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Review of RoSE
Final Report

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Executive Summary

Asset Management Consulting Limited (AMCL) is the Independent Reporter for Asset Management to Network Rail and the Office of Rail Regulation (ORR). As part of this role AMCL was remitted to undertake an independent review of Network Rail's Reliability Centred Maintenance for Signalling Equipment (RoSE) project and its potential applications to other asset types outside the signalling asset group. The scope of the audit included assessing the RoSE project to determine the positive and negative impacts on signalling equipment in Network Rail's business, including the consideration of safety, reliability, delivery of maintenance and cost factors. This document contains AMCL's findings and recommendations relating to the review of the RoSE project.

The key findings are as follows:

- The RoSE project has made progress developing new maintenance regimes for signalling assets, although the project is running significantly behind schedule. There are still important assets that have not yet been analysed, due to the lack of project resources, and progress on other asset groups has been limited.
- RoSE has contributed to a 10% reduction in signalling headcount as part of the recent re-organisation. The actual implementation and the resulting benefits have been constrained due to assets still not analysed or not suitable for RoSE implementation, as well as due to delays in changing the maintenance schedules within the Delivery Units, which could deliver even greater benefits.
- The actual cost savings achieved by the RoSE project are still estimated and no claim has yet been made for savings in non-productive time. Furthermore, the actual reliability and safety impacts as a result of the RoSE implementations have not yet been monitored or reported by Network Rail.
- RoSE has applied a recognised RCM process to determine cyclic maintenance requirements, mainly through engineering judgement workshops largely due to the lack of appropriate asset information. However, further work is required to align the RoSE project with Network Rail's Asset Management Strategy in terms of adopting a risk-based approach to determining asset interventions.
- The lack of good asset degradation and failure data, as well as cultural factors, is a constraint in further development of a risk-based approach for RoSE. Although Network Rail appears to understand this, significant work is still required to address the issue.

Over the course of the last three years the RoSE project has developed new regimes for the cyclic maintenance of almost 80 percent of Network Rail's signalling asset base, while approximately 50 percent of the asset base has had RoSE maintenance regimes authorised for implementation. The actual implementation of the new regimes is lower than that however, due to the time it takes to realign maintenance schedules, or because assets may be at a site where there are other assets which require more onerous maintenance, e.g. they are either in poor condition or have not yet been analysed by the RoSE project. However, as the RoSE project addresses a greater proportion of asset types, the poor asset condition is becoming the main constraining factor. It is also notable that, with the exception of facing point lock testing regimes, no point operating equipment has been analysed by RoSE to date.

RoSE has already delivered workload savings through increasing maintenance intervals that have contributed towards a reduction in signalling headcount of about 10 percent during the recent Network Rail re-organisation. This has been partly enabled via the authorised RoSE maintenance regimes which are estimated by Network Rail to amount to approximately £4m per annum or 34 percent theoretical 'time on tools' workload savings for those assets affected, plus as yet un-quantified savings in non-productive time. However, the estimated workload savings are not yet based on actual workload data from the DUs. No specific targets have been set for RoSE with respect to achieving reliability and safety improvements and no further formal roll-out plan has been defined, as required by the 2010 Asset Management Improvement Roadmap.

The delay in expanding the RoSE team has, according to Network Rail, probably resulted in RoSE being about 20 to 24 months behind where it could be for signalling and S&C, and about 15 months behind where it should be for Telecoms and E&P. The RoSE project team believes that the project is about a year behind the assumptions that were included in the workload projections for CP4.

RoSE appears to be perceived positively by the Maintenance Delivery Units (DUs), who identified additional benefits, such as reduction of unnecessary time on track and potential reliability improvements from using the saved time for asset condition improvements on other assets. The actual reliability and safety impacts from implementing RoSE have not yet been monitored or reported by Network Rail but the DUs believe that there have not been any adverse reliability and safety impacts. Furthermore, there has been a reduction in maintenance backlog, while the RoSE assessment process has helped identify assets that need asset condition improvements or renewal.

In one respect RoSE has helped Network Rail to look at assets as a system, as, for example, for the maintenance of points where signalling and track engineering disciplines need to co-operate. On the other hand, the RoSE project has primarily analysed signalling at asset type level, and has only partially considered the variety of configurations of equipment within an asset type. Also, the opportunity arising from Renewals in reducing maintenance has not been considered to date, apart from signals, and there is currently no integration with Minor Renewals which could be the enabler for implementing RoSE on assets in poor condition. The asset data required to assess assets against the RoSE implementation criteria is not always available, requiring site visits. This has however helped to improve asset data quality in the Ellipse database.

The RoSE project stated that more emphasis has been put on ensuring that the right maintenance is being done to each asset type to help improve reliability, which can result in either increasing or decreasing maintenance intervals depending on the performance and condition of each individual asset. For signalling assets Network Rail has stated that on-condition tasks which do not require taking into account asset criticality are being specified. Such a regime has already been authorised for the facing point lock (FPL) testing, and even though applying this regime requires a lot of effort within a DU, it is being viewed positively. However, some DUs have expressed their doubt about the benefit of reducing maintenance intervals from existing levels where the RoSE implementation analysis has identified this requirement.

The RoSE project has been following a recognised Reliability Centred Maintenance (RCM) approach, which has primarily been based on engineering judgment instead of quantitative data and analysis to extend maintenance intervals and rationalise maintenance tasks. Apart from a high level qualitative identification of the merits of the RCM process, Network Rail has not produced any documentation of why RCM was preferred over risk-based maintenance.

The core of the RoSE analysis is the RCM workshop, which derives the maintenance tasks and frequencies and evaluates whether tasks are ‘technically feasible’ and ‘worth doing’. The analysis of the magnitude and criticality of the failure consequences is not evident or documented in the RoSE analyses, and rather the resulting maintenance regimes are based on engineering judgement. Network Rail reported that this is appropriate, due to the short duration of most of the signalling maintenance tasks analysed to date, and also because it has enabled the RoSE project to achieve earlier delivery of benefits. The process does not reference any performance standards that each asset has to comply with in terms of the required level of the reliability or availability.

According to Network Rail, the main limitation in quantifying the consequences of specific failure modes is the lack of failure data against them, which are either too high level or not consistent. Also, there is poor asset degradation data available to calculate average asset age before failure or P-F intervals for non-age or usage related failure modes. Hence, RoSE is instead relying on the expert judgment and experience of Network Rail's engineers to overcome the lack of data. The deficiencies in the FMS failure data do not allow historic reliability trends by root cause failure mode to be produced. An initial improvement has been made to the Ellipse database to enable in the future the recording of FPL adjustments via future handhelds of improved technology when they become available.

The RoSE analysis has been evaluating redesign requirements for the assets, the training of the personnel, and the use of new tools, including the use of remote condition monitoring via the Intelligent Infrastructure project. Issues which cannot be addressed through maintenance are being fed to the Reliability Improvement project, while the need for new types of assets and ways to influence scheme design is still under consideration. The level of spares holding and the interaction with the depot facilities have not yet been analysed by RoSE.

Although Network Rail's Asset Management Strategy and Policy documents require the optimisation of the whole railway system whole-life costs against business risk as a result of failure, including optimising the balance between maintenance and renewals, only limited progress has been made so far in this respect by Network Rail. The focus in Network Rail and the RoSE project has been so far to minimise asset failures by aiming to prevent them from occurring, without taking into account asset criticality and the resulting downtime after failure and service redundancy available. Hence, there has been limited consideration of run to failure conditions. Furthermore, it is difficult to demonstrate that 'line of sight' from the RoSE maintenance regimes to the Asset Management Policy and Strategy is achieved as required by BSI PAS55.

In our opinion, without quantifying or estimating the order of magnitude of the failure consequences, it is difficult to demonstrate that the safety risks are reduced to As Low As Reasonably Practicable (ALARP). Also, we believe that the cost-risk optimisation approach could be used by Network Rail to help demonstrate that safety risks are reduced to ALARP.

In relation to the delivery of the Asset Management Improvement Roadmap commitments, Network Rail has established the guidelines setting out the process for determining the appropriate maintenance regimes for signalling. This process has been applied by the RoSE project, which has produced the business case for the new maintenance regimes, albeit only for

'time-on-tools' savings and only as far as the end of CP4. As noted, no risk-based maintenance and inspection regimes have been developed yet for signalling.

Network Rail stated that the RoSE project has not made use of the RSSB Railway Safety Risk Model because it is considered too high level for the purposes of the RoSE analysis, and RoSE can make use of the more detailed risk models available at the depots by the Maintenance Engineers, and through talking to the expert engineers.

The RoSE training and briefing appears to be well perceived by the DUs and adequate, while the role of 'RoSE Champion' at each DU is very beneficial. However, there is a perception that RoSE is just a cost cutting exercise by some maintenance teams. In terms of review after implementation and lessons learnt, there is not currently a formal process in place. However, RoSE has been developing a review process with one of the DUs which has recently been shared with other DUs and is going to be published in the next update of the RoSE maintenance regimes standard. During interviews, the DUs highlighted the need for improving the process and IT systems for reporting the technical details about the RoSE implementations, which could assist following up assessment issues and monitoring progress.

Finally, the review has concluded that the RCM process is fully applicable to cyclical maintenance regimes in other Network Rail assets, such as Track, E&P, Operational Property, Plant, Structures, and Telecoms, even though the benefits may vary by asset type. Network Rail is currently reviewing the gaps and opportunities around RoSE and the other related initiatives as part of the development of CP5 plans.

The key recommendations from this review are:

Current RoSE Programme

1) Given the strength of the business case, Network Rail should complete expanding the RoSE project team to enable accelerating the development of new maintenance regimes for the remainder of the signalling assets to complete the current RoSE programme and to enable recovering some of the delay incurred in the project. (by January 2012)

Improvements to the RoSE Analysis Process

2) Network Rail should make the following improvements to the RoSE analysis process:
    a. The RoSE analysis process should include a sufficiently thorough and detailed evaluation of the magnitude and criticality of the consequences of each failure mode identified by the FMEA, either qualitatively or quantitatively as appropriate, to ensure

reduction of safety risks to ALARP is achieved and documented, as well as to support optimising costs versus risks; (by January 2012)

b. The RoSE analysis process should include the appropriate consideration of run to failure conditions at the local level where this is justified depending on the asset criticality, the potential downtime after failure and the available service redundancy; (by January 2012)

c. The RoSE project should develop and implement a process for predicting the expected impact on reliability and safety by asset or failure mode as a result of the new maintenance regimes; (by January 2012)

d. The RoSE analysis process should include an evaluation of the level of spares holding in conjunction with the available depot facilities. (by March 2014)

Improvements to Data and Asset Information

3) Network Rail should improve the data and asset information used to support the RoSE analysis process as follows:

a. The recording of failures within FMS should be improved, with the use of failure coding that better matches the most critical failure modes as identified by the FMEA; (by January 2012)

b. The process of recording asset condition should be improved which will enable an improved estimation of asset degradation or P-F intervals to be undertaken. (by January 2012)

Improvements to the RoSE Implementation Process

4) Network Rail should make the following improvements to the RoSE implementation process:

a. The monitoring and reporting of actual implementation of the new maintenance frequencies within the maintenance schedules by the DUs versus authorised implementations should be improved to enhance visibility; (by January 2012)

b. A formal review process should be developed for the RoSE implementations, specifying the key factors to consider; (by January 2012)

c. Network Rail should establish appropriate monitoring and analysis of the realised reliability by asset or failure mode after implementing the new maintenance regimes against the expected impact, to enable the effectiveness of the new RoSE regimes to be assessed and to provide feedback to the RoSE project to allow further improvements to the analysis; (by January 2013)

d. Network Rail should establish an appropriate process for developing maintenance schedules, to make it easier and less time consuming for DUs to realign schedules when inspection/maintenance intervals change; (by January 2013)

e. The process of managing implementation issues should be improved and formalised, including capturing key technical details on an asset by asset basis, to allow following up on assessment issues, monitoring of progress, and tracking of performance post implementation approval within the DUs. (by January 2013)

Strategic Approach to Risk-Based Maintenance

5) To deliver further benefits in CP5 and beyond from improved maintenance regimes, Network Rail should develop its strategic approach for the development of RoSE and risk-based maintenance as follows:

    a. Network Rail should develop an RCM or risk-based maintenance strategy and decision support framework to manage business cost and risk that aligns with Network Rail's Asset Management Strategy and Policy; (by January 2012)

    b. Network Rail should set up specific targets for the development and implementation of new maintenance regimes by RoSE or risk-based maintenance across the whole of the Network Rail asset base, on an asset criticality and cost basis; (by January 2012)

    c. Targets specific to the implementation of new risk-based maintenance regimes should be developed for achieving cost savings and improvements in reliability, safety or availability; (by January 2012)

    d. The RoSE project should be more closely and formally integrated with all other RCM initiatives, such as the Reliability Improvement and Intelligent Infrastructure projects, and a formal RCM framework should be developed to govern the joint application of RCM across the business; (by January 2012)

    e. Network Rail should follow a quantified cost-risk optimisation approach to justify the selected maintenance task intervals on an economic basis, and also to evaluate the business opportunity for further reduction or increase of maintenance at local level depending on the asset configuration within an asset type, asset condition and criticality, the potential downtime after failure, and the available service redundancy; (by January 2013)

f. RoSE should be integrated with Renewals and Enhancements to enable investigating opportunities to radically reduce maintenance or install 'low-maintenance' assets via targeted renewals; (by January 2013)

g. Network Rail should establish appropriate planning of Minor Renewals on a location by location basis, through a justified business case that takes into account the local asset condition and the fact that it is the major enabling driver for the new RoSE regimes and subsequent benefits; (by January 2013)

h. Network Rail should explore the benefits and if appropriate pursue integrating RoSE with SICA. (by January 2013)

6) Network Rail should improve its whole-system whole-life cost-risk optimisation capabilities, which should assist pursuing further value for money improvements. This should involve the following activities:

a. Balancing preventive versus reactive maintenance at the local level for each asset type/configuration, following a cost-risk optimisation approach; (by January 2012)

b. Whole life cost-risk optimisation at local level for each asset type/configuration, aiming at balancing capital expenditure (Renewals and Enhancements) versus maintenance and risk (safety and service expressed as revenue) throughout an asset's life; (by January 2013)

c. System-wide whole-life cost-risk optimisation, which involves optimising whole life costs and risks for all assets as a system, taking into account the assets' and sub-systems' criticality in terms of their contribution to the system whole life costs and risks; (by March 2014)

d. The above optimisation activities should be applied at Route level based on a whole-life system-wide Route business case optimising the trade-off between costs, revenue and risks to deliver the required level of service for that Route. (by March 2014)

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1 Introduction

Asset Management Consulting Limited (AMCL) is the Independent Reporter for Asset Management to Network Rail and the Office of Rail Regulation (ORR). As part of this role AMCL was remitted to undertake an independent audit of Network Rail's Reliability Centred Maintenance for Signalling Equipment (RoSE) project and its potential applications to other asset types outside the signalling asset group.

The scope of the audit included assessing the RoSE project to determine the positive and negative impact on signalling equipment in Network Rail's business, including in terms of safety, reliability, delivery of maintenance and costs. The audit covered:

- The business case for Reliability Centred maintenance (RCM);
- The safety impact of RCM;
- The RCM Methodology;
- How RCM was / is being deployed;
- How asset information has been used;
- The potential for further application to other asset areas; and
- The potential for further improvements to the RoSE process taking account of good industry practice.

2 Methodology

2.1 Overview

The overall methodology of the RoSE audit consisted of the following eight key stages:

1) Project kick-off and logistics.
2) A desktop review of the RoSE Programme and Methodology.
3) A desktop review of the documentation relating to two sample asset type analyses.
4) Interview of key headquarters stakeholders (including process developers, implementation teams and maintenance managers).
5) Interview of six Delivery Units stakeholders, via questionnaires.
6) Three site visits at maintenance depots with their Maintenance Teams.
7) Review of the appropriateness of the roll-out programme and progress to date, including an identification of any perceived missed opportunities or future opportunities.
8) Production of this report.

2.2 Desktop Review

The desktop review of the RoSE Programme and Methodology included the following activities:

- Review of the business case rationale for the RoSE project and identified any perceived missed opportunities;
- A detailed assessment and comparison of Network Rail's generic methodology against established good practice for risk-based maintenance;
- Review of how the process considers safety risks and aligns with the Railway Safety Risk Model;
- Evaluation of the appropriateness and timescales of relevant Network Rail plans for the collation or enhancement of necessary asset information to support the RoSE programme;
- Review of the appropriateness and timeliness of relevant implementation enablers and cultural change programmes, including organisational structure and capabilities; and
- Assessment of the applicability of the current or good practice, as appropriate, process to other asset groups.

Furthermore, the desktop review of the documentation relating to two sample asset type analyses covered the following:

- How well the analyses have followed Network Rail's methodology;
- The suitability of current asset information to support the resulting maintenance regimes;
- The predicted business benefits from the resulting maintenance regimes (safety, reliability, risk, efficiency, productivity);
- The safety assessment and validation work undertaken as part of the analyses;
- The consideration of human factor issues in the resulting maintenance regimes;
- The risks associated with the introduction of the new maintenance regimes; and
- Assessment of any additional opportunities or business benefits from further enhancement of the maintenance regimes.

2.3 Interviews

The interviews with key headquarter stakeholders (including process developers, implementation teams and maintenance managers) covered the following:

- The applicability of Network Rail's current process;
- The consideration of safety and human factors in the enhanced maintenance regimes;
- The predicted business benefits (safety, reliability, risk, efficiency, productivity);
- The integration of the enhanced maintenance processes and cultural change aspects;
- The extent to which the integration of the resulting maintenance processes has been considered including cultural change aspects; and
- Expert opinion on the applicability of the process to other asset groups.

To minimise Network Rail personnel time demands, the interviews were undertaken mostly by correspondence using questionnaires and specific queries and clarifications wherever possible. However, several meetings were held with the key Headquarters stakeholders to supplement the information provided by correspondence, and close out all clarification questions.

The interviews with six identified Delivery Units stakeholders reviewed the following:

- Levels of awareness, briefing, training and competence;
- Appropriateness of implementation programme;
- Safety benefits and/or risks;
- Benefits noted by Delivery Units on the ground (safety, reliability, risk, efficiency, productivity);

- Issue identification, communication and resolution processes;
- Process optimisation and feedback opportunities for practitioners; and
- Practitioner input to potential use of process on other asset types.

To minimise Network Rail personnel time demands, the interviews were undertaken solely by correspondence using questionnaires and specific queries and clarifications wherever possible. Also, because Network Rail had identified that due to the on-going 2BC re-organisation there would not be much benefit to be gained by submitting the questionnaire to maintenance engineers at the DUs, it was instead suggested handing it over to ex-DU maintenance engineers who have recently been transferred to other roles. This approach was agreed with ORR.

2.4 Site Visits

Finally, the three site visits at maintenance depots with their Maintenance Teams covered a review of:

- Levels of awareness, briefing, training and competence;
- Appropriateness of implementation programme;
- Appropriateness of safety systems;
- Maintenance access and scheduling arrangements; and
- Appropriateness of maintenance tasks, sequencing and workflow patterns.

The following depots were visited:

- Newcastle depot;
- Edge Hill depot; and
- Ipswich depot.

3 Asset Management Strategy and Policy

This section contains relevant extracts from Network Rail's strategy and policy documents, as well as from the 2010 Asset Management Improvement Roadmap and the 2009 Best Practice Review Update. There is also a section with a brief review of good practice techniques for the optimisation of maintenance and renewal from a variety of industries.

3.1 Asset Management Strategy

According to section 3 of Network Rail's October 2007 Strategic Business Plan, the Route Utilisation and Outputs Specification should provide targets for reliability for each of Network Rail's strategic routes, and when these have been defined, it will provide targets against which major decisions on maintaining, renewing and enhancing Network Rail assets can be taken. However, it appears that no reference exists in the Route Utilisation Strategies or the Route Plans to the RoSE Project or the use of reliability Centred Maintenance (RCM) in maintenance planning. Neither is any specific target quoted for improving reliability or availability as a result of this initiative. The Route plans state that the objective will be to improve the holistic planning process for infrastructure maintenance and renewal, but the main focus appears to be on Renewals and Enhancements to support Capacity and Reliability Improvements, as well as possession management to reduce disruption and meet the needs of operations. Remote condition monitoring is referenced as another initiative to be pursued, but no reference is made to RCM or the scope of the RoSE project.

On the other hand, the 2008 Strategic Business Plan Update makes reference to RoSE, and to projects that this initiative will help deliver asset reliability improvements, primarily by releasing resources to those assets whose failure would have a significant impact on performance. An overall expectation of 26 percent reduction of failures from 2006/04 by the end of CP4 is provided as a result of all the maintenance improvement initiatives, out of which 25 percent was expected to have been delivered by the end of CP3 already. No specific projection or target is provided for the RoSE project though, which in 2008 was still in the development phase of new maintenance regimes.

Network Rail's CP4 Delivery Plan Update 2011 provides specific targets for improving safety by achieving a three percent reduction in the risk of death or injury, and also, for reducing maintenance costs by around 25 percent, which includes the benefit of the recent re-organisation. It also notes that 'there will be continuing improvements in planning maintenance and renewals work, further reduction in unit costs together with continuing challenge to the

volumes of renewals and maintenance'. According to this document, 'this will be achieved by improving asset management decisions through use of *remote condition monitoring*, greater stability in activity as a result of locking down our workbanks, and ongoing implementation of the new delivery methods that have been initiated this year'. It also notes that 'there will be more empowerment of section managers to use the *improved information and tools* to improve decision making at a local level'. However, apart from the use of remote condition monitoring (which is considered part of an overall RCM approach) and 'improved information and tools', there is no reference to RCM or the RoSE project. Further, no specific targets are provided in these areas apart from the overarching 3 percent safety and 25 percent maintenance cost improvement targets. However, the CP4 Delivery Plan Update 2011 does quote that the new standardised maintenance organisation has been introduced, which is enabling increased productivity and reduced costs, and a projection of 15 percent savings in maintenance is provided in the Appendix.

Network Rail's October 2007 Strategic Business Plan identifies in section 2 the core principles of Network Rail's asset management strategy, and this review has audited how the RoSE project has been delivering against all of these. The most relevant to RoSE are:

- 'our asset investment plans will balance maintenance and renewal work with the aim of minimising whole life costs for the whole network';
- 'we will prevent an increase in the risk to passengers, workers and members of the public from the degradation or failure of infrastructure and will reduce it where reasonably practicable';
- 'we will develop technology and methods to support fact based decisions on maintaining and renewing the infrastructure improving our capability for predicting and preventing failures'; and
- 'when making decisions, whether about our strategy for the network or about work we are carrying out locally, we will use a risk management process to identify and reduce threats that could stop us meeting our objectives'.

In addition, in the same document, Network Rail's asset management policy is cited, and the most relevant requirements to the RoSE project are:

- 'The collective totality of assets shall be managed on a minimum whole railway system, whole life cost basis.'

- ‘Asset management activities shall be aimed at achieving overall asset condition levels that balance business risk as a result of asset failure with the whole life, whole system costs of managing the assets.’
- ‘As far as is reasonably practical, new changed and renewed assets shall be designed to minimise subsequent need for attention requiring human intervention or co-existence with train movements or live electrical equipment.’
- ‘The design and construction of new and renewed assets shall minimise reliance on repetitive human examination and subjective assessment. Centralised remote monitoring by technical instrumentation of current status and aspects of condition shall be a requirement for new or renewed assets or asset systems.’
- ‘Asset examination technology and techniques shall be operated to support an overall engineering maintenance strategy of measuring deterioration trend and arranging intervention on a planned basis before asset loss of functionality or capability. This shall enable progressively replacement of traditional “find and fix” reactive maintenance with “predict and prevent” active management.’
- ‘Asset information and records shall be captured and managed sufficiently accurately and comprehensively as necessary to enable management of an asset within its life cycle.’

