, adequate strategy, programme and steering, we will monitor progress through our ongoing liaison meetings.

2. Purpose

Network Rail's historical maintenance practices were generally based on set cyclical intervals. Recently it has sought to move to a semi-predictive approach with the adoption of risk-based techniques in some asset and geographic areas.

To further continue improvement of its capabilities to deliver safe, effective and efficient maintenance, Network Rail has set targets for the current Control Period (CP6). The key areas of strategic focus include adopting remote Condition Based Monitoring (CBM) and embedding a predict and prevent (P&P) maintenance approach. The aim being to optimise cost and performance risks while improving operational and workforce safety. This is a growing area for Network Rail as a whole and no less so for Electrification and Power (E&P) assets, the subject of this review.

ORR wanted to understand how Network Rail's five operating regions are improving their condition monitoring capability for E&P assets, to support the transition towards a predict and prevent maintenance approach.

This Targeted Assurance Review does not consider the efficacy of any specific solutions or innovations. Rather, it focuses on the challenges, opportunities and risks of implementing such a strategy.

3. Background

A P&P maintenance approach relies on data from condition monitoring capability, by manual or automatic means, that supports the identification of potential asset failure to enable the opportunity for rectification to be undertaken before failure occurs.

A move to predict and prevent would present a number of advantages and is considered fundamental to ensuring a safer, more efficient rail network.

Existing techniques for checking the condition of the asset are no longer considered fit for purpose as they rely predominantly on time based manual inspections (feet on ballast). Such methods:

- put personnel at risk from working on the track;

- give only a snapshot of the condition at any one moment in time;

- are based on sample checks and visual inspections which can be subjective; and

- waste resource that can be better deployed carrying out remedial works.

Running assets beyond their technical asset life without adequate asset knowledge increases the potential incidence of service affecting failures. Maintaining a fix on failure approach for critical infrastructure is unlikely to lead to an improvement in the resilience and reliability of the network. In addition, Network Rail has a statutory obligation to maintain electrical equipment to prevent danger.

4. Scope

This Targeted Assurance Review focused on Network Rail's development of condition monitoring capability for Electrification & Power assets, by seeking to understand the following key enablers for implementing the P&P maintenance approach:

- Strategy for transition to predict and prevent maintenance

- Current condition monitoring capabilities for key E&P asset types

- Roadmap, implementation plan and resources

- Governance and Steering arrangements

- Risks and Opportunities

The monitoring capability for the following asset types were covered in the review.

- Distribution – Traction and Non-traction-HV

- DC and AC Contact Systems

- Plant – Points heating, Signalling Power supplies, Conductor rail heating and Other plants

Key Responsibilities

The move to a condition-based maintenance system is reliant on the close cooperation of all stakeholders. Within Network Rail the main groups involved with this transition are:

Technical Authority (TA) provides specialist expertise in safety, engineering and asset management and sets the policy for the move to CBM. It achieves this by managing standards, competence frameworks, supporting research and assuring the five operating regionals delivery.

Regions are accountable for defining their own strategy for delivering Network Rail's policy. They are responsible for operations, maintenance, renewals and enhancements within their respective geographic area.

Network Services and Route Services supply services and programmes that the regions managing directors collectively decide are best provided from a single support team, for example electrical safety delivery and intelligent infrastructure required to facilitate CBM.

Asset Information Services support the business by collecting, evaluating, analysing and sharing information about Network Rail assets. This function is likely to become increasingly important in collecting and processing condition-based information to allow preventative action in a timely manner.

5. Review Approach

In summer 2019, ORR informed Network Rail of its intention to undertake a Targeted Assurance Review (TAR) and requested the TA's Professional Heads of Contact Systems and Power Distribution for relevant information to support the TAR.

Following the review of the response from the TA, interviews were carried out with the 5 devolved Regions. The relevant interviewees were nominated by the Directors of Engineering and Asset Management (DEAM) of the respective regions, and the interviewees included E&P asset specialists comprising of asset management and maintenance discipline.

Based on the information provided at the interviews and the supporting documents, the findings from the review are summarised in the following section.

6. Findings

The key findings are summarised below:

Policy and strategy for transition to predict and prevent maintenance

Policy: Network Rail's policy defines how Network Rail will ensure a resilient and reliable rail network. To meet this aim, the current E&P Asset Policy, dated 2018, places an emphasis on P&P and a condition-based approach to maintenance and renewals. The policy move to a more effective and efficient maintenance regime informed the regions CP6 strategic business plans. Each region's business plan sets out how they intend to achieve the maintenance policy requirements.

Strategy: A short-form maintenance strategy, dated July 2019, was developed to assist the regions in implementing the policy objectives. This plan outlined the tools, processes and technology required to meet the aims of the asset policy.

It sets out the core principles of how the TA and the regions will work together to achieve its CP6 targets. This strategy was developed in collaboration with the regions and other stakeholders. The strategy applies to all operational assets maintained by Network Rail and is owned, maintained and tracked by the TA.

There are plans for the maintenance strategy to be further developed into a full form maintenance strategy which will further emphasis the move to CBM. The strategy aims to deliver a reduction in service affecting failures attributable to infrastructure by more than 10% over the course of CP6.

Application of policy and strategy to asset types

Overhead line equipment

Overhead line equipment provides the power to the trains using overhead conductors which is then transferred to the train via a train borne pantograph and is the most common form of electrification in the UK. Failure of the overhead line is a major cause of passenger affecting failures.

Network Rail has one specialised condition monitoring train ("MENTOR") that can part assess the condition of the overhead line. MENTOR was recently reintroduced back onto the network, after a long period of upgrade. This should enable Network Rail to:

- establish the base line condition of newly installed electrification; and

- ensure continued minimum performance parameters and enable limited trend analysis.

MENTOR however can only give a snapshot of the condition of the system every two years and has limited applicability to the adoption of a predict and prevent strategy. However, we recognise it is an important step toward an ongoing monitoring capability.

In addition to MENTOR, there are a number of ongoing trials such as mounting equipment on regular passenger services to monitor the interface between the trains' pantograph and the overhead line real time;OLErt being one such system. These have the advantage of constantly collecting information on the condition of the overhead line. There are still some challenges to this approach:

- It requires cooperation of the train operating companies to fix equipment to their trains;

- accessing and processing the volume of data collected in a timely manner remains an issue; and

- using the information to inform maintenance decisions and the ability to get access to the network to undertake remedial works in a timely fashion.

In addition, Network Rail, in collaboration with the Rail Safety and Standards Board (RSSB) and Huddersfield University are running a real time electrification system monitoring project, with a remit to asses monitoring equipment currently available worldwide for overhead line contact systems and their applicability to the UK.

There was a consensus that understanding the condition of the overhead line was critical. If the condition could be assessed in real time, then interventions could take place in a timely manner and major failures could be prevented. However there are still several major obstacles to overcome until a fully reliable technological solution is available. In our view the wider rail industry fully understands these challenges and there are several initiatives that have been developed to meet them.

3rd Rail

A second form of providing power to trains on the mainline network is the 3rd rail system. Instead of power to the trains coming from overhead lines, it comes from ground level using a conductor rail (arail similar to a normal rail but that carries power).

Within the 3rd rail area, wear of the conductor rail was not considered a critical component having an extended life span and long lead times to failure. Conductor rail measuring

systems (CRMS) provide periodic measurements of wear and tear. Concentration in this area was on the cable and cable connections (lugs), power distribution and ancillary services such as points heating.

Power distribution

Power distribution includes all the electrical systems - including switches, cables, transformers and rectifiers - that is not related to the contact system.

All regions considered power distribution to have longer lead times to failure meaning real time condition monitoring was not a priority. Time based condition monitoring such as oil sample checks, partial discharge and infra-red surveys and routine maintenance was deemed sufficient at this stage. We noted that less critical initiatives such as remote monitoring by CCTV, remote generator checks, environmental monitoring of substations and improved switchgear protective devices were all in development.

Fixed Plant

Fixed Plant has a large range of assets ranging from points heating to walkway lighting.