3.2 Signalling Policy

The latest Network Rail Signalling Policy (2007) specifies that maintenance of signalling should be carried out in accordance with Network Rail’s suite of Signal Maintenance Standards (SMS). It also notes that the intervals shown are intended to maintain the designed safety and reliability by detecting and correcting deficiencies before there is deterioration or failure.

The Signalling Policy also identifies that there are circumstances on the network where the specified intervals are not optimal, and where specific operating uses and environments can be identified, a case may be made to propose a change to the intervals shown in the SMS. The RoSE project is referenced in the Signalling Policy, and in particular it specifies that RCM will be used to change both the frequency and specification of maintenance in order to realise efficiency benefits from tailoring maintenance of assets to the reliability and risks associated with the asset. Also, RCM will be applied to optimise the safety and reliability of the railway. The Signalling Policy states that it will be necessary to ensure the Head of Signalling Engineering is aware of all implementations of RoSE, while section 2 contains the Failure Modes and Risks for signalling equipment to be considered.

Finally, the Signalling Policy states that ‘failure rate monitoring currently (2007) concentrates on the management of high risk failures, and will be enhanced to consider performance monitoring of key signalling equipment’. As part of this review, we have audited the RoSE project against all the above policy requirements.

3.3 2010 Asset Management Improvement Roadmap

The Asset Management Improvement Roadmap defines in section 2.5 the Opex Evaluation commitments regarding maintenance as part of the CP5 Asset Policies. These commitments include:

- Development of Maintenance Requirements Analysis Guidelines;
- Development of Maintenance Strategies, and a business case for the analysis and implementation of maintenance and inspection;
- Risk-based maintenance regimes for assets where the business case is positive;
- Documentation of the resulting maintenance regimes in the Asset Policies, including the expected outcomes;
- Cost-risk justification for the risk-based regimes documented in the Asset Policy Justifications.

3.4 2009 Best Practice Review Update

According to section 6.2 of the 2009 Best Practice Review Update (BPRU), it appeared that little analysis or justification was available underpinning the signalling maintenance regimes to demonstrate that these are optimised, or how there regimes will deliver the HLOS output requirements, in particular those relating to asset performance.

Also, the BPRU quoted a statement from a sample RoSE report that 'a common misconception is that the frequency of equipment maintenance should be based on either how often the equipment fails or how important it is (golden assets)'. According to BPRU, this would indicate that the methodology being used is not consistent with the strategy to develop more risk-based Asset Policies that are focused on the required outputs and risks of the different route categories.

Finally, the BPRU highlighted that despite the above limitations, the RoSE project ‘has identified a number of changes to maintenance regimes that will introduce a more logical and consistent

approach to maintenance across the network'. It also noted that these changes appear to have been well managed and communicated to the DUs.

3.5 Review of Other Industries

The optimisation of asset management via an integrated, whole-system whole-life approach has gradually becoming an imperative objective for more and more businesses across all industries and sectors. This may have been due to necessity, government and regulatory pressures, or both. The approach that each organisation across different industries has been following though to achieve this objective seems to vary. However, some standard approaches have emerged which have become good practice in specific industries, and which are increasingly recognised to be part of the asset management toolkit. Some of those which directly relate to optimising whole-life maintenance and renewal include:

- Whole Life Cycle Costing (WLCC), mostly applied in the defence sector, and to a lesser extent in the oil and gas and various other industries;
- Reliability Centred Maintenance (RCM), having its origins in the airline industry, while it has extensively been applied across a wide range of industries;
- Risk Based Maintenance (RBM) and Risk Based Inspection (RBI), mostly applied in the petroleum and oil and gas industries;
- Total Productive Maintenance (TPM) and lean manufacturing, which has been widely applied in the manufacturing and some process sectors, originating from the automotive industry;
- Total Quality Management (TQM) – Six-Sigma, mostly applied in mass production manufacturing;
- Route cause analysis and reliability analysis, having been applied in the process and manufacturing sectors;
- Failure Modes, Effect and Criticality Analysis (FMECA);
- Fault Tree Analysis (FTA).

Examples of good practice applicable to Network Rail are being referred later in this report.

3.5.1 Case study from the electricity distribution industry

The electricity distribution sector is currently intensifying the application of Reliability Centred Maintenance and Risk Based Maintenance techniques, trying to optimise reliability, safety and security, against maintenance and renewal costs. One recent example from SP AusNet shows

the use of RCM with FMECA to derive risk-based maintenance and inspection strategies, as well as replace-on-failure or replace-on-condition criteria, addressing specific failure modes, and considering alternative options for redundancy, maintenance, refurbishment or replacement.

As SP AusNet quotes in their Asset Management Plans for their distribution transformers and poles, a criticality analysis is included in the FMECA 'which charts the probability of failure modes against the severity of their consequences; the result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value'. Also, SP AusNet define RCM as 'an industrial improvement approach focused on identifying and establishing the operational, maintenance and capital improvement policies that will manage the risks of equipment failure most effectively'.

SP AusNet applies RCM via assigning levels of criticality to the consequences of failure. This informs the decision to leave the less critical functions to 'run to failure', while preserving other functions at all cost. In this way 'maintenance tasks are selected to address the dominant failure causes', while 'failures caused by unlikely events, non-predictable acts of nature, etc, will usually receive no action provided their risk (combination of severity and frequency) is trivial (or at least tolerable)'. 'When the risk of such failures is very high, RCM encourages the user to consider changes which will reduce the risk to tolerable level'. Finally, to support the RCM decision process, SP AusNet uses modelling to generate 'cost optimised' models for each failure mode, which involve producing the plot of risk against maintenance or renewal interval.

4 The RoSE Project

4.1 Background

The RoSE project was initiated in 2005, with a single project manager who has been with the project throughout. Until 2008, there does not appear to have been a great deal of enthusiasm or support for the RoSE project across the business. Network Rail reported that even though the potential reliability benefits were understood based on previous experience in undertaking Failure Mode Cause and Effect Analyses (FMEA), they were not keenly pursued. Also, Network Rail noted that within the maintenance department that RoSE belonged, there was a greater focus on specific projects, with only a small maintenance team to manage the historically based maintenance approach and regimes. It was also reported that the approach to developing signalling maintenance regimes was risk averse and, in conjunction with the fact that the maintenance specifications were primarily seen as there to deliver an 'acceptably safe railway', there appears to have been a reluctance to challenge the historical maintenance regimes.

Network Rail noted that RCM was seen at that time as the opportunity to change the dominant mindset within the business and justify change in maintenance regimes, including extending the maintenance intervals, and so the RoSE project begun aiming to develop regimes that could maintain the railway signalling assets and at the same time deliver improvements in reliability and cost savings.

The RoSE project produced an initial prioritised asset type list based on potential safety (time on track) and cost savings, using data about size of asset population, amount of time on track, and cost areas. Higher populations of assets within an asset type would mean higher potential benefits, and so AWS, TPWS, signals and facing point tests, were identified as the first asset types to progress with the RoSE analysis.

According to DU maintenance engineers, the RoSE analysis and the RoSE gradual roll-out have unfortunately been slower that they could have been due to resistance to get DUs to participate in the RCM workshop, or the RoSE regimes not having been implemented at all DUs to the same degree, even though assets may have already been indicated as 'assessed' or ‘authorised’ within the Ellipse database (refer to section 4.9.1).

4.2 Scope

According to Network Rail, maintenance is a component of asset management, and as commonly defined in the railway industry, ‘maintenance’ comprises only the routine inspection /

cyclic maintenance tasks which will prevent or mitigate the consequences of failures. Hence, the RoSE project scope covers the preventative or corrective maintenance of signalling assets.

In particular, the RoSE project aims to determine the cyclic maintenance need for all relevant equipment, while other asset management/RCM actions are being applied by Network Rail to address what cannot be addressed adequately by maintenance, such as modifications and renewal. Network Rail stated that this approach provides flexibility and that it maximises the availability of the railway for train services. Diagram 1 illustrates the approach Network Rail may follow in the future to manage the business risk associated with signalling assets, as presented by the RoSE project as part of the discussion on the new asset policy. However, it was reported that it is still early days, and because the RoSE project does not have visibility of the asset policy work, it is not definite how much of this has actually been incorporated.

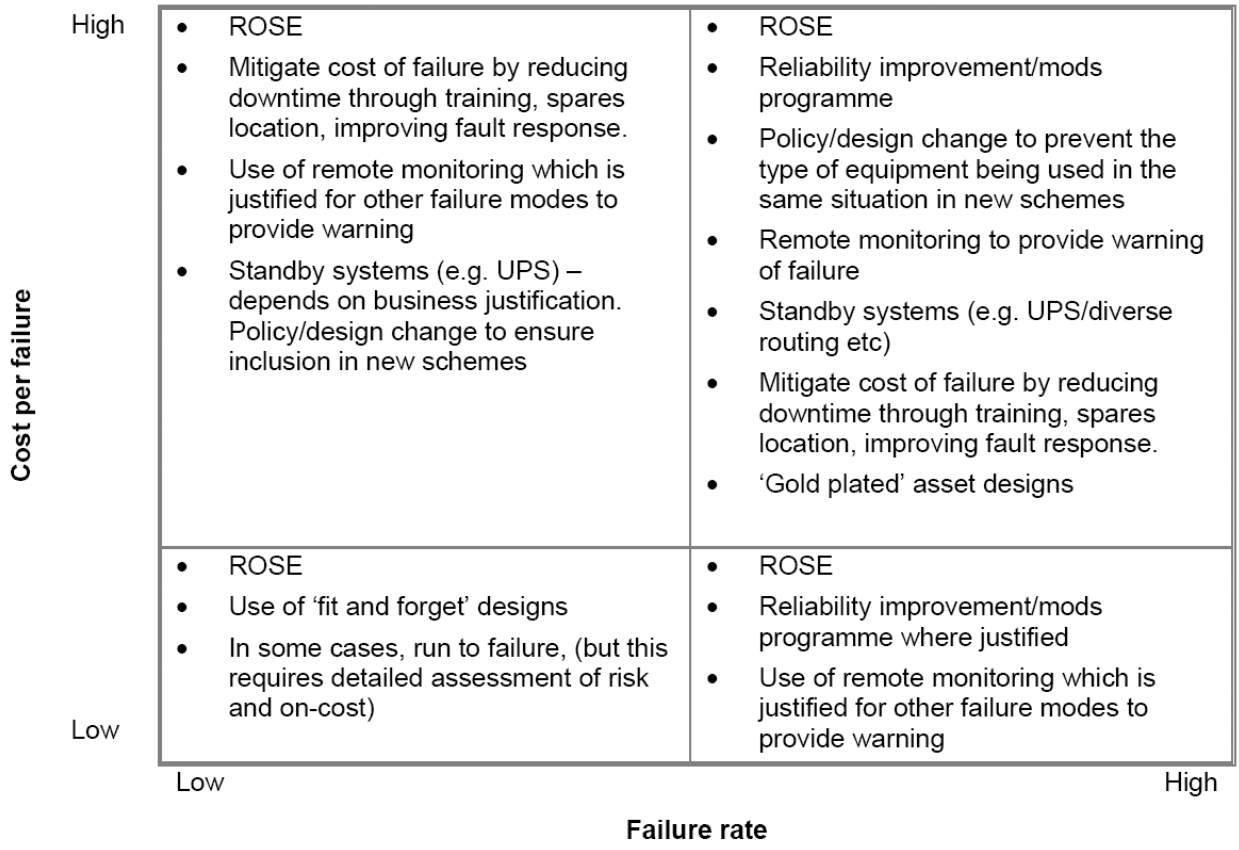


Diagram 1 Network Rail's Draft Asset Management Business Risk Process - Signalling Assets

As illustrated in Diagram 1, RoSE is considered applicable to all assets irrespective of their failure rate or cost per failure. Also, the main objective of the RoSE project, as stated by Network Rail, is to ensure that the right maintenance is being done to each asset type. RoSE therefore can result in either increasing or decreasing maintenance intervals. Furthermore,

asset maintenance, according to RoSE, should be defined by an understanding of how an asset can fail to fulfil its required functions, the importance of each failure, and the identification of appropriate maintenance tasks which are technically feasible and worth doing.

However, according to Network Rail, the main emphasis of RoSE to date has been on delivering workload savings to enable Network Rail to meet its CP4 efficiency objectives, as explained in section 4.9.2. However, by applying the right maintenance to each asset, Network Rail stated that it aims to reduce whole life cost and improve reliability and hence safety. At the same time, Network Rail believes that by focusing team effort and track access time where it is most beneficial it will improve efficiency.

AMCL believes that the interventions presented in Diagram 1 are part of what Reliability Centred Maintenance (RCM) should cover as an integrated approach. However, the definition of RoSE as 'Reliability Centred Maintenance of Signalling Equipment', soon to be extended to other disciplines (e.g. telecoms, track, etc.), can be a bit misleading of the true scope of RoSE which, as already discussed, focuses at the moment on the cyclic inspection and maintenance tasks needed to prevent or mitigate the consequences of failures. Section 4.11 (Whole-life Systemic Approach) evaluates the application of RCM as an integrated and systemic approach, which currently is being applied within Network Rail as a set of separate initiatives that look at the interventions needed as part of Network Rail's overall approach to manage business risk related to failures.

4.3 Organisational Structure

Until recently, the RoSE project reported to the Director for Infrastructure Maintenance. However, the project has recently become part of the Infrastructure Maintenance Reliability Team team. Key stakeholders include the S&T Professional Head who is accountable for the RoSE analyses and authorises the new maintenance regimes, the Maintenance Delivery Units (DUs), the Route Infrastructure Maintenance Engineering (IME) teams, and the Route Asset Manager (RAM) teams.

The RoSE project team works within the Reliability Improvement team, which aids collaboration between RoSE and other reliability improvement initiatives and the Intelligent Infrastructure workstream (RCM^2). For further discussion on this please refer to section 4.11.3.

4.4 Business Case

4.4.1 Resources

The latest version of the RoSE business case can be seen in the following table. This business case only includes 'theoretical' or calculated savings in 'time on tools', and is as close to actual as the RoSE project stated could be achieved. Also, it is being updated on a regular basis. RoSE noted that workload savings have been included only for assets that have already been authorised, or are relatively certain based on previous authorisations, and so, additional saving may arise.

However, there is no segregation of actual/realised versus potential savings, which according to Network Rail is because of significant improvements in data quality and task reporting in Ellipse[1]. This had made it impossible to align the two sets of data and produce a direct before and after workload comparison.

Business Case - Signalling Only

	2005/6	2006/7	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14
Cost	(£58k)	(£156k)	(£186k)	(£232k)	(£270k)	(£330k)	(£599k)	(£469k)	(£210k)
Time on tools saving actual				£590k	£2,114k	£1,602k			
Time on tools saving est						£2,023k	£4,000k	£4,500k	£5,000k
Net benefit	(£58k)	(£156k)	(£186k)	£358k	£1,845k	£3,295k	£3,401k	£4,031k	£4,790k
Cum benefit	(£58k)	(£214k)	(£401k)	(£43k)	£1,802k	£5,097k	£8,498k	£12,529k	£17,319k
NPV (8%)	£9,818k								
IRR	139%								

NB The savings are based on **time on tools** savings only. There will be additional savings in failure costs and in non-productive time, but these are harder to attribute purely to this project

Table 1 RoSE Business Case for Signalling Assets

When trying to assess how the current business case and realised benefits compare to the original project proposal/outline and business case which was used to authorise and fund the RoSE project, Network rail said that they did not really have a 'baseline', although at the initial stages of the project an estimate was made about the potential total cost savings of about £2 - 2.5m per annum. Then, it was predicted that ROSE would only be viable on a few signalling

[1] Previously Network Rail reported "quarterly service done", but now each element, FPL, Stretchers, Machine Service, Detectors etc is reported, and asset types have been separated.

asset types. Also, at that time several senior signal engineers predicted that Network Rail would never achieve a saving as great as £2m per annum as maintenance would not be able to be cut by much.

According to the RoSE project team, the RoSE predictions proved somewhat pessimistic and those of the senior engineers even more so. RoSE stated that the theoretical 'time on tools' saving to date is worth about £4m per annum, or 34 percent theoretical 'time on tools' workload reduction for the asset types RoSEd, plus unquantifiable but significant savings in non-productive time, plus unquantifiable reliability benefits to the ROSEd assets, reliability improvements arising from using the freed up time and people for work on other asset types, plus the opportunities to carry out more Capital works. The business case shown above includes the remaining CP4 'time on tools' benefits for signalling which, as Network Rail has already identified, is still rather conservative and excludes all other benefits that cannot be quantified.

The calculated RoSE savings, although they are still only theoretical 'time on tools' savings and do not yet capture all business benefits, appear to be in the same order of magnitude to savings achieved already in other industries that have applied risk-based maintenance to deliver more efficient and effective maintenance[2]. Diagram 2 shows the typical percentage benefit from adopting a risk-based approach in place of time-based or historically based maintenance and inspection regimes (based on analysis of such programmes in third party organisations)[3]. The benefit is calculated as the potential savings in labour and material costs whilst maintaining or improving asset reliability and risk. It should be noted here that the RoSE process is not a risk-based approach (see sections 4.5 and 4.6).

[2] 2007 Best Practice Review, Final Report, AMCL

[3] Based on all 77 studies undertaken by The Woodhouse Partnership across a range of industry sectors.

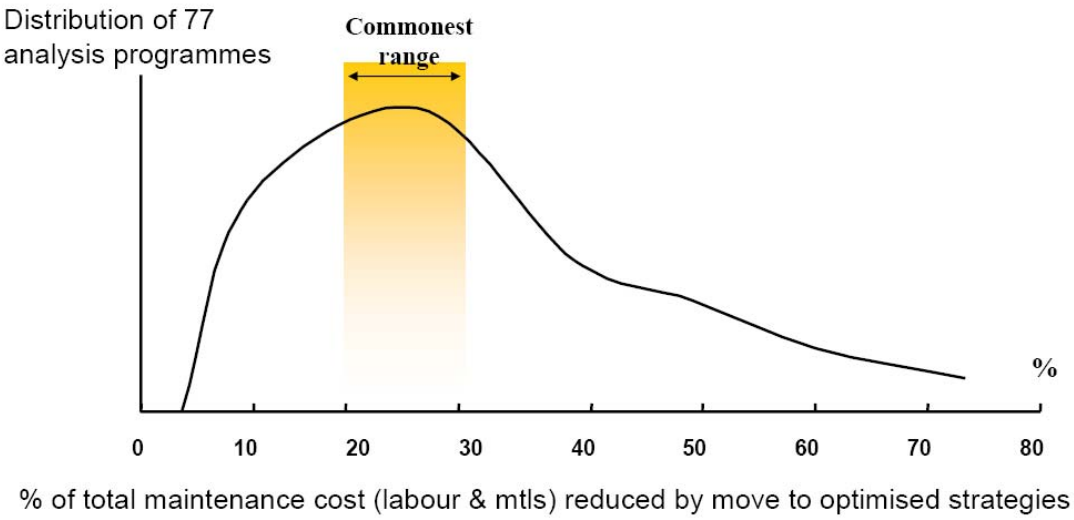


Diagram 2 Cross-Industry Benefits of Optimised Maintenance and Reliability

It should be noted that these are potential savings only and do not necessarily represent the savings actually delivered by the relevant organisations - these figures are typically difficult to obtain. In addition these savings do not take into account any mobilisation costs, such as training or analysis, but are included here to indicate the typical *potential* opportunity from implementing Risk Based Maintenance and Inspection.

This would appear to be verified by work undertaken by Tube Lines where benefits of up to 20% were identified from the application of Risk-Based Maintenance techniques. Some work undertaken by Network Rail in 2002-03 on the benefits of Risk-Based Maintenance for signalling identified similar levels of potential benefit.

4.4.2 Reliability and safety

In addition, safety and service performance impacts due to reliability changes from RoSE have not been assessed. Network Rail said this has not been done because it has not been possible to find any credible way to assess the impacts of RoSE independently from other initiatives. Network Rail stated that they do not want to double count benefits or mislead managers.

4.4.3 Whole-life evaluation

The business case only considers financial years 2005 to 2013, i.e. up to the end of CP4, and so it is not a whole life cost benefit analysis throughout the life of the signalling assets, for example 30 to 35 years. In response to whether there has been a whole-life analysis, Network Rail noted that the above business case was developed for a specific requirement, which is

understood to be the request for funding RoSE within CP4. The RoSE project noted that work is currently underway with the CP5 team on evaluating further benefits, which will be reported as part of CP5 submission.

Furthermore, no business case modelling has been done yet considering the remaining life of the existing signalling assets and the potential interaction with Renewals and Enhancements. A whole-life approach could have enabled Network Rail to optimally prioritise and integrate RoSE with other improvements, renewal and enhancement schemes with similar long term benefits, and potentially justify investing more to accelerate the programme.

Finally, Network Rail mentioned that the Business Case for the RCM^2 (reliability centred maintenance and remote condition monitoring) and Reliability Improvement workstreams does not yet capture benefits from RoSE (for example reduction in maintenance). For more information about these initiatives refer to section 4.11.

4.5 RoSE Process

4.5.1 Network Rail Standards

The Network Rail Standards that are directly related to the RoSE project are as follows:

- NR/L2/SIG/10662 Process for Introduction of new or revised Maintenance Regimes for Signalling Assets
- NR/L3/SIG/10665 Reliability Centred Maintenance of Signalling Equipment (ROSE)
- NR/GN/SIG/10670 ROSE Project – Implementation Guidance

The following Network Rail Standards specify how updates to relevant databases should be completed as part of the RoSE implementations:

- NR/L2/AIF/001 – Asset data management
- NR/L2/MTC/02020 – Ellipse for Network Rail Work Management

4.5.2 RoSE process

Network Rail has developed an RCM process, which is specified in NR/L2/SIG/10662. In addition, a more formal process is currently under development[4] which is still in the form of flow

[4] RCM Process v3.pdf

charts. One of these charts provides the overview of the current process, as can be seen on the following Diagram 3.

The core of the RCM process is the RCM analysis, which depending on the equipment complexity can take two forms; for minor complexity it can follow the 'RCM-Lite' approach, and for major complexity the full RCM analysis has to be undertaken. For the purposes of this report we will refer to the RCM analysis as the 'RoSE analysis'.

According to the RoSE project [25], the risks of implementing an RCM approach were evaluated at the start of the project, and a comparison was made against the Risk Based Maintenance (RBM) project which the RoSE replaced. However, apart from a high level qualitative identification of the merits of the RCM process, Network Rail does not have any documentation of why RCM was preferred over RBM.

RoSE has so far been applying the RCM process at equipment level and in particular by each of the existing asset types corresponding to the existing Network Rail/SMS standards. A summary of the asset types that have been so far considered as part of RoSE can be seen in section 4.9.1.

The main output of the RCM analysis, as can be seen on Diagram 3, is the production of new signalling maintenance specifications (SMS) if needed, and then, the authorisation and issue of new maintenance regimes. This is being done by the RoSE project via the publication of an updated version of the NR/L3/SIG/10665 standard (Reliability Centred Maintenance of Signalling Equipment (ROSE)), which also contains a reference to the applicable SMSs.

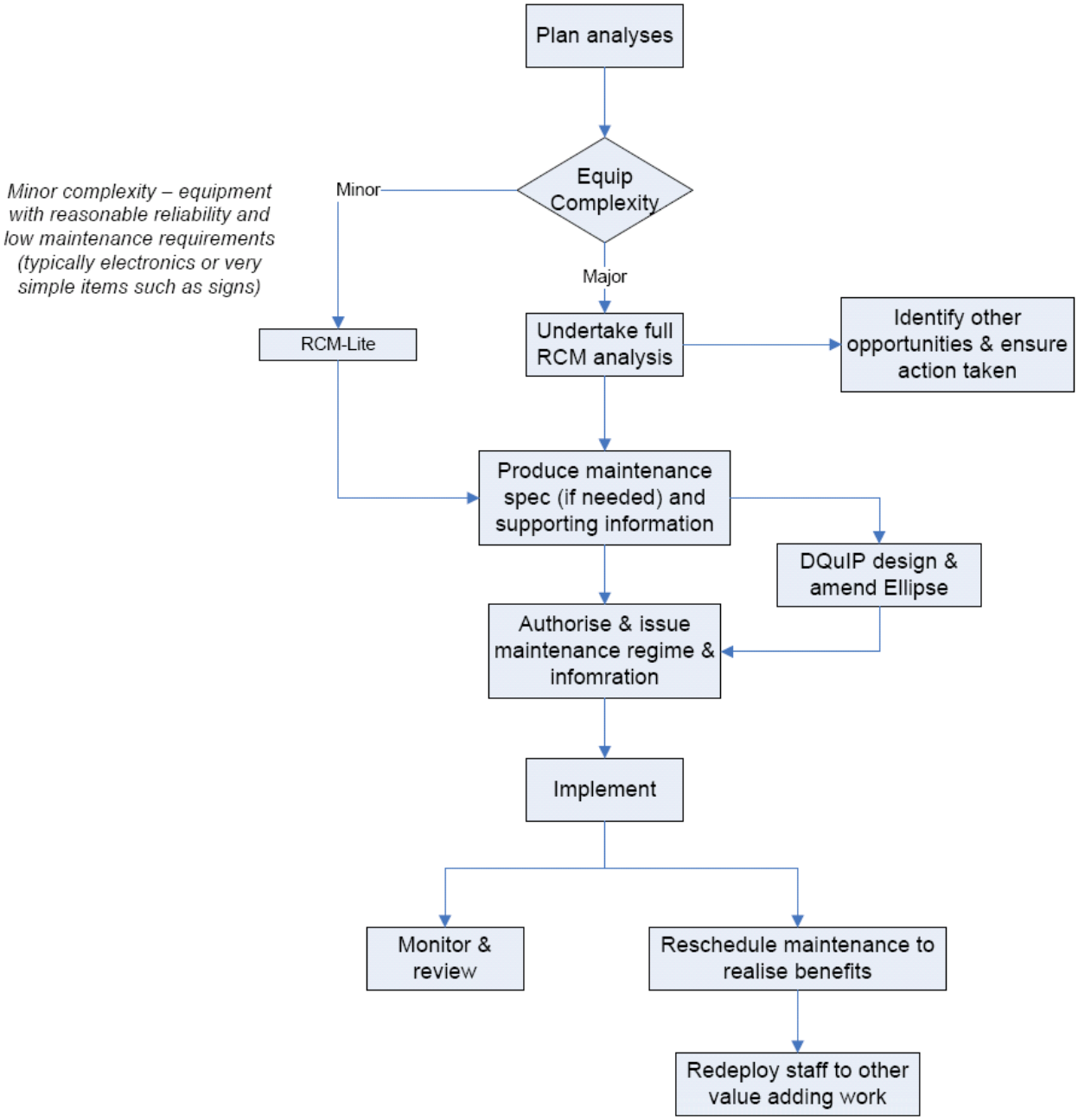


Diagram 3 RoSE RCM Process Overview

4.5.3 RCM training

The following RCM2 courses have been delivered to Network Rail by Mutual Consultants Limited[5] to enable undertaking the RCM2 analysis as per Moubray (1997):

[5] 3-day RCM Training (P).pdf, FacilitatorTraining (P).pdf, Post-analysis Review.pdf

- 3-day RCM2 Training, providing the competence and confidence to take part in an RCM2 analysis (under the guidance of an RCM2 facilitator);
- RCM2 Facilitator Training, 10 day course, aiming to prepare for and conduct an RCM2 analysis on a straightforward system. It is suggested that delegates will possibly require some mentoring/support when they undertake their first analysis after the course; and
- Post-Analysis Review, 2 days course for maintainers and operators who are not involved in the RCM2 analysis, in order to provide them with sufficient confidence in the RCM2 output to implement the new maintenance requirements.

However, Network Rail noted that the 2BC re-organisation has caused all RCM training courses for Champions and the training provided to DUs as 'background' to be put on hold since April 2010, and will not resume until mid-summer 2011. However, Network Rail has undertaken a number of courses over this period to support the RoSE analysis workshops.

4.6 RoSE Analysis Methodology

NR/L2/SIG/10662 mandates that the RoSE workshops should follow the RCM2 process as per Moubray (1997), which is a cross industry recognised RCM methodology that complies with SAE JA1011, *Evaluation Criteria for Reliability-Centred Maintenance (RCM) Processes*. The methodology followed by the RoSE analysis for the development of new maintenance regimes is described at a high level in the ROSE Project report provided by Network Rail to support the RoSE Review, as well as by the NR/L2/SIG/10662 and the RCM Process v3 document.

However, the RCM2 analysis methodology, which is the core of the RoSE analysis, is not sufficiently covered in either NR/L2/SIG/10662, which notes that details of the process can be found in Moubray's book, or the RCM Process v3 document, which simply refers to the RCM analysis as 'hold workshop'. However, as mentioned earlier, the RoSE Project team are currently developing a more formal process, which will be necessary with the expansion of the core RoSE team. The value of having a formal Network Rail detailed RCM analysis would be to be able to formalise any improvements or deviations in the RCM2 process as applied by Network Rail over time against that described by Moubray (1997) or any other references of good practice. It would also allow documenting the process steps which are needed to integrate RoSE with other Network Rail work streams or headquarter departments.

The SAE JA1011 mentioned above is a standard intended for use by any organisation that has or makes use of physical assets or systems that it wishes to manage responsibly. According to this standard, RCM is a specific process used to identify the policies which must be

implemented to manage the failure modes which could cause the functional failure of any physical asset in a given operating context. This document is intended to be used to evaluate any process that purports to be an RCM process, by specifying the minimum characteristics that a process must have in order to be an RCM process. According to SAE JA1011, the RCM process entails asking seven questions about the asset or system under review and the following table indicates how the RoSE analysis aligns with each of these questions. The rest of this section analyses RoSE against these criteria in more detail.

RCM questions (SAE JA1011)	RoSE RCM analysis
1) What are the: a. functions, and b. associated performance standards of the asset in its present operating context (functions)?	The RoSE analysis properly defines the functions for each asset type analysed. However, there is no reference to any performance standards, e.g. the required level of the system or sub-system reliability or availability influenced by the asset type analysed. Rather, according to Network Rail, the strategy has been to prevent asset failures from occurring, i.e. to minimise failures as much as possible.
2) In what ways does it fail to fulfil its functions (functional failures)?	The RoSE analysis properly defines the functional failures for each function analysed.
3) What causes each functional failure (failure modes)?	The RoSE analysis properly defines the failure modes for each functional failure analysed.
4) What happens when each failure occurs (failure effects)?	The RoSE analysis uses expert judgment based on the experience of the RCM2 workshop teams to evaluate the failure effects of each failure mode, and this is documented on the RCM2 analysis worksheet.
5) In what way does each failure matter (failure consequences)?	Network Rail highlighted the fact that the RCM2 process followed treats failure modes with safety consequences

RCM questions (SAE JA1011)	RoSE RCM analysis
	as separate from other failure modes, hence preventing a low likelihood safety failure from being ignored. However, while the failure effect of each failure mode is sufficiently evaluated and documented on the RCM2 analysis decision worksheet, the failure consequences are only indicated by a yes or no for each type of consequence as per the RCM2 Decision Diagram, while the analysis of their magnitude and criticality is not evident or documented (i.e. the how does the failure matter). Hence, it is not possible to assess that the failure consequences have been properly evaluated. No quantified failure consequence analysis has been performed so far by the RoSE project. Furthermore, no estimate of the service **downtime** has been produced - which could inform the worth doing assessment. Neither has a cost-risk optimisation exercise been undertaken in order to define the specification of the preventive maintenance tasks and set their frequencies to minimise the total business impact, i.e. cost plus risk (safety and service risk). No consideration is being made of the resulting downtime after failure at local level (i.e. at Route level) and the available local **system redundancy** which could minimise the safety and service consequences, i.e. the resulting downtime.
6) What can be done to predict or prevent each failure (proactive tasks and task intervals)?	The RoSE analysis follows Moubray's RCM2 Decision Diagram to guide the decision of the appropriate proactive tasks and task intervals, in conjunction to expert judgment based on the experience of the RCM2 workshop teams. According to Network Rail, for signalling assets the short

RCM questions (SAE JA1011)	RoSE RCM analysis
	duration of each task means that the worth doing assessment rarely requires a detailed calculation of the failure consequences, with the experience of the workshop teams being used to assess whether the task is worth doing. Also, according to Network Rail this approach has enabled the RoSE project to achieve earlier delivery of benefits. Finally, only one maintenance specification for each asset type is being produced, hence not allowing the relaxing of the maintenance specification or extending the task intervals at local level if it was justifiable to do so depending on the required level of Route availability, or as a result of a system whole-life cost-risk optimisation exercise at Route level. Network Rail stated that this is a conscious decision pending the ability to positively link an asset, work order and maintenance specification on the handheld, and hence reduces the risk that the wrong spec will be used. On the other hand, the new RoSE regimes allow DUs to increase maintenance task frequencies if they judge necessary due to local asset condition, configuration and environment.
7) What should be done if a suitable preventive task cannot be found (default actions)?	The RoSE analysis follows Moubray's RCM2 Decision Diagram to guide the decision around default actions, such as: ▪ No scheduled maintenance ▪ Redesign (e.g. redesign of the asset, the person (training), or the process (tools & information)) ▪ Walk-around checks (i.e. foot patrol)

RCM questions (SAE JA1011)	RoSE RCM analysis
	'No scheduled maintenance' is one default action used extensively in the RoSE analysis. Also, maintenance activities performed by P-way maintenance are being taken into account in deciding the need for a signalling scheduled maintenance task. Redesign requirements are primarily identified in the form of training, tools, and information. Also, equipment design issues and modification requirements, or remote condition monitoring has been considered for a few asset types, e.g. for IRJ and TI21. There has also been some interaction between RoSE and the Reliability Improvement and Intelligent Infrastructure work streams, i.e. by undertaking joint RCM2 analysis, e.g. for IRJs (Reliability Improvement) and TI21 (RCM^2). On the other hand, there has been limited co-operation so far between RoSE and the scheme designs as part of the Renewals and Enhancements, i.e. in order to highlight configurations and condition which allow reduced maintenance. Foot patrol is being taken into account by the RoSE analysis when determining the appropriate maintenance tasks and frequencies.

Table 2 Questions an RCM Process Should Cover - as per SAE JA1011

NR/L2/SIG/10662 specifies that the outputs of the RCM2 workshops should be:

- FMEA
- Decision Worksheet
- Task List
- Non-maintenance issues list(s)

The sample RoSE analyses provided as part of this review include all of the above.

4.6.1 FMEA

The RCM2 FMEA as applied by the RoSE analysis asks what-if questions to provoke thinking of DU engineers participating in the RoSE analysis. It also involves an independent reviewer who has not participated in the RCM2 workshop. In addition, when new technology is being analysed, equipment manufacturers are being brought in to help with the FMEA (e.g. LED signals). When there is not yet sufficient understanding of the Failure Modes, an annual review for 2 to 3 years is followed.

The FMEA undertaken by RoSE is different to an FMECA in that it does not include a Criticality analysis, which is in general a prioritisation of the failure modes based on an estimate of the magnitude and the importance of their consequences. However, such an approach has been followed at a high level for one of the analyses performed by RoSE as part of the S&C study to support various recommendations from the RAIB Grayrigg report.

The review questioned how the RCM2 analysis undertaken by RoSE can ensure that all possibilities across the Network Rail network are covered, i.e. in terms of known or anticipated failure modes, as well as the knowledge of the local environmental conditions that each DU faces. RoSE responded that the maintenance support engineers coming from the RAM teams have the local knowledge of the assets and their current condition across the network, while the RoSE analysis is being reviewed by a member of the RAM teams from a different part of the country to where the depot DU engineers that have participated are from. Also, RoSE mentioned that members of the team actively 'go around' talking to depots across the country tapping local knowledge post-RoSE review.

In addition, RoSE highlighted that the RoSE maintenance regimes focus on using asset condition to capture the need to vary maintenance, more than usage, which helps taking the local conditions into account before implementation. On the other hand, even though local knowledge as part of the RCM2 analysis is important, getting the required input from the DUs is time consuming, and despite the DUs wanting new regimes, they have some times been slow in coming forward offering resources to assist the development of new regimes. However, DU engineers think that RoSE has been giving due consideration to input suggested from the ground, and occasional changes have been made to reflect this.

4.6.2 Determination of how to best manage each failure mode

The diagram below summarises the process of determining how to best manage each failure mode according to good practice. The greyed part of the diagram highlights what parts of the process RoSE has not yet applied.

As part of this review we considered how RoSE establishes on-condition tasks before any other options, and how P-F intervals are taken into account to determine the optimum task intervals. In particular, we looked at whether RoSE:

- Distinguishes between failures with economic consequences versus safety or environmental consequences.
- For economic consequences: whether it compares monitoring/maintenance cost vs. economic consequence of failure, to determine whether monitoring/maintenance is financially justifiable.
- Safety (or environment): whether it establishes that monitoring/maintenance is considered worthwhile if risk of failure is reduced to a tolerable level (ALARP).

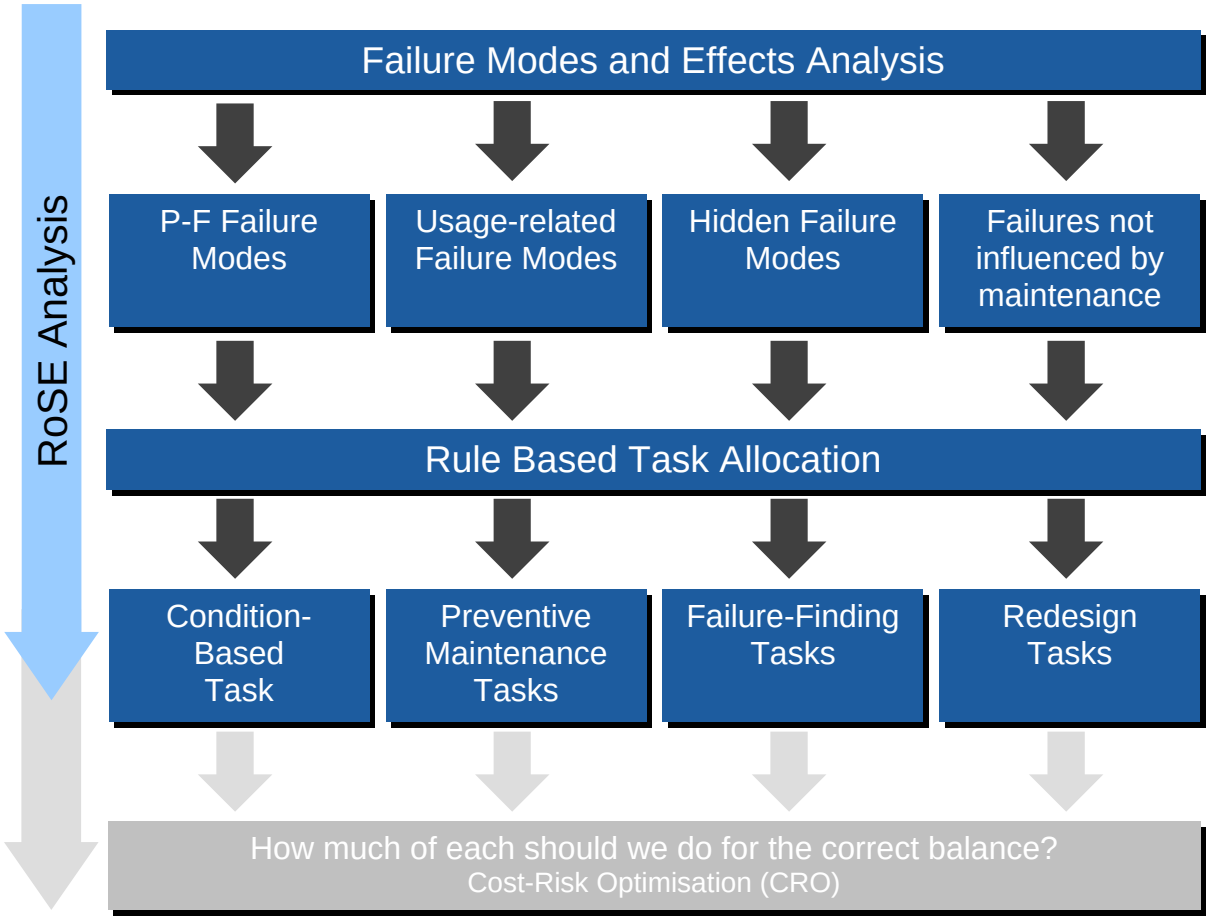


Diagram 4 Good Practice Process to Determine how to Best Manage each Failure Mode

As noted earlier, the RoSE RCM process has provided a structured approach for deciding how to best manage the particular failure modes in the future. As shown on Diagram 4, the approach followed by the RoSE analysis does not include a Cost-Risk Optimisation (CRO) exercise to determine the optimum specification and frequency of a maintenance task that would minimise the total business impact. For failure modes with safety or environmental consequences the Cost-Risk Optimisation approach is compliant with The Yellow Book, i.e. in reducing risk to as low as reasonably practicable (ALARP). For failure modes with operational consequences only, without any safety or environmental risks, this approach is also applicable in establishing whether a proactive task is worth doing, which is if over a period of time, it costs less than the cost of the operational consequences plus the cost of repairing the failure which it is meant to prevent.

Instead of a Cost-Risk Optimisation approach, the RoSE project has been following the Expert Judgment approach in determining the appropriate task and frequency to mitigate each failure mode, making use of Moubray's RCM2 Decision Diagram to allocate appropriate Rule Based Tasks (RBT). Network Rail stated that the approach followed has been appropriate for two reasons:

1) For signalling assets, the short duration of each task means that the 'worth doing' assessment for each maintenance task rarely requires a detailed calculation, with the experience of workshop teams being used to assess whether the task is 'worth doing'.
2) Network Rail is experience-rich, but data-poor, so quantification of the consequences of specific failure modes would be difficult with the existing data available.

Hence, no quantified calculation of the 'worth doing' has been done so far. However, when the scope of RoSE is extended to asset types that the maintenance cost is greater, then the RoSE project team believe that the calculation of the 'worth doing' is going to be more important. In that case, asset criticality will become more important as well.

The process followed by RoSE to allocate appropriate Rule Based Tasks follows Moubray's RCM2 process distinguishing between failures which are age related and exhibit a deterioration pattern, and failures which are not age/usage related and are usually referred to as failures exhibiting a P-F interval. The degradation information for age related failures is generally derived from the experience of the workshop teams, and provided the expected degradation is reasonably constant, the inspection interval will relate to expected degradation and the lead time to repair, as shown in the following diagram provided by Network Rail. RoSE identified that

in the longer term, the use of remote condition monitoring will assist in validating some degradation intervals.

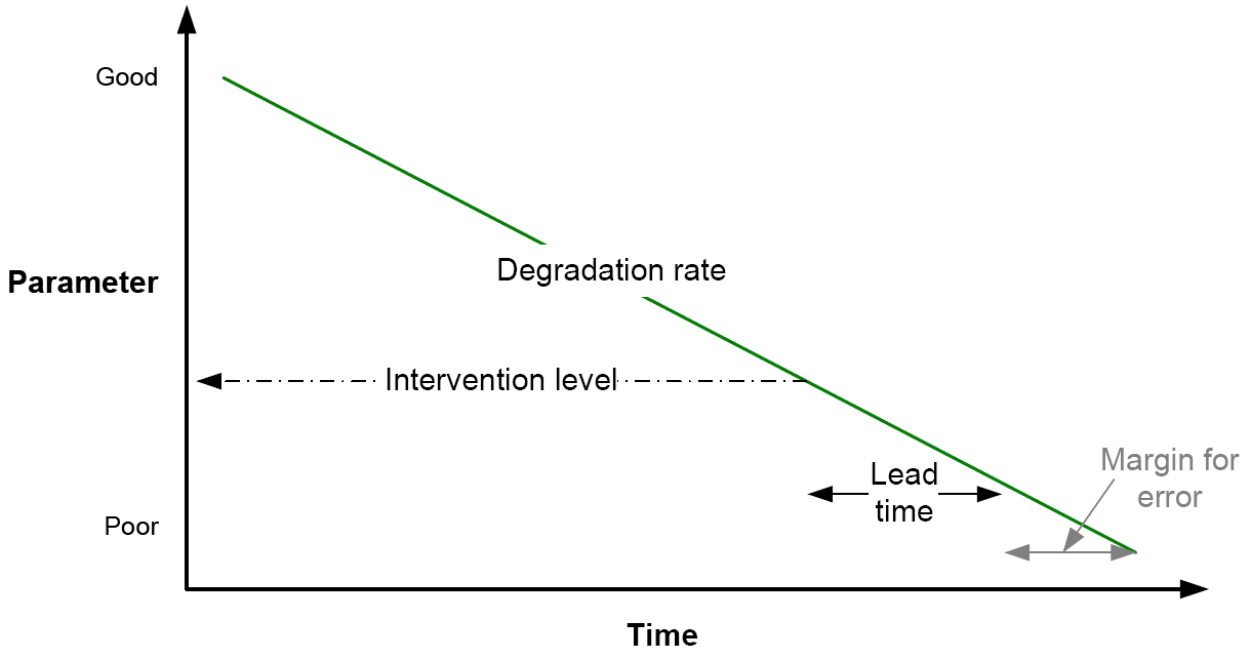


Diagram 5 Age/Usage Related Failure Modes

For failures that do not exhibit age/usage behaviour and which give some sort of warning that they are in the process of occurring or about to occur, the P-F interval[6] is used to define manual inspection. According to RoSE, manual inspection more than often than 1/2 – 1/3 the P-F interval will show no appreciable benefit and will increase the risk incurred by staff when on track. On the other hand, inspection at less than 1/2 – 1/3 the P-F interval will increase the risk that a failure will occur. The following diagram provided by Network Rail illustrates this principle.

RoSE mentioned that where necessary Network Rail Operations are being consulted, i.e. to identify impact on operations/train delay, but it was suggested that generally the RoSE analysis team participating to the workshops have sufficient knowledge of the system to know whether a failure will result in trains being cautioned, etc. However, no quantified estimation of the potential impact of failures on service, and as a consequence on revenue, has been done as part of the RoSE analyses.