Points heating has asset condition monitoring through intelligent infrastructure as it is a key asset for performance. It is monitored to check the system is operational and when it is actively in use.

Work is ongoing in Network Rail to improve asset condition monitoring for fixed plant, for example the UPS remote condition monitor research and development work.

Signal power supplies

Signal power supplies provide the power to the signalling system which controls train movements to enable the trains to run safely.

The monitoring of signal power supplies was found to be at an advanced stage with Network Rail supporting partners in developing proprietary systems with ongoing trials of equipment supplied by Bender, Viper and Schneider. These systems have the potential to:

● reduce service affecting failures by accurately predicting failure modes and initiating preventative measures;

● demonstrate legal compliance; and

● reduce invasive inspection and test requirements releasing staff to carryout targeted maintenance activities.

Summary of technologies

A number of technologies to provide suitable condition monitoring are already deployed for E&P Assets (e.g. measurement trains, pantograph monitoring and insulation resistance monitoring). In addition, a range of new technologies are in various stages of readiness, being researched, evaluated, developed and implemented, in CP6.

These new technologies, when implemented, will extend the range of asset types covered under P&P and will enable asset life of certain assets to be extended longer than ever previously achieved.

The summary of the current condition monitoring capabilities and key initiatives being undertaken or planned in each region are set out in the Appendix A.

Delivery plan and resources

The regions in general did not have a roadmap or an implementation plan with milestone dates and dedicated resources for the projects being led and delivered.

The short form Maintenance Strategy states that a plan of activities to deploy infrastructure monitoring technologies and develop predictive and preventative maintenance will be in place by November 2020. However, at the time of this review, there was no evidence that this plan had been shared with the regions.

Governance and steering

Regions:

Regional projects and initiatives are being delivered by E&P Asset Management and Maintenance team resources in addition to their regular duties of managing the assets.

We were advised of a general shortage of resource at all levels within the E&P discipline, which is likely to hamper the progression of the proposed initiatives. A number of the regions are looking to review the resourcing strategy and seek the growth of resource in this area to help address this risk but could be delayed due to the impacts of COVID-19 19 and wider Network Rail changes.

Technical Authority:

Technical authority is responsible for assuring the quality of some condition monitoring data (e.g. for Contact Systems), that are collected by trainborne monitoring fleets and provided by Asset Information Services.

The assurance is targeted on measurement accuracy and repeatability and is carried out following planned preventative maintenance of the vehicles and at a regular periodic interval.

Although the assurance of the network coverage is the responsibility of the Region Asset Manager [E&P], Technical Authority maintains a level of network wide oversight and are a conduit for escalation of unresolved service issues.

Opportunities and risks

Identified opportunities

In our view an effectively implemented P&P strategy would bring substantial benefits to Network Rail that include:

- meeting statutory responsibilities to demonstrate maintenance of equipment to prevent so far as is reasonably practicable danger;

- improving the resilience and reliability of the network and reduce service affecting failures;

- minimising Red Zone working and unnecessary maintenance activities;

- enable equipment to safely and reliably run beyond its assumed technical asset life;

- target interventions to where and when they are most needed; and

- enable accurate trend analysis to better predict failure modes of both an imminent and chronic nature.

Identified risks

Failure to adequately fund or develop a clear strategy and solutions would undermine the goal of achieving a reduction in service affecting failures. The reliance on a fix on failure policy requires significant reactive interventions which drain resources and increase inefficiencies. Continuing such a strategy is unlikely to meet Network Rail's wider legal and license obligations.

The main risks we have identified include:

- lack of a national strategy and plans to ensure it is fit for purpose with clear regional inputs;

- lack of development of clear regional strategies, plans with milestones and steering governance for predict and prevent transformation. It is clear each region must refine any national strategy to fit their infrastructure type and age;

- failure to gain cooperation with train operating companies to enable equipment to be fitted and data accessed in a timely manner. This should be a formal process and may mean industry agreement such as a memorandum of understanding;

- not collating and evaluating innovations to ensure the effectiveness of solutions and minimising duplication of effort; and

- data collection and processing. Delivering results in a timely manner remains and must be challenged if the full benefits of P&P are to be realised.