[6] P-F interval: the time between being able to detect that a failure is starting to occur and the failure occurring

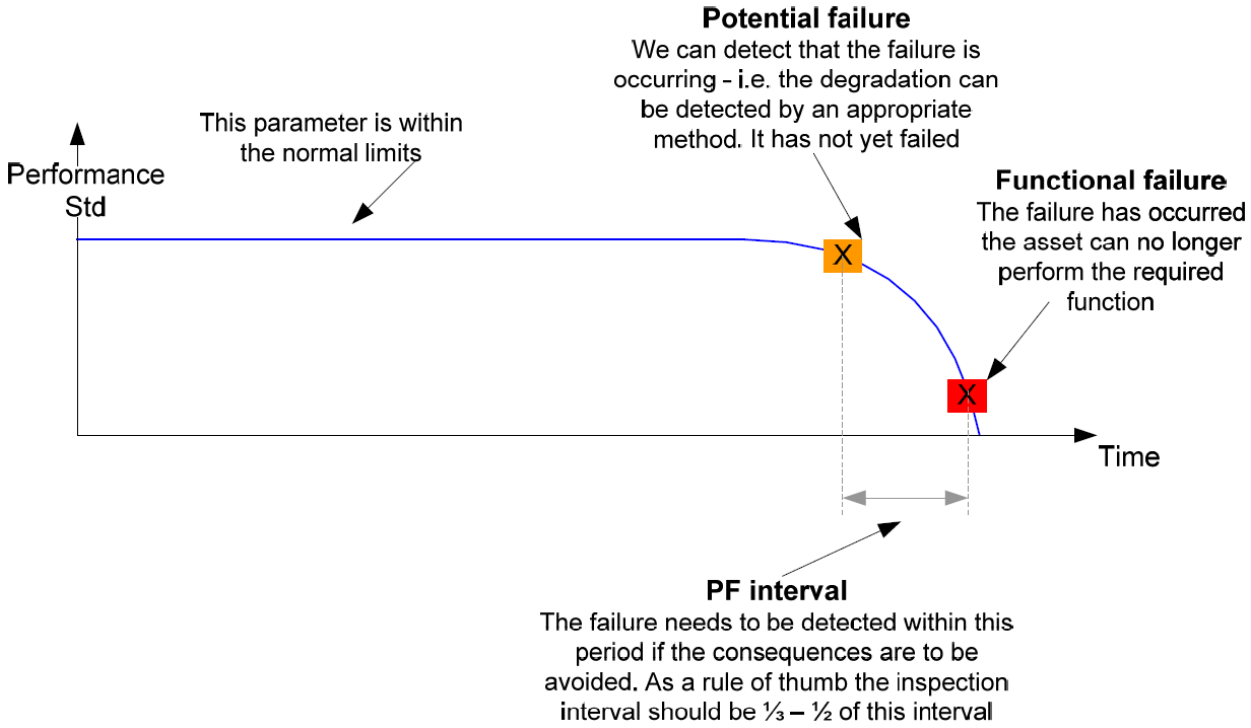


Diagram 6 Non Age/Usage Related Failure Modes (P-F interval)

As noted earlier about the RoSE analysis, asset criticality has been excluded from the decision logic of all maintenance regimes developed by RoSE. In particular, the FPL testing RoSE analysis states that 'the frequency of FPL testing is defined by how long it takes the failure mode to occur rather than the criticality of the points in operational terms'. We understand that this could be an appropriate strategy for points with a high potential safety and service risk if a failure occurs. However, for other asset types that the safety and service risk may be much less, RoSE still applies the same strategy as for points, i.e. it does not take into account asset criticality in determining how to best manage each failure mode.

In some cases, such as the new specification for the FPL testing frequency rationalisation, the new range of allowable frequencies derived by the RoSE analysis are still based on the existing range of frequencies applied across the network, with the main difference being that a logic has now being introduced to ensure that the right frequency is selected for each point end. In the past, according to the RoSE analysis for FPL testing[7], FPL testing had been performed at a variety of frequencies, within the 4 to 13 weekly interval range, with little rationale for the frequency at any particular installation.

[7] FPL Full report v2.pdf

The RoSE analyses completed so far have resulted in small changes to a few of the existing maintenance specifications (SMS) by asset type. For example the RoSE analysis for HVI track circuits suggested a visual examination to be added to the existing test as specified in the NR/SMS/Test/035. In addition, the maintenance specifications for AZLM axle counters, TI21 and Aster U type/SF15 track circuits, and TPWS have been supplemented following RoSE analyses. Finally, the RoSE project is currently producing maintenance specs tailored for delivery on the handhelds, which is rapidly increasing the number of RoSE specs (i.e. that have greater differences to the SMS).

An opportunity that has not fully been exploited by RoSE yet is moving whenever possible to low maintenance assets when new assets are installed. For example, Network Rail stated that this could potentially be done with LED signals, as according to Network Rail there appears to be an aging process in the deterioration of the colour of the LED and which has to comply with specific tolerance standards. In fact, ROSE has been used to support the business case for installing LED signals to replace certain types of filament signals on particular sections of routes.

Finally, in the sample RoSE analyses provided[8], some failure modes identified have safety consequences and the RCM2 analysis has found that they cannot be mitigated through scheduled maintenance. For a few of these cases it is noted in the corresponding RCM2 analysis worksheet that the solution falls outside the scope of the particular RCM2 analysis as it affects several signalling assets[9]. When asked whether these cases have been followed up afterward by separate analyses, RoSE responded that for obvious reasons boundaries are defined for each analysis and so inevitably there are crossovers between analyses for different asset types. RoSE suggested that a better example is earth faults on cables[10], where Network Rail felt that the necessary data was not available, or specialist expertise was lacking within the analysis group. It was suggested that at that stage Network Rail Engineering didn't have the resources to carry out the work in-house, and for that reason Atkins was commissioned to carry out a study which in the end supported the initial conclusions reached by the analysis group.

[8] HVI.pdf, TI21 Authorised.pdf

[9] For example, in TI21 Authorised.pdf on page B24, Failure Mode 03A28 (multicore cable (between locs) faulty - short circuit): it is mentioned that 'merger testing is technically feasible', but 'outside scope of TI21 analysis as affects several signalling assets'

[10] Cable Testing Report Issue 01.pdf

4.6.3 Risk management

According to good practice, the core of a risk management oriented organisation is to apply a robust process for assessing risk. There are two types of risk assessment. The first is a Qualitative analysis, which can take two key forms; Expert Judgment, or Qualitative Risk Ranking that ranks failure modes according to the frequency and severity of their potential consequences. The second form is a Quantitative analysis, which comprises a similar analysis using quantified data in conjunction with expert judgment. The RoSE analysis as part of the RCM2 workshop has been following the Expert Judgment approach to assess risk.

RoSE could have followed either a Qualitative Risk Ranking or a Quantitative analysis to undertake a cost-risk optimisation exercise aiming at evaluating the worth doing and determine the optimum interval for each maintenance task that can mitigate each failure mode. Also, **levels of criticality** could be assigned to the consequences of failure, e.g. to allow assessing whether functions that are not critical to be left to 'run to failure', while other functions that are more critical may have to be preserved at all costs. Failures caused by unlikely events, e.g. non-predictable acts of nature, etc. could receive no action provided their risk is trivial or tolerable (ALARP).

Finally, in the sample RoSE analyses provided, optimum asset replacement intervals are not considered (i.e. analysis of the trade-off between failures, preventative and reactive inspection/maintenance, and renewals). For a more thorough discussion about this please refer to section 4.11 (Whole-life Systemic Approach).

4.6.4 Safety risk management

Even though Network Rail has an overarching target to reduce safety risk by 3% by the end of CP4[11], there is no specific target for the RoSE project to improve reliability and reducing safety risk by doing the right maintenance. Network Rail responded that it is difficult to set specific improvement targets by asset or failure mode, because it is difficult to measure or distinguish the impact the new RoSE regimes have on reliability and safety due to several other initiatives being implemented at the same time.

To assess the consideration of safety risk by the sample RoSE analyses provided by Network Rail, we compared them against the requirements and guidance as set in the following documents:

[11] CP4 Delivery Plan Update 2011

- The Yellow Book
- Guidance on the preparation and use of risk assessment profiles
- Risk Profile Bulletin v6

Also, the applicability of the Railway Safety Risk Model (SRM) and supporting templates (representing 120 hazardous events), developed and supported by RSSB, was evaluated, as governed by the 'Guidance on the preparation and use of risk assessment profiles'. Network Rail stated that the RoSE project has not made use of the Railway Safety Risk Model because is too high level to support the RoSE analysis, and RoSE can tap into the more detailed risk models available at the depots by the S&TMEs, and via talking to the expert engineers.

According to the Yellow Book and the 'Guidance on the preparation and use of risk assessment profiles', a risk should be reduced to a level that is as low as reasonably practicable (ALARP) via a practical and effective ALARP demonstration. The guidance also notes that most risk assessments, particularly for hazardous events of low frequency with potentially high consequences, require a level of risk quantification or ranking. As this has the potential to become overly detailed and sophisticated, the guidance emphasises that the qualitative aspects of the risk assessment and the dissemination of this information throughout a company provide the most significant potential benefit from the risk assessment.

According to RoSE, safety failure risk is assessed by the RoSE analysis on the basis of tolerability rather than cost. Network Rail justified that this is done on the basis that signalling maintenance interventions are not sufficiently expensive (i.e. have short duration) to warrant detailed analysis of safety costs, due to the fail-safe design of the vast majority of signalling equipment. Network Rail said that only a small number of tasks drive maintenance frequencies and many of these are related to safety.

When questioned whether this means that safety risk is being reduced to ALARP, Network Rail responded that usually, failures at Network Rail are either 1 in 1000 years, i.e. very low frequency, or very often, so there is no point to try to accurately quantify their probability x consequence, i.e. calculate the safety risk. However, as already mentioned earlier (see Table 2), the sample RCM2 decision worksheets reviewed do not capture the magnitude and criticality of the failure consequences of each failure mode (i.e. in what way does each failure matter), and hence does not provide sufficient evidence that safety risk is reduced to ALARP by the selected maintenance tasks and frequencies.

On the other hand, because the RoSE project has so far appeared to have been following a low risk approach in setting the new task intervals while maintaining in most cases the existing maintenance specifications, and provided safety has been properly considered by the RCM2 workshops based on expert judgment, it is anticipated that there will not have been any adverse impact on safety risk so far. Until now the only available evidence for this is the initial draft RoSE implementation review, showing no adverse impact on reliability since the implementation of RoSE regimes (see section 4.9.2).

Also, the lack of historic failure data at failure mode level within Network Rail would mean that any accurate quantification of risk based on statistical analysis would be difficult, if not impossible. Furthermore, the use of statistical analysis on historic failure data to determine the most appropriate failure management policy may not be of value for failure modes that are very rare and may have not happened yet (Resnikoff 1979).

However, this does not mean that a qualitative analysis based on expert judgment or a qualitative risk ranking of the **potential** failure rates and consequences at failure mode level is not feasible. The proof that this approach can be followed is the recent S&C study that RoSE supported after the Lambrigg accident[12]. As per 'Guidance on the preparation and use of risk assessment profiles' (RSSB), a Fault Tree and Event Tree Analysis may be needed for 'high risk hazards and locations, and for situations where there is little operational data or understanding of a safety issue'. This is indeed the approach followed by RoSE for this S&C study.

4.6.5 Failure management (failure rate analysis and monitoring)

As part of the RoSE review, the use in the FMEA of historic data about past failures was investigated, aiming firstly to check whether they are used in assuring that known failure modes are not neglected as part of the FMEA, and secondly, whether they are used in the calculation of the appropriate maintenance task and interval as part of the RCM2 process.

The RoSE project noted that the FMS database records failures in a way that does not readily tie into RoSE, i.e. the FMS 'failure modes' are considered too generic for use in the RoSE

[12] Network Rail noted that phase 1 of this study used the RCM2 process and applied a fairly basic criticality analysis (even though that was not an RCM consequence analysis). This highlighted specific failure modes which required further investigation. Then, the Phase 2 of this S&C study involved creating logic diagrams (e.g. based on Fault and Event Trees) which looked at combinations of events/failures, and involved a Quantified Risk Assessment (QRA) with 1 to 5 probabilities for the top 10 to 20 failure modes, as well as combinations of failure modes. That study was handed over to the S&C team to influence the Design, and to be used for training purposes. The outcomes of the S&C study were reported to ORR in respect of Lambrigg. The recommendations are driving a number of activities within the S&C team, and the work is now being extended into other configurations of S&C.

FMEA. Network Rail provided two examples of historic FMS failure data used as part of RoSE analyses for level crossings and LV DC TC13, which illustrate the fact that failures have indeed been recorded at too high level by Network Rail, i.e. mostly at asset type level, and only in a few limited cases at functional failure or failure mode level. Hence, the RoSE project team noted that mainly due to the lack of sufficient historic data the FMS and SINCS databases are only used on an as-needed basis, but also, that this has limited use for RoSE purposes. For that reason, Network Rail insists that the RoSE analysis facilitators are experienced railway engineers specific to the discipline under consideration and internal to Network Rail, because they are better placed to overcome the lack of data than a facilitator with a more general engineering background.

RoSE highlighted that current failure data is of limited value in determining inspection/maintenance intervals. Also, when available, failure data is just used as a back check to any assumptions made during the RCM2 workshop. RoSE noted that for hidden failures modes, failure rate data is needed to calculate failure finding task frequencies, as per Moubray (1997). However, Network Rail also noted that fortunately these are rare in signalling, as signalling assets have few hidden failures. Also, this data is very hard to come by according to Network Rail. One example was provided[14], where the external help of Mutual Consultants was used to sense check rough reliability data for TPWS as provided by Thales in relation to a hidden failure mode (failure to detect a fault), due to lack of experience with that particular asset type within Network Rail. RoSE said that a significant margin of error is included in these cases to allow for any data inadequacies.

As another example, according to the RoSE analysis for FPL Testing Frequency Rationalisation[15], FPL adjustments have not been recorded robustly so far by Network Rail, hindering failure statistical analysis to assist with the RCM2 process. However, the FPL RoSE analysis made use of a ‘unique’ source of adjustment data from a database covering the Doncaster area to undertake statistical analysis to assist in confirming characteristics of points which relate to more frequent adjustments. According to RoSE, this statistical analysis was undertaken to test aspects of “received wisdom” that relate to the need for FPL adjustments. That statistical analysis, according to RoSE, established that there is no statistical relationship between FPL adjustments and number of point operations, tonnage or high line speed. Based on this, RoSE concluded that a mechanism which relates testing frequency to **asset condition**

[13] AHB Failure Breakdown for 2010.pdf, Breakdown of LV TC FM by Route.pdf

[14] TPWS Trackside equip rel.pdf, Network RailGC03 TPWS FiFi.pdf

[15] FPL Full report v1.pdf

would enable Network Rail to adequately manage the risks associated with points' deterioration. It would also provide an additional incentive to rectify the underlying failure cause, thus reducing points' failures.

Finally, failure monitoring is not currently part of the RCM process followed, as this is considered by Network Rail to be part of wider asset management, with other interventions being applied depending on the level of risk, as defined by the combination of failure rate and cost per failure.

4.6.6 RoSE decision logic as part of implementation by the DU

The RoSE analysis is producing specific criteria for the applicability of the new maintenance regimes for each asset type, including exclusions due to asset configuration, condition, or environment. These requirements are then being included in NR/L3/SIG/10665 part A & B. The RoSE project team noted that feedback from the DUs is that the presentation of the maintenance requirements in this standard is liked and understood. RoSE mentioned that if feedback from users identifies an opportunity to change the presentation to better meet their needs, then changes will be introduced.

In addition, for the FPL Testing Frequency Rationalisation, the RoSE analysis has produced a step by step methodology and supporting flow charts for the DUs to apply, which requires them to take into account recent equipment failures and adjustments done as part of regular maintenance in setting the appropriate maintenance intervals and prompting an investigation of the underlying cause for the failure or adjustment. A summary of this logic is shown in Diagram 7. For further details about this new maintenance regime please refer to Appendix 'RoSE FPL Testing Frequency Rationalisation'.

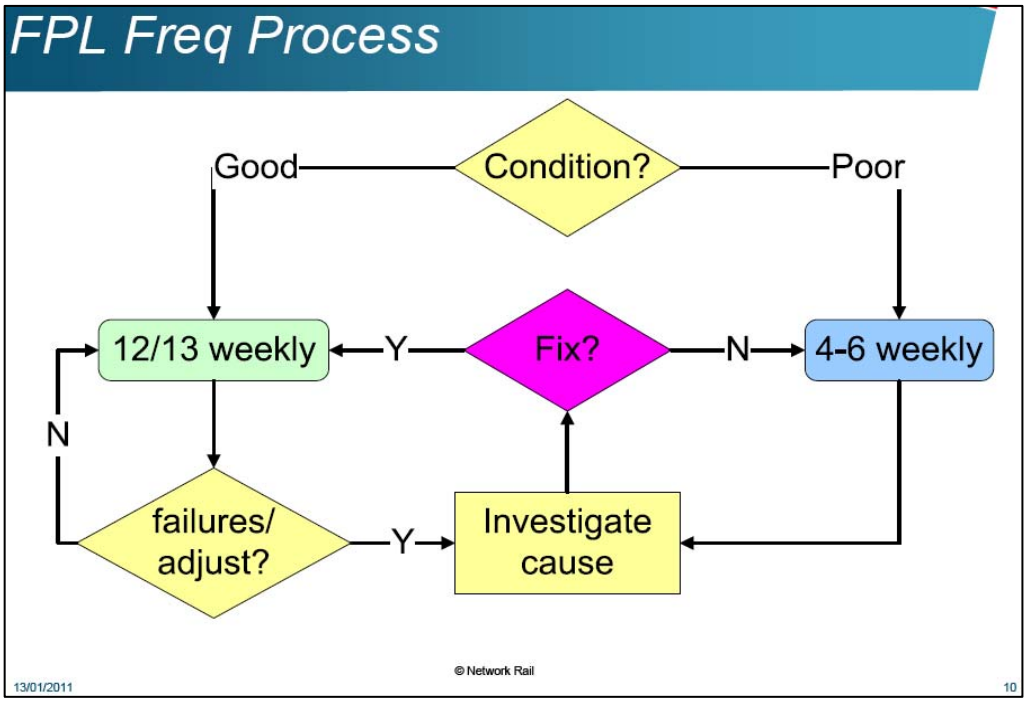


Diagram 7 FPL Testing Frequency Rationalisation

The RoSE review explored the use of failure rate monitoring in helping DUs to identify the need for preventative replacements if failure rates are increasing, in lieu of a measurable parameter for condition monitoring. However, apart from the FPL Testing, failure rate monitoring has not been added so far in the new maintenance regimes developed by RoSE. Network Rail suggested that failure rate monitoring is viewed as simply a means of prompting the DU to consider the change in reliability and, hopefully, to notice an improvement. According to the RoSE project team, the section manager/S&TME will notice a change in failure type/rates before it is reflected in the data.

4.6.7 Technology assessment

The RoSE analysis is assessing the need for new tools and equipment for inspection and maintenance, including the use of remote condition monitoring (a part of the Intelligent Infrastructure project). The technology assessment arises as part of each individual failure mode analysed, and usually when what is technically feasible is being discussed. These requirements would be logged as a 'redesign', which can be redesign of the asset, the person (via training), or the process (in terms of tools and information).

However, facilities requirements have not been assessed so far by the RoSE analysis. For example, this could include an assessment of the adequacy of the location of depots. Network

Rail noted that this is one of the other factors that are out of the current scope of RoSE that needs to be considered in the future.

4.6.8 Need for new types of assets

RoSE has not yet assessed the need or opportunity for new types of assets. However, according to Network Rail there are discussions underway between RoSE and the RAM teams to identify how the RoSE analysis could be used to influence scheme design, i.e. by highlighting configurations and conditions which would enable reduced levels of maintenance. However, this is still in early stages of debate with the S&T RAM teams. RoSE noted that this will also link to work to identify more radical changes to maintenance, most of which will require equipment modification or the use of remote condition monitoring.

4.7 RoSE Implementation Methodology

The RoSE implementation is the work that the DUs carry out, and it starts when they get a copy of NR/L3/SIG/10665 produced by the RoSE project team and an asset list from Ellipse, and ends when the revised work order appears on the handheld.

According to NR/L2/SIG/10662, which specifies the process for introduction of new or revised maintenance regimes for signalling assets, the S&TME is responsible for the project management of the implementation of the new regime at a depot, while the maintenance support engineer from the RAM team is responsible for ensuring that the correct maintenance regime is being applied to the correct assets in Ellipse and that asset classification is correct. The requirements in this standard are summarised in Diagram 8. According to Network Rail, the S&TME and the RAM maintenance support engineers have the knowledge of the local assets and the local asset condition, so they are best placed to manage the implementation process.

Further guidance on the RoSE implementation at depots is being provided in NR_GN_SIG_10670. This guidance requires all new RoSE regimes to have been authorised for pilot or full implementation by the relevant Professional Head, which for signalling is the Professional Head for S&T. It also notes that the RoSE project team can provide support for ‘many aspects’ of implementation. NR_GN_SIG_10670 also requires the preparation of an implementation proposal by the S&TME, which has to be signed by the RAM according to this standard. This proposal should include roles and responsibilities, scope of implementation, brief risk assessment on implementation risks, briefing/training arrangements, implementation date, and finally, Ellipse changes (i.e. asset lists and new frequencies). An example of an

implementation proposal is available on the Network Rail Knowledge Hub, which can be used as a template.

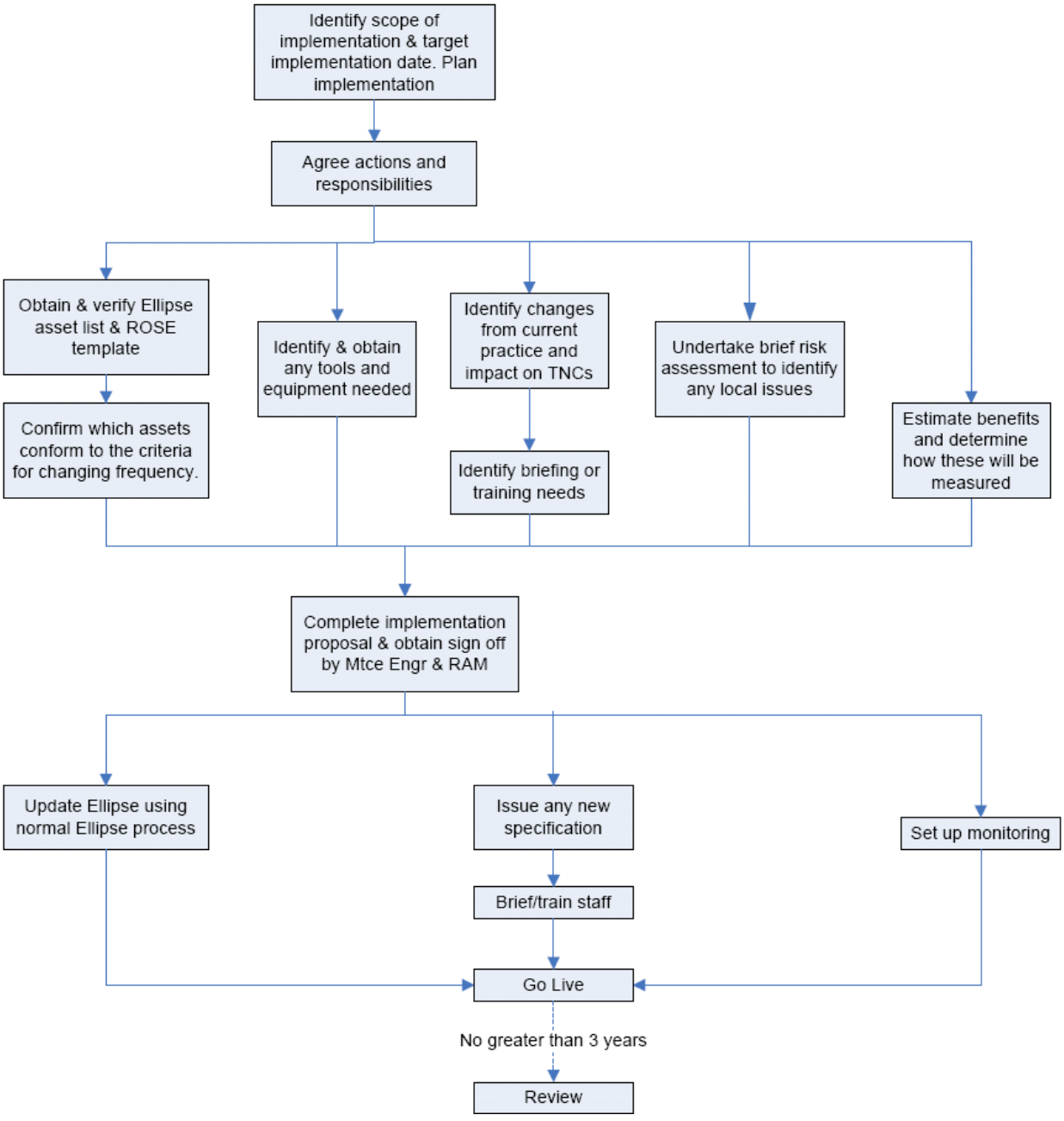


Diagram 8 RoSE Implementation Process[16]

Network Rail provided two sample authorised implementation proposals[17] which approved a pilot implementation for signals at Warrington Bank Quay depot from 15th of April 2010, and for

[16] NR/L2/SIG/10662, Issue 5

[17] Warrington ROSE.pdf, FPL Test pilot implementation at Newcastle area – paper copy

FPL Testing at Newcastle area (Tyneside IECC) from 12th of December 2009. Both documents appear to fully comply with the requirements as set out by NR_GN_SIG_10670.

According to the DU maintenance engineers, approval of RoSE regimes has only been given after sample checking (with the use of local knowledge) to check the validity of the assessment documentation produced by the DU. However, they pointed out that not all assessment documentation has been produced for approval from some DUs, even though the Ellipse recording system shows that assessments have been produced. They also conceded that this may have resulted in material issues not having been reported which either should have delayed implementation, or would benefit the review of the RoSE analyses.

One of the S&TMEs interviewed questioned the role of the RAM organisation in approving the ROSE implementations. In particular, he believed the RAM does not know the physical asset, nor does he understand Ellipse, and as such added little assurance to the overall process.

On the other hand, what we found as part of the site visits is that the RAM maintenance support engineer can provide invaluable support in terms of time and effort to do all the necessary work as part of the implementation process, including assessing the implementation criteria (e.g. for FPL testing frequency rationalisation), as the S&TME may not have enough time to devote to the RoSE implementations, which may cause significant delay. Finally, some DU engineers noted that each maintenance change has been reviewed personally by the RAM and challenged for more information or further work if deemed necessary. However, it was mentioned that the RAM organisation is also facing challenges meeting the workload, like the DUs, which results in delays to sign off the implementation proposals.

4.7.1 Prerequisites

NR/L3/SIG/10665 contains specific prerequisites by asset type, mainly including checks or basic maintenance tasks to be undertaken prior to RoSE implementation. In addition, for the FPL testing frequency rationalisation the standard specifies a new methodology to be followed by the DUs to determine the appropriate frequency for the FPL test depending on the failure / adjustment history and the underlying asset condition of each specific point, as already discussed in section 4.6.6.

4.7.2 Risk assessment on implementation risks

According to Network Rail the brief risk assessment on implementation risks is simply a sense check to verify that the DU has the time and resource to undertake the regime change, and also that there are no major issues (e.g. a big re-signalling that will render the changes pointless). If

there any issues of this type then the implementation would stop at that point so there would not be any paperwork. Network Rail stated that there is no value in the DU having to revisit the detailed risk assessment work that has already been done by the RoSE project team, as that would massively increase the project cost. According to Network Rail, the RoSE project does the risk assessment as part of the RoSE analysis (as required by NR/L2/SIG/10662), and that covers all depots. So, there is no need for the depots to repeat that risk assessment.

However, it was found as part of the site visits that the implementation process of the new FPL testing frequency rationalisation requires the S&TME to undertake a detailed assessment of the failure/adjustment history and underlying asset condition of each point, and then to apply their engineering judgment to assess the risk associated with each point (safety and service) to decide what is the right inspection frequency. According to the RAM maintenance support engineers, this also entails taking into account **asset criticality** parameters such as the 'Through Route Line Speed', as well as interacting with the P-way engineers to investigate underlying causes of poor condition which may not directly relate with S&T but with P-way assets.

4.7.3 Staff briefing

NR_GN_SIG_10670 requires a full briefing to all staff involved with the delivery of the RoSE process before the implementation. RoSE briefings and updates are being done in various ways, such as technical briefings, Connect bulletins, and internal publications (Aspects and Frontline Focus). Two sample staff technical briefing exercises were provided for review by Network Rail[18], which have been prepared by the RoSE project team. These appear to be well prepared and to adequately highlight the key reasons behind RoSE and the anticipated benefits.

Also, the ex-DU engineers interviewed appeared to confirm that the technical guidance/training has been adequate and sufficient, and is well documented and communicated. Moreover, they noted that the RoSE project team have always been able to provide guidance, support and clarification when requested. RoSE also noted that for the main briefing document to be presented within each DU, the DUs pick the relevant assets applicable to their depot area to present across the maintenance team. In terms of communicating the potential benefits and risk of implementing the revised maintenance regimes, the DU engineers believe that all safety and risk elements were well conveyed and shared throughout the RoSE programme.

[18] ROSE briefing for 10665 issue 4.pdf, FPL testing v2.briefing.pdf

The DU maintenance engineers interviewed identified that the level of awareness of relevant DU staff of the purpose, approach and benefits of RoSE varies across different levels of staff within the depots, but they think the management staff are well aware. Also, briefings and regular updates within each DU are taking place. They also believe that the understanding of RoSE within DUs is also considerably 'influenced' in differing degrees by cultural factors that can shape perceptions. One of these factors is that some technicians view RoSE as a cost cutting exercise. However, the DU maintenance engineers see RoSE quite positively and believe it has been long over due.

Network Rail noted that because of timing issues with the briefing cycles, the implementation reports do not always contain the briefing record. Provided briefing is completed and recorded this is a minor issue according to Network Rail. Briefing records are held by the DU[19], and now that RoSE is well understood, it is being incorporated in routine briefs (i.e. is becoming part of business as usual). Many DUs also display RoSE progress and information on the DU notice board[20].

Furthermore, ex-DU engineers mentioned that maybe further briefings should have been undertaken when staff had been promoted into new supervisor and management roles. However, even though this was offered by RoSE, not many DUs have taken the offer up. Finally, they believe that the level of competence implementing RoSE is continually progressing, while it has provided an opportunity to start focusing on quality maintenance including a better understanding of the equipment. Also, it has prompted a concentration on safety and reliability elements that are important in keeping the assets fully operational between maintenance services.

4.7.4 Ellipse changes

Because the Ellipse side is 'standard Ellipse', no further guidance to the two standards has been issued, although there is some basic guidance on the Ellipse aspects within the following documents:

- NR/L2/AIF/001 – Asset data management
- NR/L2/MTC/02020 – Ellipse for Network Rail Work Management

[19] Briefing Tyneside RoSE.pdf

[20] Briefing Document Newcastle STME 2010.pdf

The implementation work in Ellipse is usually done by the Works Planner, but in some DUs the ROSE Champion has sufficient competence in Ellipse that they can prepare the script in parallel with the assessment.

According to Network Rail, the RoSE Project Manager had in the early days of RoSE spent time with the signalling DUs talking them through the process and, based on the early implementations, the RoSE Champions were also trained enabling them to lead the work at each DU. When DUs have specific questions then they get in contact with the RoSE project team.

The DU engineers identified that the Ellipse database could be used to record and hold assessment issues regarding the RoSE implementations, so that changes to assets or RoSE regimes could be more easily implemented at future dates. Examples provided are type of cells in locations cases, and type of track feed set and track relay, which are issues that are needed for assessing against the RoSE exclusion criteria. DU engineers also noted that the implementation process involves many tasks with sub-components that require action by different people, with no standard mechanism to get visibility of how the process is going or which stage prompted issues. Also, the process does not include following up or reviewing actions prior to the assessment for implementation, and neither does it include tracking them after approval is given. The DUs suggested that the RoSE implementation should be managed through an Ellipse process, where the implementation can be managed and reviewed by the DU System Support Manager (SSM), with ownership by the discipline engineer.

4.7.5 Modification of Implementation Schedules/Plans

NR_GN_SIG_10670 requires the DUs to identify new scheduling opportunities, for example, where a service is moving to 26 weeks, to check whether it would be preferable to do all the assets in the same maintenance periods or to spread the work over all 4 periods. The review found that DUs are just starting currently to try rescheduling maintenance. RoSE provided one example[21] where rescheduling was tried by Woking DU, and the following diagram shows the benefit that they claim to have achieved.

[21] Woking DU presentation.pdf, Realising the benefits.pps

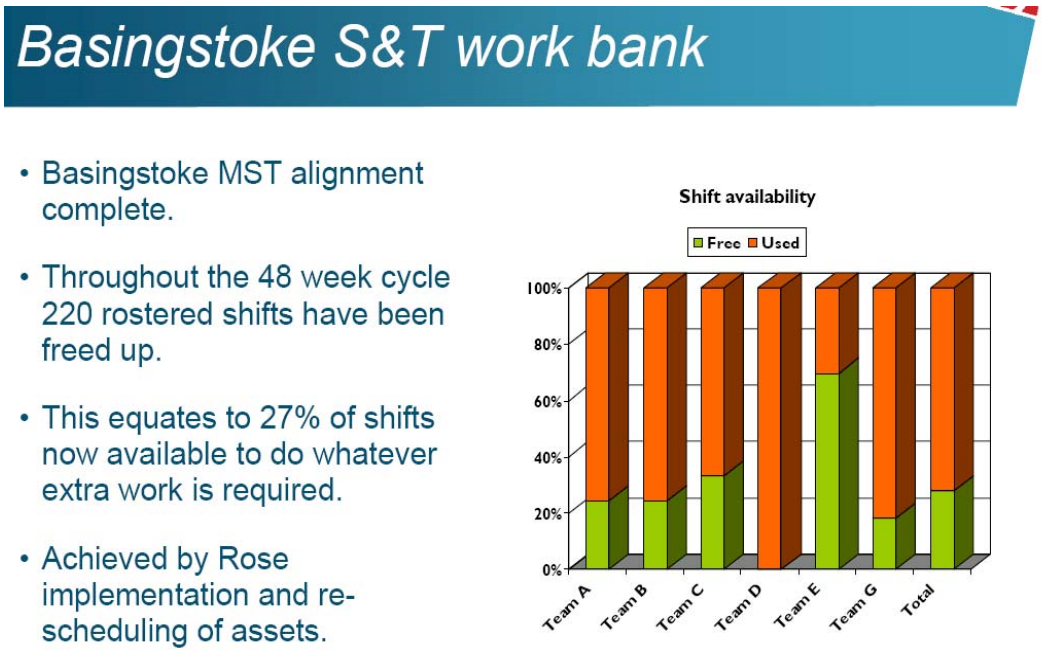


Diagram 9 Example of Rescheduling Time Savings from RoSE Implementations

This case study claims that the 27% of shifts were freed up and that was almost entirely due to the realignment of maintenance to take advantage of the savings offered by ROSE. Network Rail said that it was carried out to allow the DU to undertake other work, for example some of the Capex work vital to Network Rail.

However, what was found in the site visits, is that alignment of Work orders is not being done in a systemic way at the moment, and that maintenance teams don't find the weekly planning system particularly user friendly. Ellipse is used to produce weekly maintenance plans, and then the maintenance teams have to work out the actual plan on the ground. We believe that there is a need to empower local DUs and maintenance teams to be able schedule maintenance work more efficiently.

Finally, when the RoSE implementations result in doing maintenance at longer intervals, which is the case for the majority of the assets, the DU maintenance engineers interviewed mentioned that changing the maintenance schedules to 'release' time is complex and time consuming for the DUs, and because the RoSE implementation is perceived as a one-off task, it has to compete with other delivery unit priorities for management time. In addition, according to the DUs the RoSE implementation process requires skills in different parts of the DU which are not part of the 'steady state' cyclic maintenance regimes that DUs tend to run. For there two reasons, there are some areas where RoSE is recorded as being 'fully assessed' but the actual implementation levels are still low, when they could be much higher. RoSE noted that another team within Network Rail has been developing an approach to assist rescheduling maintenance,

although at present this does not meet the needs of the RoSE project. RoSE noted that they are trying to influence that work.

4.8 Asset Information and Prioritisation

4.8.1 Asset prioritisation and selection

Asset type prioritisation in developing new maintenance regimes is being done by RoSE according to:

1) Workload associated with the asset type;
2) Non-productive time (worth doing if RoSE already makes changes to the maintenance regimes for other nearby assets);
3) Regulation or recommendations;
4) Reliability concerns expressed by the RCM2 workshop facilitators, who have access to reliability data, as well as from the Professional Head of S&T. The RoSE analysis can also help understand the reliability variation among asset types; and
5) When the DUs can make a team available for undertaking the FMEA.

The RoSE asset prioritisation also takes into account requests from the DUs to help with the understanding of specific failure modes through the FMEA (for example the RBJ FMEA).

The DUs interviewed identified that most maintenance time and effort is being spent on points which, apart from the FPL testing, have not been analysed by RoSE yet. Also, the DU teams expressed their concern that it will probably be difficult to do any change to the maintenance of points, such as extending the maintenance intervals, due to the high potential safety risk and subsequent justification required.

Finally, the NR/L3/SIG/10665 standard has specific selection criteria for the applicability of the new maintenance regimes developed by RoSE, and in several cases it offers an explanation for the reason of exclusions. Also, there are specific prerequisites for ensuring, or even improving asset condition before applying the new RoSE regimes.

4.8.2 Asset information to determine appropriate cyclic maintenance

According to good practice, the asset information that should be used to determine the appropriate variation of cyclic maintenance for each asset type, as well as for each individual asset, includes:

- Asset Type / Configuration,
- Condition,
- Location: Usage and Environment
- Task Duration / Maintenance Cost,
- Maintenance history,
- Historic record of Failure Rates & Downtime,
- Safety hazards,
- Performance risks,
- Condition monitoring data, either collated via manual surveys or remote condition monitoring.

Asset Criticality is a term frequently used in asset management, which as defined by Network Rail is the performance impact if an asset fails. Network Rail also considers usage as part of asset criticality, i.e. reflecting the potential impact on performance. The RoSE project has stressed that the RoSE analysis and implementation for signalling does not use asset criticality because it is believed that this does not affect cyclic maintenance. However, RoSE identified that for analysis of other asset types the worth doing calculation is likely to be more significant, and in that case Schedule 8 data by route section could be obtained to represent criticality in terms of performance risk.

In our opinion, asset criticality should also include safety risk and the whole-life cost for maintenance and renewal of an asset. For individual assets, this should reflect the current asset condition and configuration, as this influences both the amount of performance and safety risk and the required maintenance to meet the asset's operational requirements (i.e. required availability). As discussed in section 4.5 (RoSE Process), the current approach followed by RoSE does not include a quantified evaluation of the magnitude and significance of risk (safety and service performance) and cost. On the other hand, RoSE already considers asset condition and configuration as part of the implementation of new maintenance regimes, but due to difference in terminology, it is not being referred as 'asset criticality'.

The new maintenance regimes developed by RoSE for signalling assets allow variation of maintenance mainly based around **condition**, **configuration** and **environment**. For other asset types, different factors may be more relevant. As per the implementation process and criteria in NR/L3/SIG/10665, RoSE modified intervals and specification consider **asset type**, **condition** (results of inspection as per TIs), **environment**, and also, **failure history** (including **adjustments**, e.g. for FPL). RoSE has stated that this source of variation allowed by the new

maintenance specification provides a mechanism to deliver improved asset reliability by providing an incentive for a DU to address identified causes of unreliability in return for reduced maintenance workload. For example, NR/L3/SIG/10665 specifies for the FPL Testing Frequency that 'once the initial selection and implementation has been completed, the selection criteria shall be reviewed as the asset condition changes'.

ROSE noted that the asset information about the individual asset configuration and condition needed to vary maintenance on the ground is generally available at DUs, albeit from a variety of sources (paper, some IT systems, and via local knowledge), and when not readily available, site visits are performed to get this. So, this information has to be gathered by the DUs to enable implementation. This presents Network Rail with an opportunity according to RoSE; if, having collected this info for RoSE, Network Rail collates and maintains that data in one location, whether local spreadsheet or national system, it would be of use for other purposes (reliability improvement, planning modifications and minor renewals etc.).

As noted earlier, **usage** information (and asset criticality) is not directly taken into account as part of RoSE for signalling. According to Network Rail, the ROSE analysis has shown no link between usage and reliability for the majority of signalling assets (see section 4.6), and even on S&C & Level Crossings it only applies to a limited number of failure modes. So, usage may not prove to be the frequency driver (for example, RoSE noted that it is not a driver for FPL testing). Also, RoSE indicated that where remote monitoring is available, this could be used to improve understanding of failure/degradation rates. Until this is available, a relatively cautious approach is taken, particularly where safety or major service affecting failures are concerned.

It is important to note, that when the ROSE approach is applied to other assets, such as track, then usage would probably need to be monitored and used to define the appropriate inspection/maintenance intervals, as well as all other relevant variable factors that drive maintenance task/frequency. However, according to Network Rail, asset condition will always have to be the main driver for setting intervals.

In terms of **environmental** conditions, NR/L3/SIG/10665 allows for applying shorted intervals when necessary, for example as written by the standard for SL35 signals, 'this change in frequency is not applicable to signals in hostile/dirty environments'.

In NR/L3/SIG/10665 there is consideration of assets without **remote condition monitoring**, and no extension of intervals applies in some cases.

4.8.3 Asset information systems – RoSE analysis

NR/L2/SIG/10662 specifies that the information gathered through the RCM2 workshops and any subsequent investigations shall be recorded on the **RCM Desktop©**[22]. Apart from the RCM Desktop©, no other information systems are being routinely used by the RoSE analysis. Network Rail stated that this is due to the fact that the RCM2 workshop preferentially uses engineers' experience and knowledge.

However, the **FMS, TRUST** and **SINCS** databases are used by the RoSE analysis on an as-needed basis, but as discussed, Network Rail has stressed that this has limited use for the RoSE purposes. According to Network Rail, one of the reasons for selecting the RCM2 process was that it fits Network Rail's situation where there is wealth of expertise, but rather poor asset degradation data. Hence any gaps in data have not limited RoSE too much, as the RCM2 workshop facilitators are experienced railway engineers specific to the discipline under consideration and internal to Network Rail, and this has allowed the RoSE analysis to deliver some of the potential benefits sooner, rather than waiting for when complete data may become available. According to Network Rail, this has also helped define what asset degradation data need to be collected in the future, which should help to avoid spending unnecessary time and effort to collect data no value

When data are collated as part of the RoSE analysis (e.g. number of failures), this is included in the relevant RCM2 analysis worksheet for each failure mode or, in the case of a significant additional item of information[23], this is added into the analysis pack.

One important finding as part of the site visits is that asset criticality, as discussed in section 4.8.2 earlier, is not currently adequately available in Ellipse. So, if and when the RoSE scope is extended to take into account asset criticality, then there is a risk that this will require a significant amount of work to collate this data and load it in Ellipse to enable implementation.

4.8.4 Asset information systems – RoSE implementations

As part of the RoSE implementations, the **Ellipse** database is being utilised to manage and record RoSE implementations by the DUs. Before October 2009 a Job Description code was being used to change an asset from the old maintenance regime to a new RoSE regime. This was changed in October 2009 by the DQUIP project, and the new asset level process is

[22] www.rcmdesktop.com

[23] E.g. Cable Testing Report Issue 01.pdf produced by ATKINS

described on the MESD website. The controls for changes within Ellipse use existing processes, and therefore there is no additional risk due to the RoSE implementations. The technical detail in the maintenance record cards is being changed with the introduction of RoSE, but there has not been any change in the way they are used. The Knowledge Hub in Network Rail's intranet is used to distribute the main RoSE documents.

In terms of the adequacy of existing IT systems and asset data, Network Rail stated that the implementation process was developed to work within/around the existing IT processes, and therefore it does not limit the implementation process. Where DQUIP and RoSE address the same asset, the DQUIP design incorporates instructions for RoSE. Network Rail identified that there are opportunities to improve the reporting of ROSE implementations, but at the same time the Asset Information department said that they are not aware of any planned improvements or past improvements to address specific RoSE requirements. The RoSE project responded that even though there has not been a specific Asset Information workstream for RoSE, improvements are being discussed as part of other initiatives.

The DU engineers highlighted that there are sometimes not sufficient data in the existing Network Rail systems to assist with the evaluation of assets against the RoSE implementation criteria, which usually requires timely site visits to gather this information. However, due to resource availability and other priorities at the DUs this usually delays the implementation process. For example, the DU engineers noted that in location cases the types of batteries at some sites were not listed, which is what determines whether or not the new RoSE regime could be implemented.

Network Rail also highlighted that implementing RoSE actually results in asset data improvement as a 'by product', as it identifies where there is a discrepancy between the asset on the ground and the data in Ellipse (for example where Ellipse shows a GPL to be a filament type, whereas the actual asset is an LED GPL) and requires this to be corrected before ROSE is implemented. In addition, the new specification for the FPL testing requires that maintenance teams to record all adjustments to points as a prerequisite, which in the past was not necessarily been properly recorded.

Furthermore, for RoSE regimes such as the FPL testing frequency rationalisation, the S&TMEs check whether facing point ends have had 3 or more repeat failures before implementation of the new regimes, and if yes then they are not RoSEd and they are put under monitoring after remedial work. Then, they are reviewed and if no repeat failures occurred they are RoSEd. The

systems used by DUs to assist with checking the presence of repeat failures are the National League Tables and Ellipse which holds defects and the resulting work banks).

Finally, a very important improvement to support both the RoSE analysis and implementation would be to improve the recording of failures within the FMS by using appropriate **Failure Coding** on the handhelds that relates to the FMEA failure modes. This, according to Network Rail and the DUs interviewed, will depend on the available technology and will probably require upgrading/renewing the existing handhelds. Recording of failures by Failure Mode should help relate historic failure data to the specific failure modes of the FMEA undertaken as part of the RoSE analysis, and in this way support the on-going review and improvement of FMEA and maintenance regimes. However, the RoSE project believes that the RCM2 workshop will always be more helpful to extract the tacit information that cannot be captured by FMS.

4.9 Implementation and Realised Benefits

4.9.1 Progress of deployment

According to Network Rail[24], Ellipse records show that there are about 260,000 signalling assets (excluding sub-components). Out of those, about 4% (10,000 assets) are unlikely to be assessed under RoSE due to their small population and the fact that they are obsolete assets with minimal workload. Hence, approximately 250,000 signalling assets are considered 'RoSEable', i.e. likely to be worth analysing using RCM. The following two diagrams illustrate the progress of the development and implementation of new maintenance regimes by the RoSE project for signalling assets.