Network Rail appear to be fully engaged and understands the opportunities and risks outlined above.

7. Conclusion and Observation

Conclusion

Currently, Network Rail does not have the capability to meet the policy aspiration to adopt a P&P strategy as part of their maintenance programme, but is making good progress towards it. However, this is a dynamic situation and it is important that standards and requirements provide the flexibility to innovate.

It is important that any initiative is thoroughly reviewed for effectiveness and any findings are acted upon. Without an adequate review process, the expected efficiencies will not be realised.

We found that the opportunities and risks were well understood and there were several initiatives that were in trial at both regional level and the Intelligent Infrastructure Programme overseen by the TA. These covered the major areas of overhead line, dc contact systems, power distribution and signal power supplies. The regions had prioritised their interventions based on their respective risk profile and incident data.

We noted that a possible downside of each region having its own programme was that there did not appear to be an overall strategy, which could lead to a lack of knowledge sharing, although at this stage we found no evidence of duplication of effort. Closer cooperation and coordination between the regions would in our view improve the governance structure. This, in turn, would encourage an approach that prioritises risk with a clear means of sharing information. Inevitably, much of the emphasis is on the over headline system but this should not be at the expense of iterative solutions elsewhere incorporating off-the-shelf solutions.

The lack of central control may encourage innovation and faster development of workable solutions and seems appropriate for the initial stages of the move towards P&P. However, a clear strategy and assessment criteria will be required to manage the move from proof of concept to full implementation across the whole network.

In our view, subject to a continued focus of efforts in this area, sufficient progress is likely over CP6 into CP7 to make significant improvement in asset knowledge and failure modes to make a success of a P&P strategy.

The reasons for the above conclusion are set out below.

Network Rail and the rail industry have a clear understanding of the need to improve their asset knowledge and maintenance outcomes. The Intelligent Infrastructure programme

has resulted in several innovations that should be developed further through CP6 into CP7 to ensure the successful implementation of a P&P strategy.

Applying predict and prevent to the overhead line system with real time analysis would be transformative. However, it is unlikely to be fully effective before the end of CP7. This is an ongoing programme and benefits should be realised throughout CP6. There is likely to be a hybrid approach of comprehensive instrumentation such as MENTOR or fully instrumented pantographs and innovations such as pattern recognition cameras, monitoring equipment, sound mapping and track side equipment including high-speed cameras. It is likely that one or more technologies trialled will make a significant impact.

The former will generate high quality comprehensive data that will map the condition of the overhead line and will eliminate the need for manual interventions. It will also enable comprehensive trend analysis, failure mode analysis and ensure ongoing compliance to standards. However, this will only give a snapshot in time. The data processing requirements and complexity of equipment required will mean these systems will be fitted to limited rolling stock only. To complement this quality data, there is a need to explore more cost effective solutions that could be fitted to every train looking at specific precursors to imminent failure whether that be damaged pantograph, unusual arcing, unexpected noise or specifically monitored items such as sway or uplift.

The development of P&P tools for 3rd rail, distribution and signal power supplies are in progress, often utilising off-the-shelf solutions. These incremental improvements with clear cost benefits form an important part of any strategy.

Observations

- The challenge remains how to get and process relevant data and prioritise work in time to make meaningful interventions. Involvement of the train operating companies remains critical to any successful P&P strategy. It is important that any strategy involves the whole industry and that they are incentivised to become involved.

- Network Rail will need to ensure that they continue to develop sufficient asset knowledge to inform their preferred maintenance strategies.

- Where a mix of maintenance strategies are employed (i.e. Predict and Prevent, Risk Based and Fix on Failure) these should be reviewed moving to CP7 to ensure they are fit for purpose.

ORR will keep the project under review as part of our normal liaison activities. Progress will be monitored as part of the stakeholder processes in place such as our quarterly

liaison meeting process with Network Rail on E&P assets and wider industry consultation with RSSB.