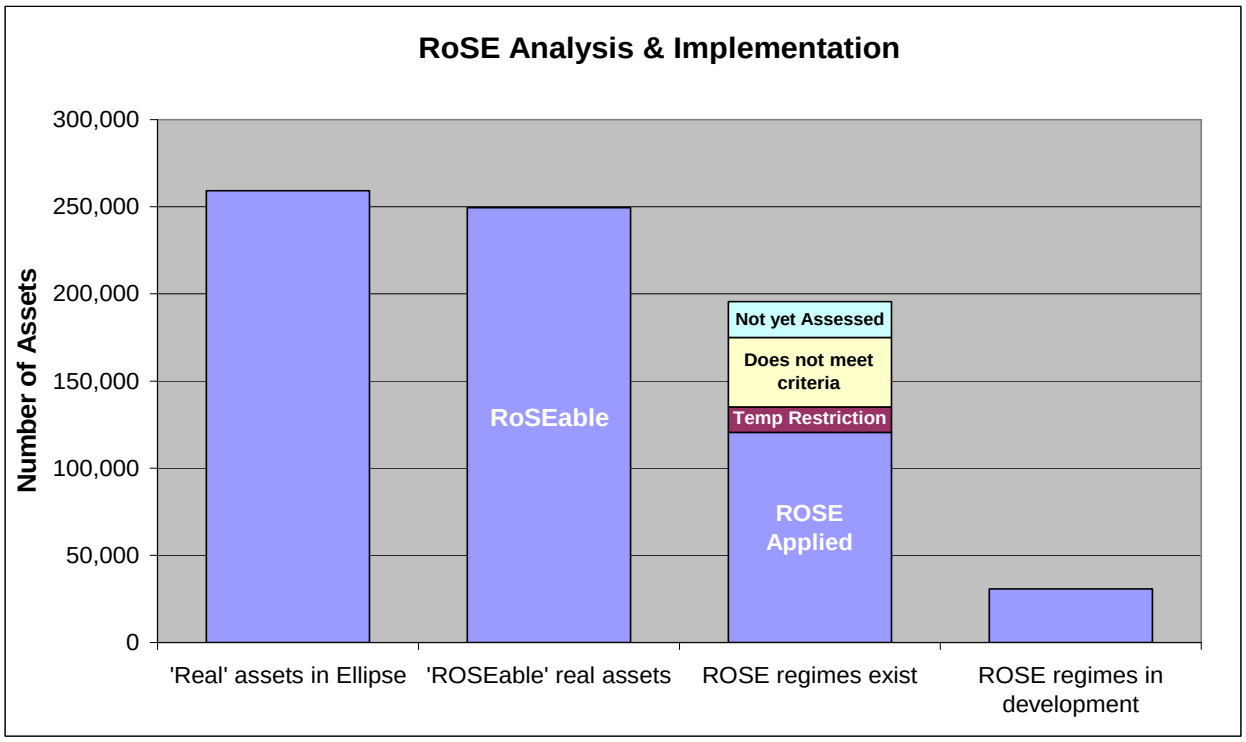


Diagram 10 RoSE Progress

The terms presented on the above diagram are explained below:

- 'RoSEable' refers to assets that can be analysed under RoSE. Some small population/low maintenance assets will not be subjected to ROSE analyses.
- 'RoSE Applied' refers to assets that have been assessed against the application criteria (as set out in NR/L3/SIG/10665) and a new maintenance frequency/regime has been applied.

[24] The ROSE Project 101113.pdf, ROSE Implementations 07-03-2011.xls

- 'Temp Restriction' refers to those assets that have been assessed against the application criteria but cannot currently move to RoSE, which is typically because some work is required on the asset. However, some DUs have also used this to signify that the analysis is in progress.
- 'Does not meet criteria' refers to assets that have been assessed against the application criteria but do not meet them in order to move to a new frequency.
- 'Not yet assessed' refers to those assets that have not yet been assessed against the application criteria.

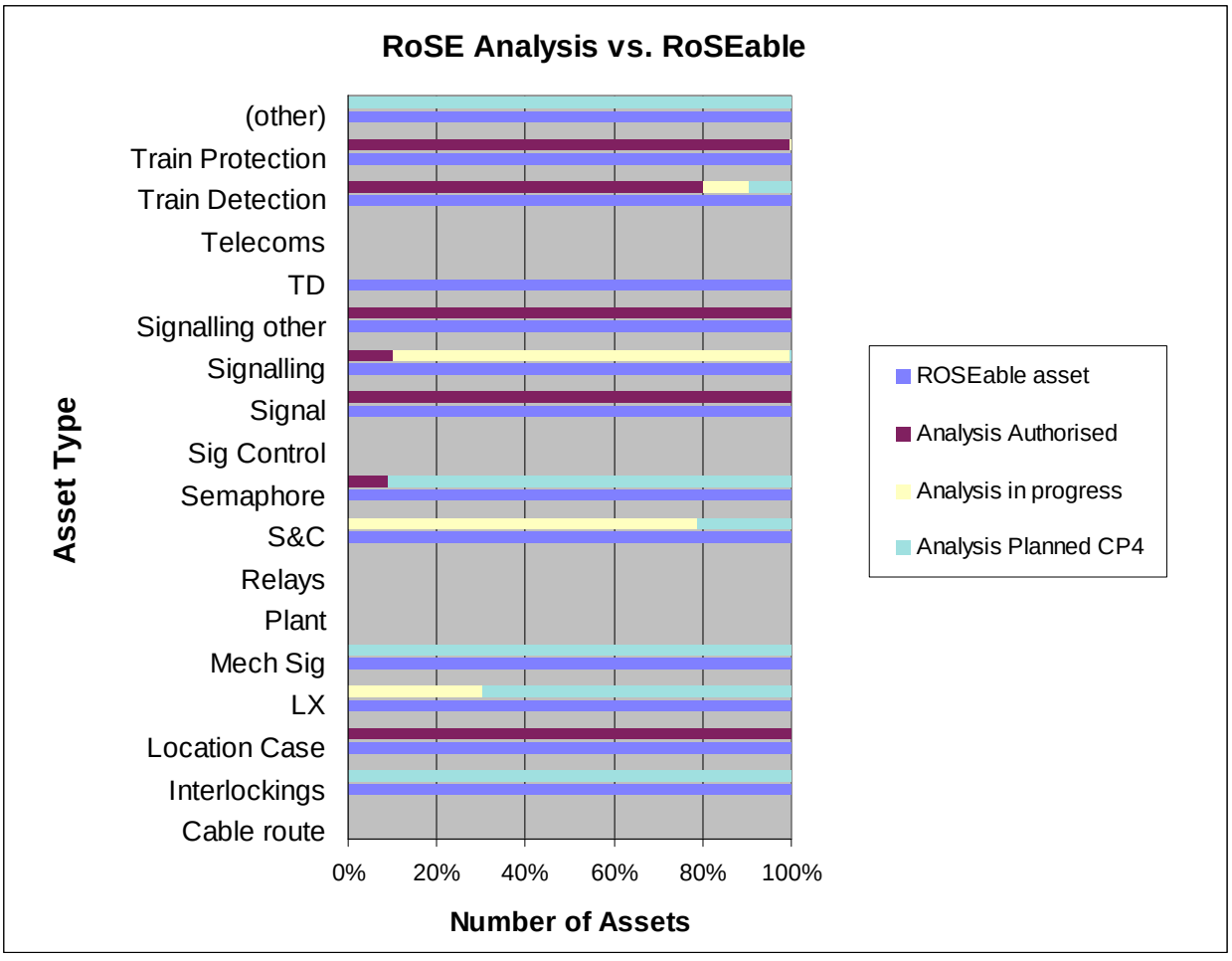


Diagram 11 Progress of RoSE Analyses vs. 'RoSEable' Assets

As of the 18th of March 2011, RoSE analyses have been authorised for approximately 195,500 assets, or 78% of RoSEable assets. Out of those assets, 48% have had new maintenance regimes authorised (identified as 'RoSE Applied'), although some of the authorised regimes have only just been published or will have been published by the end of March 2011, so DUs would not yet have started to implement. Furthermore, 6% have had a temporary restriction applied to them during the implementation process by the DUs and 16% have been categorised

as not meeting the RoSE criteria, so the existing maintenance regimes continue to apply to them. Work in progress also accounts for another 12% of the total assets. For the remaining 8%, Network Rail noted that they are likely to be analysed, but this will be reviewed for each asset type prior to starting work, as the Ellipse data are not completely up to date.

Network Rail noted that assets identified as 'RoSE Applied' in Ellipse have actually had revised maintenance regimes applied on the ground. However, the DU engineers highlighted that the ‘RoSE applied’ entry in Ellipse does not automatically change the frequencies in the MST, and so, the actual application on the ground only happens when the MSTs are manually updated. Furthermore, according to the DU engineers the actual application of RoSE is less than that measured as being assessed or authorised, due to timing differences between the time that the new RoSE regimes are being authorised for implementation and when the DU engineers believe is the right time for the new maintenance intervals to be incorporated into the maintenance schedules, and also, the significant time it takes to incorporate the new intervals into the maintenance schedules. These assets are included in the ‘RoSE applied’ figures in Diagram 10.

As part of the RoSE implementation process, the majority of ROSE regimes to date were authorised as pilots to allow Network Rail to withdraw any regimes if problems emerged. The following diagrams provide a better view of the progress of implementation by Route, as well as by asset type.

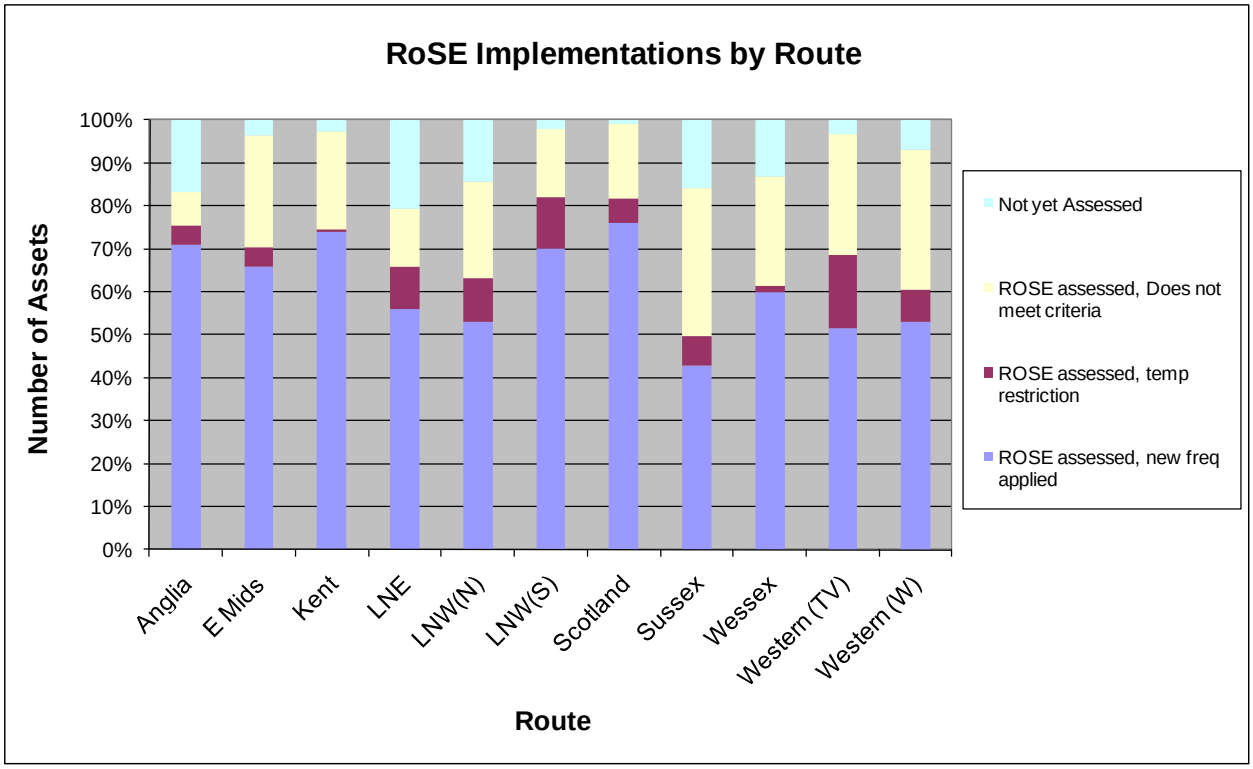


Diagram 12 Progress of RoSE Implementations by Route

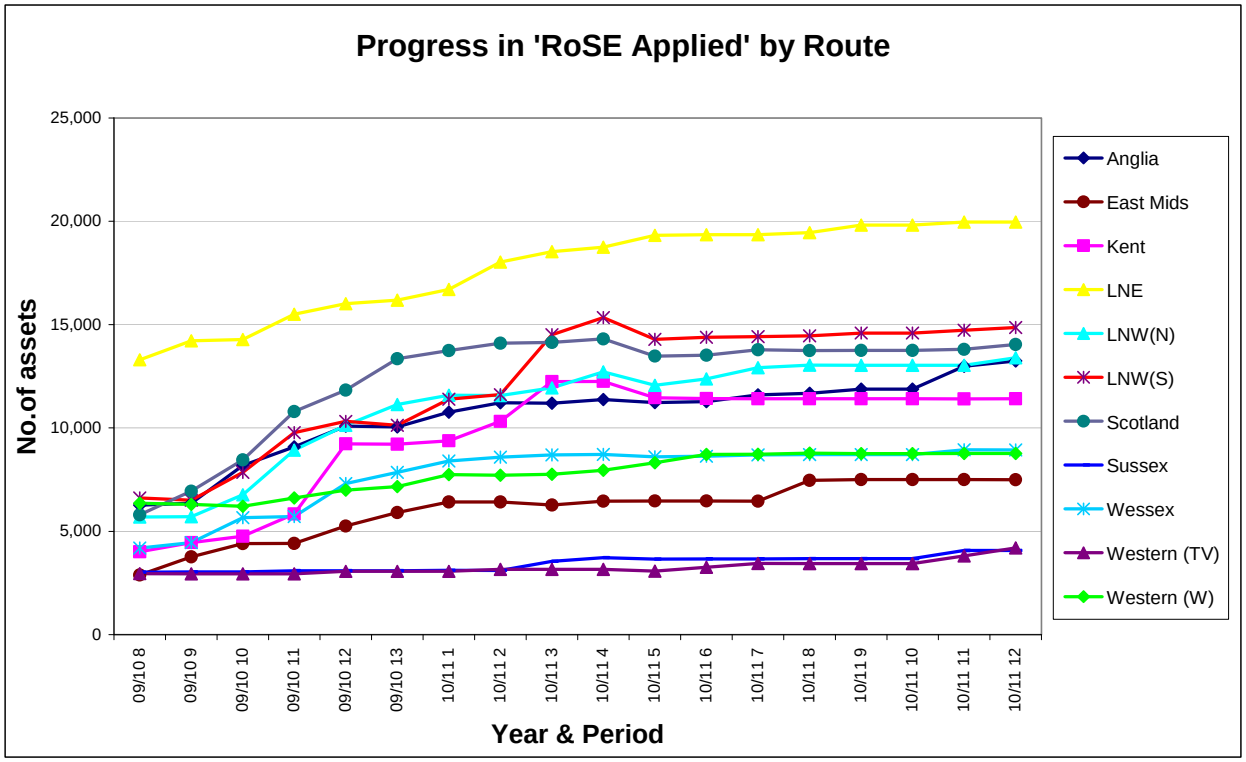


Diagram 13 Progress of 'RoSE Applied' by Route

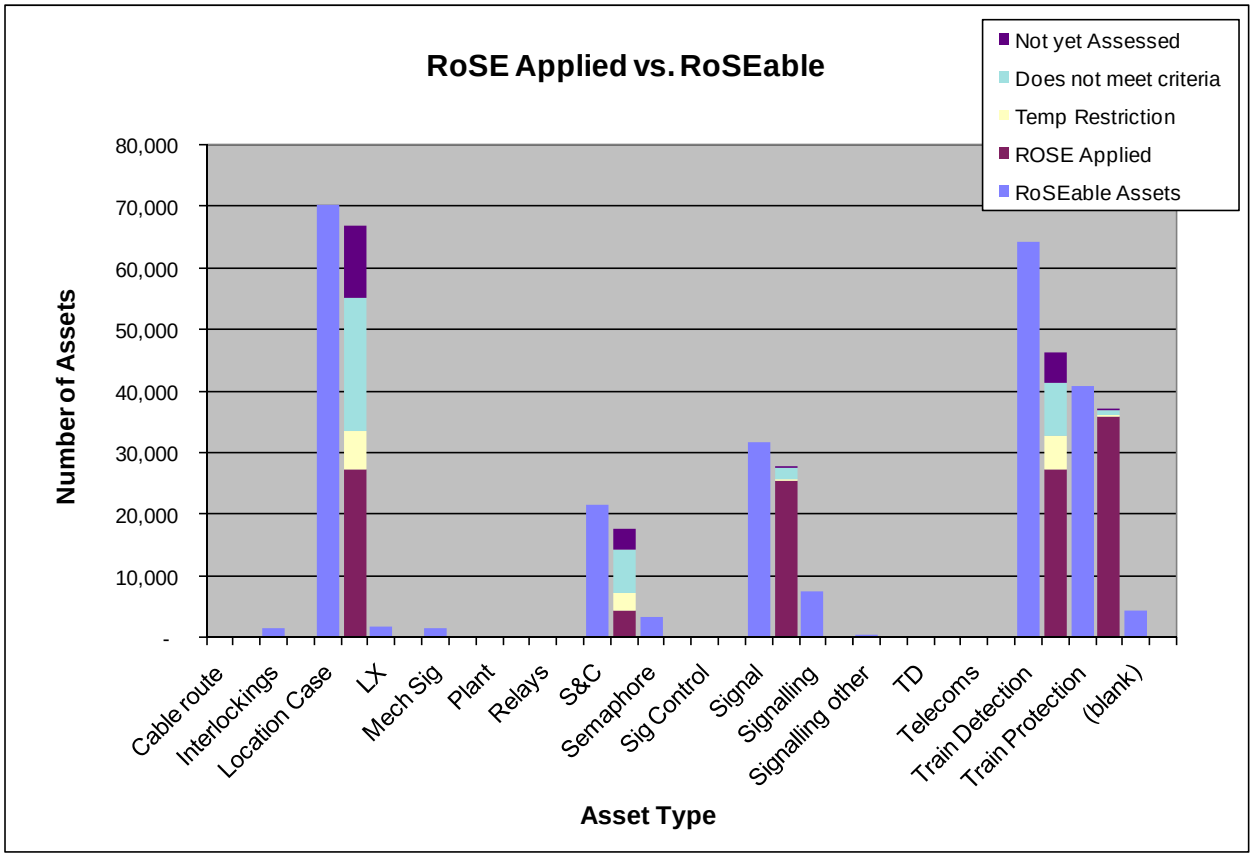


Diagram 14 Progress of 'RoSE Applied' vs. 'RoSEable' Assets

The DU engineers interviewed broadly believe that the speed of developing new maintenance regimes has been about right. On the other hand, it was also identified that although the staggered development and implementation is better than doing too much too soon, some new maintenance regimes such as the new FPL testing regimes for bullhead rail should have been produced at the same time as for non-bullhead rail.

The RoSE project has been using a high level project plan to manage the RoSE analyses that are in progress or in planning stage, which for the small size of the team so far may have been adequate. However, there has been no formal Gantt chart or detail forward looking plan for the development and implementation of new RoSE maintenance regimes. Again, the main reason according to Network Rail has been the lack of resources for the RoSE project. Now that the team is expanding, the RoSE project is looking at the best way and appropriate effort for planning and monitoring the RoSE analyses.

In terms of actual implementation on the ground, the DUs manage implementation locally. According to Network Rail this allows them to adapt to local opportunities and priorities. Again,

the RoSE team has not had enough resources to plan and manage the RoSE implementations centrally.

In trying to assess how the current progress of ROSE development and implementation compares to the baseline plan, the RoSE team noted that they do not have a 'baseline', although, as noted earlier, at the initial stages of the project an estimate was made that ROSE would only be viable on a few signalling asset types. However, to date RoSE has been applied to the majority of signalling assets.

The delay in expanding the RoSE team means, according to Network Rail, that RoSE probably is about 20 to 24 months behind of where it could be for signalling and S&C, and about 15 months behind where it should be for Telecoms and E&P. The RoSE project team believes that the project is probably about a year behind the assumptions that were included in the workload projections for CP4. These projections were being used as an input to the remaining CP4 projections, with ROSE being a part of the overall Network Rail strategy and also an enabler for other activities and benefits.

4.9.2 Benefits realised

Network Rail has reported[25] that overall there are several direct benefits as a result of undertaking the RoSE analysis and implementing the new regimes, such as:

- Change in workload arising, mainly from a change in maintenance frequency;
- Improved reliability due to more appropriate maintenance tasks;
- Improved railway safety due to reduced asset failures;
- Improved staff safety by reducing maintenance services and therefore time on track;
- Improved understanding of assets and their maintenance needs;
- Improved productivity arising from reduced travelling and other non-productive time where applying RoSE removes some maintenance visits on a specific section of track; and
- Improved line capability where implementing RoSE allows maintenance to be rescheduled to make better use of track access and staff time/skills.

Also, Network Rail reported that derived benefits arise via other workstreams and are enabled by RoSE:

[25] The ROSE Project 101113.pdf

- RoSE implementations form part of the 'go-live' criteria for 2BC. Therefore RoSE contributes to the 2BC savings. The DUs confirmed that a minimum level of RoSE implementations was a pre-requisite of 2BC for them.
- Improved reliability where reliability improvements work (e.g. improving asset condition, modifications) are undertaken within time released by reduced maintenance requirements
- Improved asset whole life cost where the analyses are used to identify modifications which will further improve reliability or reduce maintenance requirements

Specific projections for the above expected improvements have so far only been produced for the 'time on tools' savings (refer to section 4.4). However, no realised benefits have been formally reported yet. The only realised impact since the RoSE implementations currently under preparation for reporting[26] is the reliability trends over the last few years for a few of the assets that had RoSE regimes implemented on them (AWS, DC TC, Signals), aiming according to Network Rail to identify any adverse trends or, improvements in reliability. However, this draft review report highlights that due to the number of initiatives which affect reliability both directly and indirectly, its findings could not be taken as an indication of cause and effect. Neither does the report provide realised impact on workload, because according to Network Rail it is not possible to monitor workload changes directly. In particular, other changes to the recording of work in Ellipse mean that it is impossible to produce a direct before and after workload comparison. Only changes in theoretical workload are reported in the RoSE implementation report (see earlier a section 4.9.1).

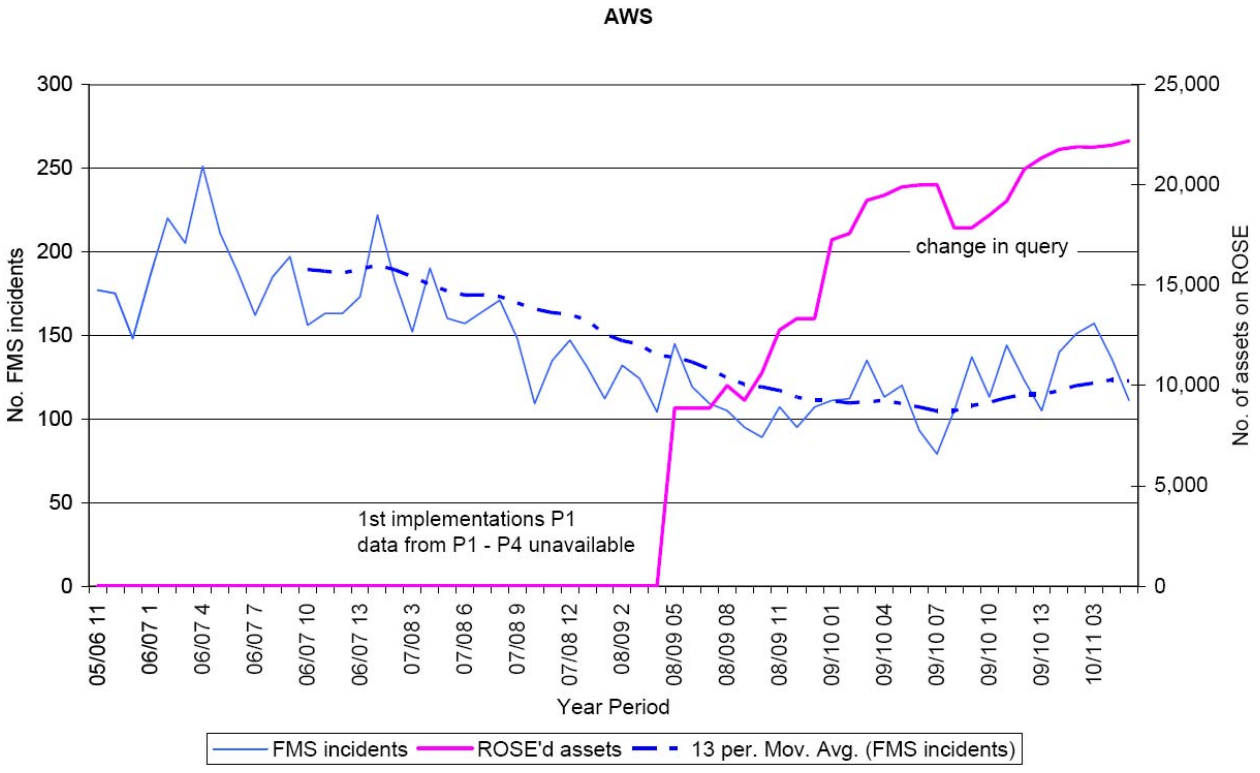
On the other hand, according to Network Rail, RoSE (along with changes in how rapid response is managed) has delivered workload savings that have been a major contribution towards a reduction in signalling headcount as of 1st of April 2011 of about 10% compared to June 2009, after the recent 2BC re-organisation. These workload cost savings as a result of RoSE are not directly tracked as part of the Transformation Programme, but whey will be reported in the Annual Return as a reduction in employment costs for maintenance. It is worth noting that the 2BC re-organisation, which was about rationalising utilisation versus available resources, has affected all DUs. One of its outcomes was the number of S&TMEs to be reduced from 56 to 40. According to Network Rail, RoSE has helped to justify closing the 56 to 40 realignment.

The above mentioned draft review report[26] highlights that the majority of the RoSE regimes to date have been authorised as pilots to allow Network Rail to withdraw any of the regimes if

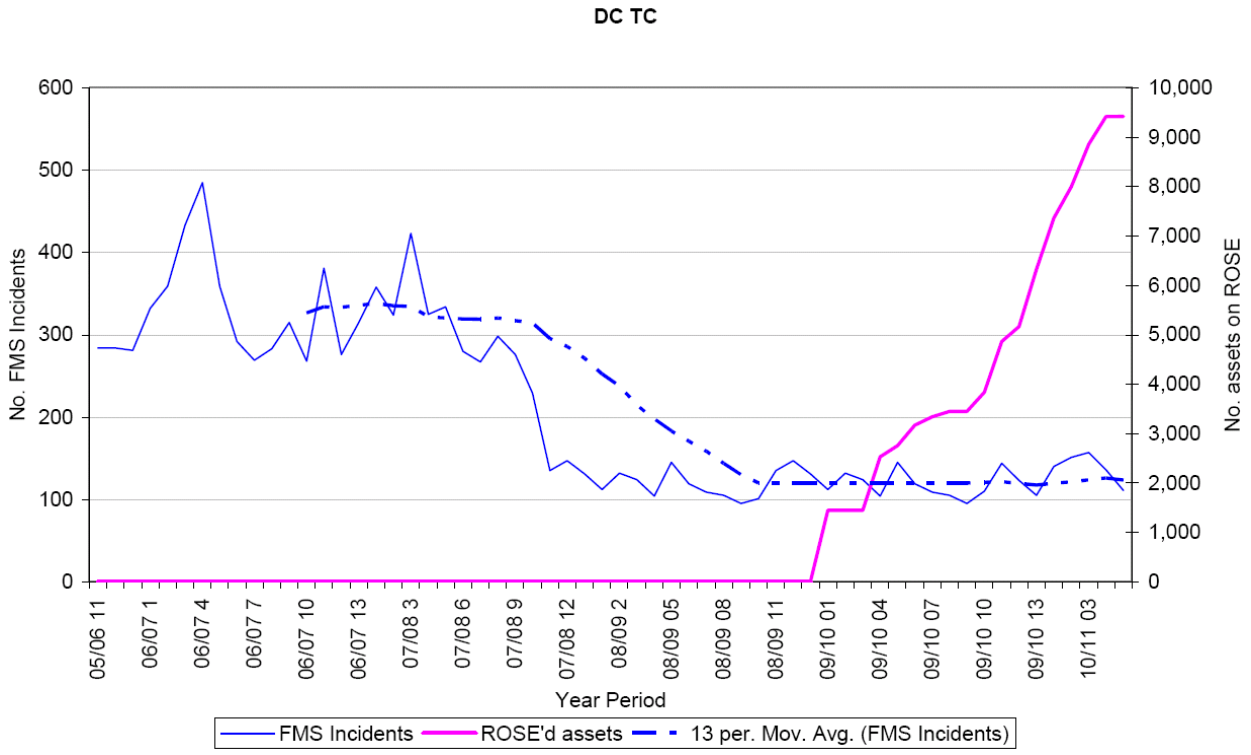
[26] RoSE Reviews.pdf

problems emerge. An analysis is included in the report of the reliability trends extracted from the FMS database and which can be seen on the following Diagram 15.

The RoSE Project report[25] issued by Network Rail to support this audit states that 'the small team size and high demand for the project to deliver whole life cost benefits meant that a low risk approach needed to be adopted'. For example, the new FPL Testing Frequency Rationalisation logic allows going to 12/13 weekly maintenance from 4-6 weekly, even though maintenance intervals could possibly be extended even further. In particular, the RoSE analysis for the FPL Testing Frequency Rationalisation[27] notes that 'FPL testing is currently undertaken at a variety of frequencies, with little rationale for the frequency at any particular installation'. This could mean that the selected 13 weekly interval as the upper bound for FPL testing is based on legacy practice within Network Rail with no direct justification in the RCM2 analysis.



[27] FPL Summary report.pdf



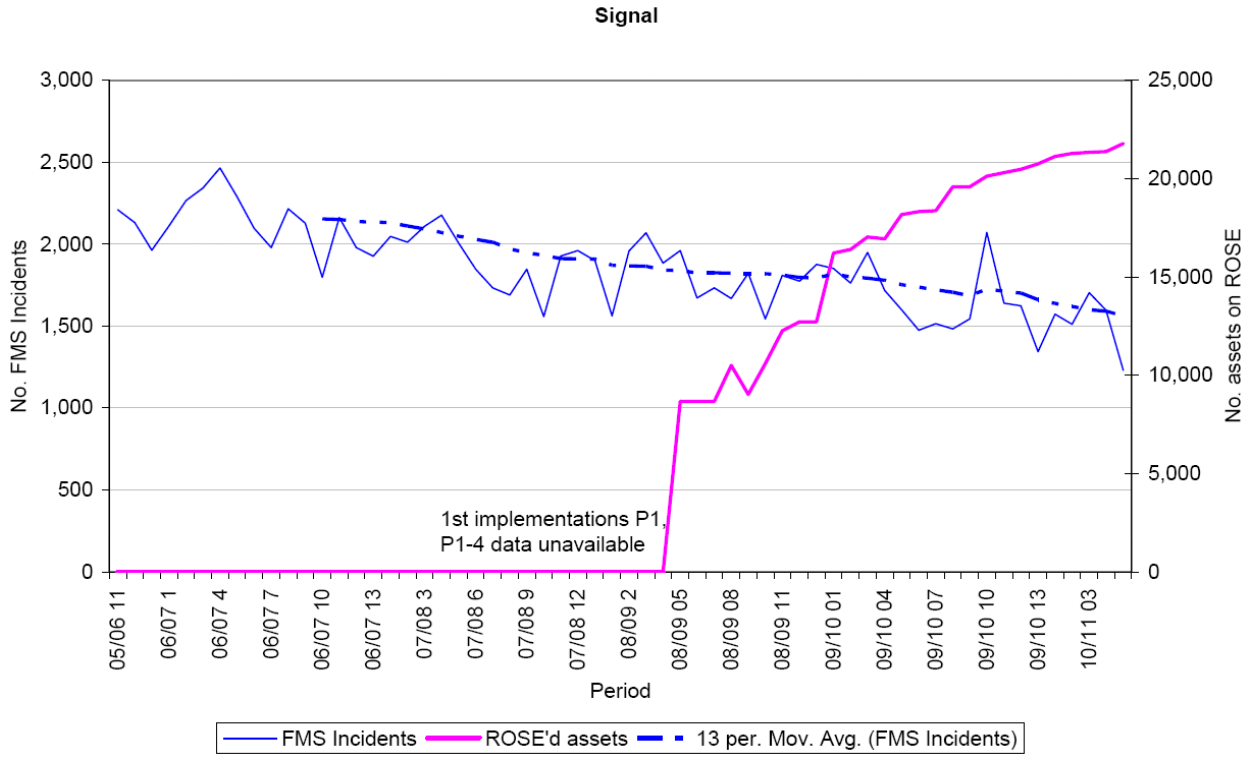


Diagram 15 Reported Reliability Trends since RoSE Implementations

In Diagram 15 an improvement in reliability since the implementation of RoSE can only be seen for Signals. However, as Network Rail has conceded too, it cannot be taken as an indication that it is a direct result of RoSE due to the number of other initiatives. For AWS there is an apparent worsening in reliability, but according to Network Rail this reflects changes in SINCS reporting criteria and external causes such as damage sustained during P-way works and cable theft.

Impact on safety risk is not directly reported, but Network Rail reported that it can be implied by the identification that there has not been any decrease in reliability as reported in the above report. The report shows an improvement trend in reliability based on the FMS failure database, a trend that did, however, start about two years before the implementation of the new RoSE maintenance regimes, and which appears to have flattened in the last year apart from signals. This trend, as noted above, does not show any definitive correlation with the RoSE implementations.

Network Rail has stated[25] that no adverse safety impacts have been identified so far by the introduction of the new maintenance regimes. In addition, at the interviews with the Headquarter stakeholders and ex-DU maintenance engineers, as well as the discussions at the site visits with the Maintenance Teams, no identified adverse impact on safety has been reported so far.

The DU maintenance engineers have expressed that RoSE has indeed delivered the qualitatively identified benefits it claims, including better use of scarce maintenance resources, less unnecessary time spent on track and more of the work being planned for green zone activity. The DUs also expressed their view that RoSE had managed to implement what has been known in the rail industry for years, i.e. that, in some cases, railway assets do not need as much maintenance as Network Rail has been undertaking. It was also mentioned that RoSE has resulted in less maintenance backlog, which in turn results in less pressure on the team delivering. Finally, DUs mentioned that when assets meet the exclusion criteria for safety related failure prevention this identifies the need for asset change/renewal.

Furthermore, the DU engineers noted that RoSE has allowed maintenance teams to find time to start doing more asset condition improvement work, in terms of corrective activity and repairs. The RoSE implementations have also identified workstreams to improve asset condition in order to enable more of the new RoSE regimes. They also believe that asset performance has remained stable and has shown signs of improvement. Finally, it was mentioned that the asset assessment and verification process as part of the RoSE implementations has resulted in better understanding of the asset types on the ground, and improved asset data quality in Ellipse.

However, the DU engineers interviewed highlighted that the benefits realised after the implementation of RoSE have been limited. This is mainly due to implementing RoSE on one asset at a site but not yet implementing RoSE on other co-located asset types. Therefore, until all the assets at a 'site' are RoSE'd the benefits will always be somewhat less than expected. For example, if a location case has been RoSE'd but the maintenance team is still going there to maintain a track circuit at a lesser frequency, then the potential benefits have not been optimised yet. Also, it was mentioned that even though points with non-bullhead rail have been moved to 13 weekly FPL testing intervals, the DUs still have to go to the sites for only a small number of end of points that are bullhead rail type and which are not yet within the scope of RoSE. So, subject to authorisation, these assets will move to the same maintenance frequencies as for other rail types providing a significant saving in non-productive time which is anticipated to be significantly larger than the time on tools saving.

The theoretical time on tools saving of about £4m per annum achieved to date (see section 4.4), does not take into account that effect. However, according to RoSE, the benefits that the ex-DU engineers are referring to is the reduction in non-productive time (e.g. 'time to site' travelling time). Non-productive time savings has not yet been reported by RoSE as a benefit, because the best way to measure this would be through productivity and that measure is affected by many other factors. So, RoSE wanted to avoid double counting or suggesting that RoSE is delivering all of these benefits and hence fail to give credit to all the other value-adding initiatives. Equally, RoSE did not want to generate any expectation that benefits were higher than were realistically achievable prior to the full roll out of RoSE. Network Rail agreed that ROSE benefits will not be fully realised until:

- All assets on a stretch of track are ROSE'd and all relevant assets moved to new regimes;
- Any assets which can't change maintenance frequency are repaired or renewed; and
- The maintenance schedules have been realigned by the DU to release time.

The DU engineers noted that there are many configurations of equipment within the generic asset types that RoSE have analysed which could have reduced or increased frequency based on specific asset configuration and detail. As an example, a 'location cabinet' can range from a brand new cable only termination location in good condition, to an older location with more equipment where inspection is required. In the RoSE regimes developed so far there is little differentiation within some asset types. The same applies to usage of point operating equipment, and some types of signal head according to the DU engineers.

Finally, one of the DU engineers interviewed expressed his view that there is great benefit for assets that have just been renewed which has not being looked yet at in terms of a greater business benefit. He referred to the opportunity for a 'Super RoSE' regime, which could justify a Network Rail policy to invest more money in the renewal of its assets when this is supported by the cost savings of reduced maintenance. As this would require all snagging items from a renewal scheme to be resolved before it can be applied, for example for a low maintenance RoSE regime for suitable asset types, then this could be the driver to achieve resolving snagging items much faster.

4.9.3 Management and DU commitment

Network Rail stated that there are no major cultural barriers within Network Rail that would hinder gaining further benefits from RoSE. Its more just a case of people understanding that maintenance can change over the life of the asset and being geared up to adjust this. Initially, may DU staff were very nervous about extending frequencies at all. Now many DU people and Headquarters engineers are complaining that the RoSE team have not changed maintenance enough.

Furthermore, the RoSE team mentioned that it has been important for the project to communicate to the DUs that RoSE is not about increasing maintenance intervals, but about doing the right maintenance. However, although the new RoSE regimes use the existing SMS format for signalling and it is easy for the DUs to take up, when there is a requirement to reduce the maintenance intervals (e.g. from 1 year to 6 months) then there is an issue for the maintenance engineers to get the extra work fitted in to the maintenance schedules. For example, the RoSE analysis for FPL testing has identified the potential issue with compliance from DUs where the new maintenance regime could increase their workload, stating that DUs which stand to reduce workload are more likely to apply the new criteria than depots where most points are currently tested at 13 week intervals. The strategy by the RoSE project is to have a few publicised increases in workload to help pass the message across all DUs.

However, some of the DUs interviewed as part of this audit stated that perception about RoSE across DUs is influenced by cultural factors, and they think that this causes delays in the implementation of the new RoSE regimes. For example, it was noted that in the case of the FPL testing that has been done every 13 weeks under the former IMC practice and was considered adequate by the DUs, changing that to more frequent testing under the new RoSE specification can be viewed as an unnecessary change by them. The reason for that, based on ex-DU engineers interviewed, is that the move to a RoSE regime, which is a company standard, can be

seen as a challenge to existing regimes, due to general pride in them and a sense of local ownership due to past involvement stretching back to former IMC/Railtrack and British Rail. At that time, the former IMCs had more locally written processes and variations. Finally, it was noted that not all DUs staff have a sense of 'ownership' of RoSE and some view it as 'imposed'.

4.9.4 Human factors and effectiveness of implementation

There is a need for the DU teams and the RAM maintenance support engineers to spend a lot of extra time to do the asset classification according to the new ROSE maintenance regimes, which in some of the regimes involves adjusting the maintenance intervals according to current condition. One of the most onerous regimes is the new FPL testing frequency rationalisation regime, which requires a lot of additional time and effort by the relevant DU managers to assess initial selection criteria and monitor ongoing condition. This implementation effort is required in addition of the 'day job'. Also, the data required to assess asset condition against the requirements of the RoSE implementations is not always readily available, and site visits are often required. Due to resource availability and other priorities, this usually delays the implementation process. In addition, the DU signalling engineers mentioned that to implement the new FPL testing they require information from P-Way to assess the underlying asset condition, and some of them identified that P-way teams could be slow in managing and providing that data.

It was also mentioned that there are times that there is not always sufficient understanding of what is required before making an implementation submission to the RAM (see section 4.7, RoSE Implementation Methodology). The DU engineers think that this is either due to not clear requirements in the RoSE specifications, or due to misinterpretation by the individual making the submission. They believe that this could be resolved by sitting down with all parties concerned and coming to a clear understanding on what is required.

In terms of the aspects of human factors considered in deriving and implementing the new maintenance regimes, Network Rail noted that the opportunity for human error to cause a failure or to fail to resolve a failure is picked up in individual failure modes. Maintenance regimes issued to date are similar in presentation, format, and requirements to the Red Book, which was a deliberate approach to minimise risk, and given the small RoSE team make the project viable. It will be more of an issue where RoSE changes how maintenance is done, e.g. greater use of remote condition monitoring etc.

One other factor that Network Rail is exploring is how the presentation of maintenance specifications can be improved to make it easier for maintainers to do exactly what Network Rail

need them to do. Network Rail are exploring what can be achieved with the current handheld, but also considering what could be done with that constraint removed (this was at an early stage of development and was not yet ready for demonstration).

Network Rail mentioned that they have not seen any evidence of human factor issues that could result in the actual time savings from the new maintenance regimes to be less than those theoretically possible. Network Rail did state that some DUs have given implementation a lower priority than other DUs. However, realistically this has to do more with delays in rescheduling maintenance to reflect the ROSE regimes. The main reason for this delay is the 2BC reorganisation (i.e. according to Network Rail it wasn't sensible to reschedule the maintenance prior to the implementation of 2BC).

Also, RoSE does have a champion at each DU who can help to raise awareness of the project. Initially RoSE offered each Champion an RCM course and an additional 'RoSE course' where cultural barriers and ways to address them were discussed. Once 2BC has finished, RoSE intends to revitalise this 'champion' role and extend it to other disciplines.

As part of the RoSE implementation by the DUs, any asset that fails the selection criteria in NR/L3/SIG/10665 stays at the existing maintenance frequency. These are shown in the RoSE implementation report as 'temp restriction' or 'out of scope'. Furthermore, local managers can elect not to apply the revised frequency (where it is lower that the existing), and a couple of examples are:

- North London Line - because a re-signalling was due within a year from when ROSE really started to roll out, the DU decided that it was easier to live with the 13 weekly maintenance on the old kit and to implement ROSE on the new assets.
- Carlisle DU - the previous S&TME decided to hold off applying ROSE for a while because of the significant change in usage with the VHF timetable on West Coast. They are now applying ROSE more fully as they have realised that the change in train service has had no impact on the applicability of ROSE.

The review also looked at whether there are cases where the DUs significantly modified maintenance frequencies, for example to make them fit with shift patterns, resulting in shorter intervals than those the ROSE project aims for, and hence not achieving the target savings. The RoSE project team said that there have been no such cases, as RoSE was specifically designed to fit around the 13 week roster pattern used by most DUs. Some DUs use a 12 week roster so are out by a week or two but that is understood to be the extent of the variation.

Finally, what has also been identified is that there is a major opportunity to link the RoSE implementations to **Minor Renewals**, so that renewal is planned before the maintenance intervals are extended. In many cases, this would be the enabler for implementing the new RoSE regimes due to the **poor asset condition** of many existing assets that hinders implementation. According to information from the DUs, this is a major constraint at the moment in realising the full benefits from RoSE, as there are many cases that only a few assets in a railway section that are in poor condition keep the maintenance team going to do maintenance to them more often than the new RoSE regimes would allow. This is exacerbated by the fact that DUs do not have dedicated budget to spend on improving asset condition to allow RoSE implementation to go forward. Hence, there is a need to improve planning of Minor Renewals on a location by location basis, through a justified Business Case that takes into account the local asset condition and the fact that it is the major enabling driver for the new RoSE regimes and the benefits of doing maintenance at longer intervals.

4.10 Review Process

4.10.1 Monitoring & Analysis

The progress of the RoSE analyses and their implementation across the railway network is being reported on a regular basis, as presented in section 4.9.1. In addition, RoSE is currently in the process of developing the first review report for a few of the most advanced implementations in terms of their roll out across the network, as discussed in section 4.9.2. This report will be extended in the future to the other asset types which have sufficient history since the RoSE implementations. However, most implementations have not yet run for sufficient time to trigger the local review as part of the RoSE implementation process. Finally, Network Rail noted that, the work for CP5 is going to review what has been delivered, and at the same time what enablers would allow further benefits to be delivered[28].

Apart from the above high level reporting of reliability by asset type, there is currently limited monitoring in place as part of the RoSE project of the realised reliability by function or failure mode, such as statistics for MTBF, MTBSAF, MTTR and downtime which could allow assessing the effectiveness of the new RoSE maintenance regimes in greater accuracy and provide feedback on areas for further improvement.

[28] ROSE review extension.pdf

Also, according to the DU engineers interviewed, even though the RoSE procedure requires a review after implementation of new regimes, there is still no guidance in the Standards on forms or formats, or the key factors to consider. For that reason they believe that there is no formal evidence that any review at DU level has been done so far, and when it has happened, they think their value will be different in each DU. However, the RoSE project noted that a review process has not been developed yet as until now it was not needed, but work has been underway on developing and testing a formal review process. In particular, RoSE has been developing a review process with the Newcastle DU which has recently been shared with other DUs and is going to be published in the next update of the RoSE maintenance regimes standard. This approach should result in a process that is pragmatic and easy to apply. It will also be easier to sell to other Routes and DUs as it will not be seen as an 'HQ creation'.

The DUs suggested that a nationwide review, such as a RoSE discussion forum, could include discussing issues around new asset types to add to RoSE, further improvements to the SMSs, ways to improve asset condition, and rescheduling issues especially where there are assets that cannot be RoSEd yet.

The DU engineers mentioned that apart from the Ellipse codes which are used to monitor the roll-out of the RoSE implementations (for example if an asset is not ready yet it is assigned as ‘Temp Restriction’ in Ellipse), there is no nationwide system to report technical details about these implementations. It was noted that review and feed-back is currently up to the individual S&TME, for example to give a call to the RoSE project team and discuss issues.

There are currently 3 monthly RoSE reviews that happen locally at the depots. Also, all team and technical meetings have an agenda item covering RoSE and the impact it is having on the equipment, highlighting whether it needs to be reviewed. When wrong-side failures are reviewed it is factored into the discussion whether RoSE influenced the incident. According to a few DU engineers, no faults have been attributed to RoSE so far. They also said that they believe the review could be based on a sample to get a feel for the effect of implementing RoSE.

4.10.2 Continuous Improvement

Most literature about bext practice RCM highlights the fact that Reliability Centred Maintenance is not a one-off or fit-and-forget approach. Rather, it should evolve with each asset, i.e. RCM analysis should be reviewed periodically, when there is:

- Change in operating context;
- Changes in asset performance expectations (functions);

- Unanticipated failure modes may have occurred;
- New maintenance techniques may have become available; or
- Different failure consequences over time.

Network Rail provided one example[29] showing one amendment made to a previously issued maintenance regime for location cases within NR/L3/SIG/10665. This amendment was done to address the exclusion of all location cases that are fitted with wet cell batteries, and to clarify which types of wet cell batteries with low maintenance needs can be included in the new RoSE regime. In addition, Network Rail noted that revisions have also taken place for the RoSE maintenance regimes for AzLM axle counters and TI21 track circuits.

As noted in the previous section, no formal review or 'lessons learnt' process exists at the moment. However, the DU engineers stated that there have been local reviews 12 months after the initial RoSE implementations, and even though there is no formal process to feed back their findings and issues to the RoSE project team they believe that the team is aware of what has happened at the DUs. Also, one DU engineer said that there have been sessions looking at how migration could be split into manageable chunks, which can help produce a model for future implementations, whether it is signalling, track or plant.

4.11 Whole-life Systemic Approach

4.11.1 Systems approach in RoSE analysis

Until now the RoSE project has followed a sub-system or equipment approach in developing new maintenance regimes. The same is true for the FMEA as part of the RCM2 analysis, which is done by Function, e.g. to prove absence of a train, and then identifying component failures that can affect this function. We believe that in the longer term, a systems approach should be the ultimate objective in the RCM analysis, as system redundancy or operational impacts may influence the optimum maintenance/renewal tasks and intervals. System redundancy is currently being considered in the FMEA by ROSE at a sub-system or equipment level only.

4.11.2 Systems approach in maintenance planning & scheduling

According to Network Rail, at the initial stages of the FPL testing frequency rationalisation, the Newcastle DU first saw the opportunity to extend maintenance intervals if no adjustments are required on a consistent basis. As a result, 90% of point ends could move to 13 weekly intervals

[29] loc extn.pdf

from 4 weekly, and in addition, an opportunity was identified to align P-way maintenance with signalling maintenance. However, there has been resistance in integrating maintenance activities across maintenance teams.

Network Rail provided as an example the Waterloo area, where due to limited access the FPL testing was already being done at 13 weekly intervals before RoSE was introduced, even though FPL adjustments were constantly needed due to an underlying P-way problem. This highlighted a cultural problem, where previously the P-way maintenance teams were leaving it to Signalling maintenance teams to do the adjustments, instead of looking at the points as a system. Currently, there is an integrated S&C focus in the Headquarters, but this way of thinking and working is still to be disseminated at the DU level.

In addition, as already noted in section 4.7.2, what has been identified is that there is a major opportunity to link the RoSE implementations to Minor Renewals.

RoSE has already identified the need to improve the way scheduling of inspection, maintenance and renewal/enhancement works is undertaken to maximise efficiencies. However, little progress has been made as the team only consisted of one or two people until now. Network Rail is currently debating 'ROSE for CP5' which is a more integrated approach, but it has not yet been agreed. This discussion centres around issues such as asset information, culture change and whole life trade-offs. For more information please refer to section 5.4.

4.11.3 Whole-life systemic approach in Reliability Centred Maintenance

As described in section 4.2, the scope of RoSE does not cover the full extent of a good practice integrated Reliability Centred Maintenance approach. This is currently being considered by a set of initiatives within Network Rail that look at the interventions needed as part of Network Rail's approach to manage business risk related to failures (refer to Diagram 1 in section 4.2). These initiatives or asset management actions are considered here and include the Reliability Improvement (section 4.11.4) and Intelligent Infrastructure (4.11.5) workstreams, Renewals and Enhancements (4.11.6), and finally, a study undertaken for S&C (4.11.7).

Based on good practice, Reliability Centred Maintenance should consider Failure Rates and Cost per Failure in determining Asset Criticality and the optimum:

1) Inspection intervals (predictive maintenance);
2) Preventive maintenance intervals;
3) Run to failure conditions;

4) Condition monitoring requirements;
5) Renewal intervals, and/or changes in the design or configuration of the system; and
6) Level of Spares holding

The scope of RoSE fully covers the first two aspects. In relation to 'run to failure' conditions, which is part of the RCM2 process as defined by Moubray, the RoSE analysis has extensively used the default action of 'no scheduled maintenance' for a significant proportion of failure modes. However, because as noted in section 4.6, the strategy that has been followed by Network Rail and RoSE has been to aim at preventing failures from occurring, i.e. to minimise failures as much as possible, and because no cost-risk optimisation has been performed so far, we believe that 'run to failure conditions' at asset type level have not been sufficiently evaluated and explored yet.

Network Rail stated that because the RoSE analysis has shown no link between usage and reliability for the majority of signalling assets, reducing maintenance on low value routes will lead to decreased reliability. So, although allowing assets to run to failure on low value lines may be considered as part of a route strategy, it does increase risk in terms of signaller workload as trains are talked past the failed asset, and increases workload for faulting teams. Therefore, according to Network Rail, this would require careful evaluation which has not yet been undertaken. Network Rail also noted that there are often more appropriate and effective ways of reducing maintenance cost on lower value lines and increasing system resilience on higher value routes.

Network Rail said that aspects of the above are part of a wider asset management process, with the RoSE analysis being a foundation for this wider process. A draft set of two flow charts[30] was provided by Network Rail to illustrate how RCM is being considered jointly by RoSE and the Reliability Improvement and RCM^2 workstreams. However, no integration is shown on these charts with Renewals and Enhancements.

Until now, RoSE has been undertaking the FMEA required for supporting all the maintenance initiatives noted above. However, it does not relate to the Route FMECA completed by the RAM team as part of the Renewal and Enhancement programmes. Network Rail noted that the RAM team applies FMECA at the system level, which is a much higher level than that applied by the RoSE analysis that until now has only looked at individual sub-systems or equipment. However, this team has already asked RoSE for help, and Network Rail acknowledged that there should

[30] Rel Imp & RCM-sqrd.pdf

be a link between RoSE and RAM for analysis and determining Renewals, for example for E&P which are large scale assets and will make a stronger argument for this integration.

So far the RCM analysis undertaken by RoSE has not produced RCM Decision Rules or Diagrams for the DUs to use to support integrating maintenance with remote condition monitoring and with Renewals and Enhancements (including Minor Renewals as discussed earlier). This would provide a structured approach for DUs on how to best manage specific failure modes in the future.

Finally, the RoSE project has not yet analysed the existing strategy regarding spares levels and the interaction with depot locations. According to Network Rail, it hasn't yet been considered how RoSE could contribute to spares planning, and it is believed that this would be more relevant when RoSE is applied to new asset designs with spares which have a high unit cost and a long delivery lead time.

4.11.4 Reliability Improvement

As part of the Reliability Improvement project, the RoSE FMEA is used to identify failure modes which cannot be adequately addressed through maintenance, for example those arising from poor component quality or which occur due to the rapid failure of electronic components. This helps to inform the reliability improvement work undertaken by other members of the Reliability Improvement team.

The reliability improvement specialists (RIS) and the RoSE team sit at adjacent desks so much of this work is undertaken through discussion, hence, most of this work is not evidenced. One example for which evidence was provided is an IBJ study[31]. The IBJ workshop was undertaken at the specific request of one of RISs. Having completed this assessment and identified actions, the management of the next phase of this IBJ initiative has been passed back to the RISs. This example in our opinion provides good recommendations for design changes, staff training, improvement of installation instructions, checking of manufacturing processes and factory testing, evaluation of post-installation testing requirements, etc.

4.11.5 Intelligent Infrastructure

According to Network Rail, the failure modes identified by the RoSE analysis are being used by the Intelligent Infrastructure project to identify which failure modes would benefit from being monitored remotely. This includes failures where the P-F interval is too short to be identified

[31] ROSE IRJ FMEA actions & resp.pdf

through manual maintenance or where manual maintenance is not applicable. The Intelligent Infrastructure project is part of the corporate Transformation Programme.

One of the key objectives when the Intelligent Infrastructure project is implemented is that degradation data from the remote monitoring systems will be used to validate the assumptions made during the RoSE analyses. Network Rail's objective is to reduce manual maintenance if possible in the longer term where remote monitoring has demonstrably identified relevant failure modes. This will require close collaboration between RoSE and the Intelligent Infrastructure project, which Network Rail refers to as RCM^2.

For example, a recent update of the TI21 analysis[32] was undertaken to address the design changes (digital Tx & Rx) as part of the regular RoSE review cycle. The opportunity was taken to identify each failure mode that may be amendable to remote monitoring, and a detailed task list was generated. The workshop included the relevant manufacturer's remote monitoring experts, which were part of the debate and are now starting the development of a remote monitoring solution based on the workshop output. This example illustrates good practice, with RoSE and the Intelligent Infrastructure project working together to identify which manual inspection tasks - aiming to address specific failure modes - should be done by remote condition monitoring.

Network Rail noted that external resources are being regularly used to support RCM^2, such as TR21 - Bombardier for TI21, Balfour Beatty and Thales for SSI, and Invensys. However, it was highlighted that none of them has been applying remote condition monitoring in a way that would help Network Rail, because there is no tie between the failure modes from the FMEA and the remote condition monitoring data collated.

Hence, the FMEA undertaken by RoSE can help establish which failure modes need remote condition monitoring, as well as what remote condition monitoring should measure, such as 4 or 5 key parameters to record on the handhelds, which can help determine the P-F interval and proportion of residual asset condition.

4.11.6 Renewals & Enhancements

According to Network Rail, it is still early days on integrating the RoSE project with Renewals and Enhancements (including Minor Renewals). To date there have been several discussions as part of 'ROSE in CP5', but no significant progress has been evidenced yet.

[32] TI21 RCM sqrd eg.pdf

No link exists at the moment between RoSE and SICA, based on the findings of this review and the SICA review that AMCL completed in May 2011[33]. However, we believe that it could be beneficial for Network Rail to explore the potential benefits and pursue the following:

- Integrating SICA with the FMEA done as part of the RoSE project, for example to assist understanding degradation mechanisms and failure consequences and exploring opportunities for improvements either via maintenance or renewal/enhancements;
- Taking into account the level of cyclic maintenance applied as part of the RoSE implementation as an asset condition indicator in SICA;
- Considering within SICA the option to increase the level of cyclic maintenance as a life extension measure or to mitigate poor performance;
- In addition, many of the recommendations about Reliability Centred Maintenance and whole-life system optimisation would require some integration between SICA driven Renewals/Enhancements, minor renewals and RoSE.

4.11.7 S&C Study

The initial work on S&C that RoSE has undertaken was used and extended in a study to support various recommendations from the RAIB Grayrigg report. This work was published and presented to ORR in July 2010 in respect of Lambrigg and is now being extended to other types/configurations of S&C. The study report highlights failure modes within S&C, and because it is a confidential document on restricted circulation a copy has not been provided as part of this review. In addition, the RoSE S&C study recommendations are driving a number of activities within the S&C Engineering team.

The RoSE project noted that further work on S&C is now underway. Workshops have been completed for points operating equipment (HW, 63, HPSS, hydrive, Clamplock, IBCL) and due for completion this month are for points fittings. The plan is for the draft maintenance specs to be available by September 2011. Also, the feasibility study for RoSE application to track is due to completion by September as well.

4.11.8 Whole-life System Optimisation

The audit also reviewed to what extent RoSE has undertaken whole-life system-wide optimisation according to good practice, which typically would encompass:

[33] Review of SICA and Signalling Renewals Volumes, Final Report, Version 1.1, 13th of May 2011

- Step 1: Balancing preventive versus reactive maintenance at local level for each asset type/configuration, following a maintenance cost-risk optimisation approach as illustrated in the diagram below;

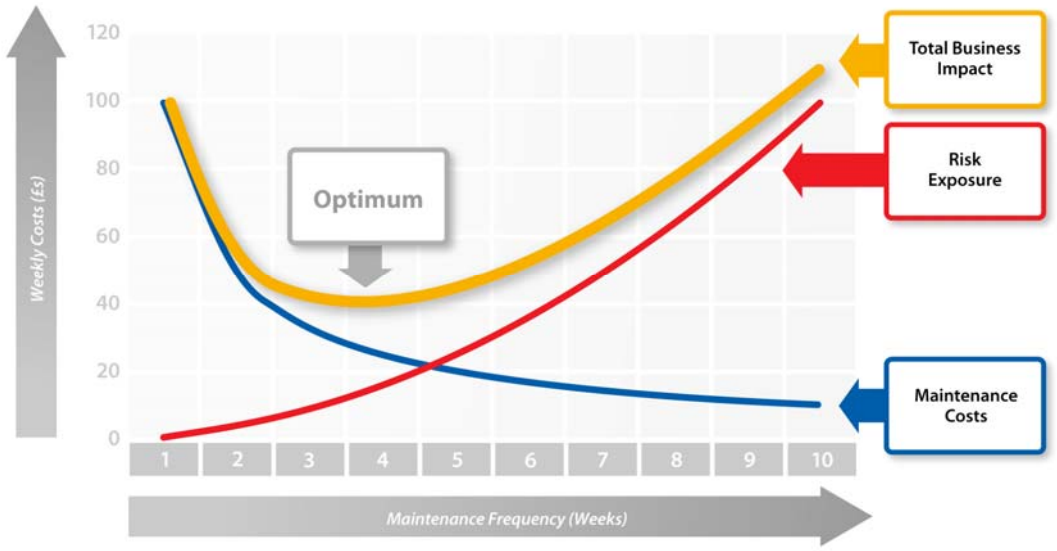


Diagram 16 Maintenance Cost-Risk Optimisation Principle

- Step 2: Whole life cost-risk optimisation at local level for each asset type/configuration, aiming at balancing Capital expenditure (Renewals and Enhancements) versus maintenance and risk (safety, and service expressed as revenue) throughout an asset's life; for example, lower cyclic maintenance towards the end of an asset's life could be justified with more frequent Renewals and/or the undertaking of mid-life Refurbishments, while Renewals/Enhancements with better quality assets could result in lower maintenance for the same performance; and
- Step 3: Whole life system-wide cost-risk optimisation, which involves optimising whole life costs and risks for all assets as a system, taking into account the interaction and inter-dependencies among assets and sub-systems (i.e. among signalling assets, as well as among signalling and other sub-systems such as track, rolling stock, power, etc.), and in addition considering the assets' and sub-systems' criticality in terms of their contribution to the system whole life costs and risks (safety, and service expressed as revenue).

In addition, these activities would support demonstrating whether the new RoSE maintenance regimes will deliver the output requirements defined in the HLOS (in particular to asset performance and cost efficiency).

The RoSE project has not yet undertaken any of the above optimisation steps. Network Rail mentioned that these are some of the trade-off opportunities highlighted in the 'ROSE for CP5' discussion (see section 5.4). As part of the 'ROSE for CP5' discussion, Network Rail stated that the fundamental assumption that all failures should be avoided (i.e. prevented) is going to be looked at, for example for lines where these is small amount of traffic and a more cost effective solution could be sought. Options could include:

1) Minimise failures (current strategy everywhere), or
2) Minimise cost, but according to Network Rail, without allowing any negative impact on safety (e.g. FPL testing, which could potentially go even further than the 13 weeks that the current RoSE FPL regime allows).

Network Rail noted that this approach has already been applied for Track, based on usage and asset criticality. Network Rail also said that one reason for following a risk averse, incremental asset-by-asset approach for signalling has been because degradation and P-F data are not available, even from the equipment manufacturers. So, any increase to maintenance intervals by RoSE is being done cautiously. Then, the objective is that as part of the ROSE review process, further opportunities to extent the intervals will be considered. Currently only 13 weekly maintenance steps have been selected as part of RoSE, and that could only change for big possessions, i.e. when doing major railway works. Hence, the ROSE project has so far focused more on whether Network Rail is doing the right maintenance or not, and has not yet tried to trade-off reliability (safety and service performance) versus maintenance or capital costs.

Network Rail identified that, ideally, ROSE should be undertaken as part of the Route Asset Management Process, which should include the following activities:

1) Firstly, the target level of Route availability should be determined, to allow setting specific RAMS targets by asset, such as required asset availability and reliability; and then
2) The required level of maintenance (and capital) work would be derived that is needed to deliver that reliability.

Also, as part of the Route Asset Management process, how much is being spent by each Route should be monitored closely to identify high or low maintenance work volumes for the required level of reliability for that Route.

In our opinion, to be able to fully align with good practice, Network Rail should aim at going even further, i.e. applying the three optimisation steps mentioned above at Route level, as follows:

1) Firstly, the required level of service by Route should be defined, in terms of train paths (services and timetable);
2) Then, the required level of Route availability should be determined based on a whole-life system-wide Route business case optimising the trade-off between total Route costs (maintenance and capital), revenue, and risks (safety and revenue) to deliver the required level of service for that Route;
3) Afterwards, the business cases (cost, revenue, risk) among Routes should be compared in terms of cost efficiency, in order to assist identifying gaps and opportunities for sharing good practice and optimising cost efficiency even further;
4) Finally, the above steps would enable Network Rail to optimise funding and resource allocation among Routes, so that the total Network Rail business impact is optimised and profitability is maximised, i.e. the sum of revenue minus costs and risks is maximised on Present Value terms. This could mean transferring funding and resources from some Routes to others if this is justified in economic terms.

Whole life system optimisation as described in this section, in conjunction with pursuing innovation and promoting R&D, would in our opinion help Network Rail deliver a more efficient and profitable railway for stakeholders. It would also align with the conclusions and recommendations of the recent Rail Value for Money Review, which was published in May 2011. RoSE would in this way help achieve higher value for money by optimising maintenance.

Finally, as expressed by SMSEs interviewed as part of this audit, R&D is needed to make innovative or radical changes to the design of the assets that would help significantly reduce maintenance costs and improve performance by providing solutions to known problems (for example addressing whether Network Rail does need stretcher bars which have high maintenance requirements).

5 Future Improvements

5.1 Project Targets and Roll-out Plan

As noted in section 3.1, no reference exists currently in the Route Utilisation Strategies (RUS) or the Route Plans to the RoSE Project, or the use of RCM in maintenance. Neither is any specific target quoted for improving reliability or availability as a result of the project. As already noted (see section 4.9.2), Network Rail believes that setting specific targets for reliability improvements is not possible due to the difficulty in measuring the effect that the new maintenance regimes have on reliability after they are implemented. Also as discussed earlier in the report, no formal Gantt chart or detailed forward looking plan for the development and implementation of new RoSE maintenance regimes has been developed yet, mainly due to the lack of resources, and that, according to Network Rail, could have slowed down the RoSE analyses. Now that the team is expanding, the RoSE project said that it is looking at the most appropriate way for planning and monitoring the RoSE analyses.

In our opinion, the lack of specific targets for reliability improvements in the RUS and Route Plans and an agreed forward looking roll-out plan for RCM highlights the fact that RoSE has so far been done in a ‘silo’ within Network Rail Headquarters, and in particular within Signalling in the Maintenance department. We believe that this may have been the main reason why RoSE has not been allocated yet with the necessary man power to achieve all its objectives and aspirations faster.

5.2 RoSE Project Team

Network Rail plan to expand the RoSE team and the currently agreed team structure of 10 people can be seen in the following diagram. Currently, the RoSE project has four full time people and one seconded person about to start, while several secondments/contracts are just finishing. As per the following diagram, the Benefits realisation/Signalling Facilitator is being 80% committed to RoSE, the signalling facilitator 100%, the Telecoms facilitator 10%, while the technical author is a contractor for the time being. The E&P facilitator, when brought to the team, will help with the prioritisation of the E&P assets to apply the RoSE to. The anticipated timescales to fill in the 9 posts is four to six months, and Network Rail is currently in the process of recruiting the remaining posts.

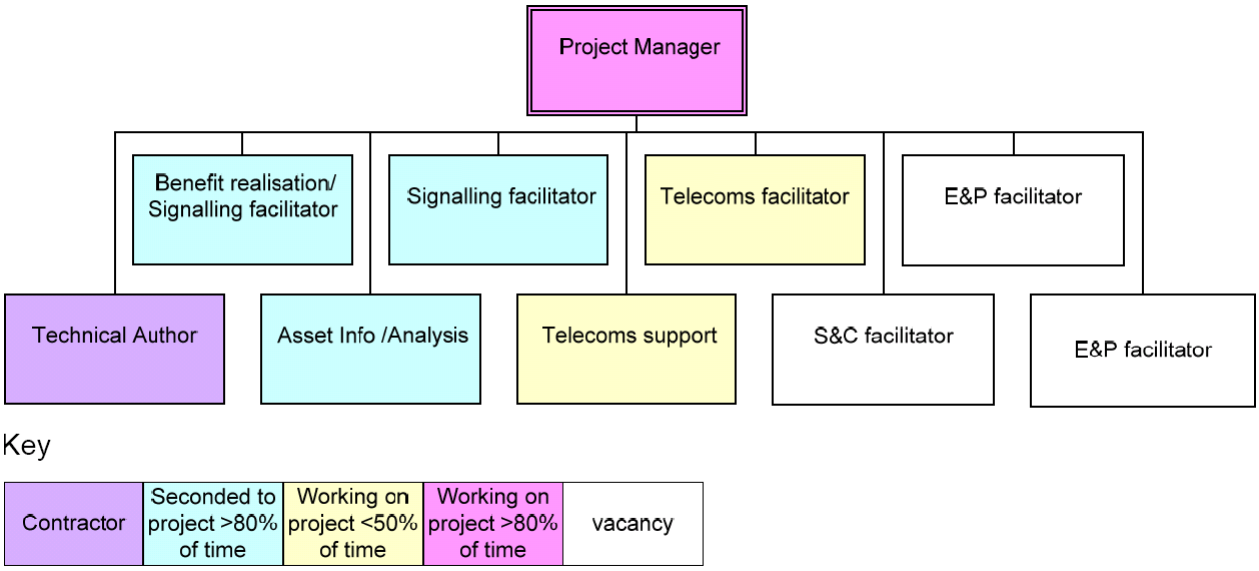


Diagram 17 RoSE Project Team Expansion

Network Rail aims for the larger team to allow work to start on aspects of the project that could not be delivered so far. Also, the addition of a technical author could allow investigating the opportunity to develop alternative forms of presentation for the new maintenance regimes that may be more effective in terms of compliance and ease of use. Until now, RoSE regimes have either used the existing SMS or the same format as the SMS.

In addition, the bigger team could enable consideration of how to release more benefits from the RoSE implementations. According to Network Rail, some work has already been undertaken by others to reschedule maintenance to improve productivity. However, it is considered that a more effective maintenance regime could be derived by also considering the Rules of the Route and compliance. This is currently under investigation.

5.3 Asset Information

As discussed earlier in section 4.8.3, due to the lack of reliability and asset degradation data at failure mode level, RoSE had to develop an RCM process that relies mainly on engineering judgment. So, the FMS and SINCS databases, even though they are used on an as-needed basis by RoSE, have provided limited benefit so far to the RoSE analysis. RoSE has recognised the opportunity for improving asset data, and using them to gain further benefit from enhanced maintenance regimes in the future, in the following areas:

- Asset degradation data, obtained via remote condition monitoring, which is currently been pursued via the Intelligent Infrastructure project. This data could be stored in Ellipse.

Network Rail aims to use improved handheld technology for improving asset identification, and also capturing degradation data automatically by uploading the necessary data on the handheld from remote condition monitoring to assist inspection. This will make it easier for operators to undertake inspection, as well as easier to capture degradation. These improvements according to Network Rail are part of the 'phase 2 Asset Information Strategy'.

- Failure data for the most important failure modes, which could be obtained via implementing improved and appropriate Failure Coding within the existing failure reporting systems, such as FMS and SINCS, that matches to the most critical failure modes as indicated by the RoSE analyses. This Failure Coding should aim to better record reliability and downtime/service impact at failure mode level, which would allow matching the consequences of failure against specific failure modes and their causes.

As noted in section 4.8.3, asset criticality is not currently being adequately recorded in Ellipse. So, to be able to derive business case based maintenance interventions that trade-off cost and risk, or when RoSE is applied to other assets such as track, then there is a risk that this will require a significant amount of work to collate this data and load it in Ellipse to enable implementation.

5.4 RCM Process

The RoSE project provided the following table outlining the areas where there is scope to evaluate more radical changes to regimes and working practices, which is currently being considered as part of the ‘RoSE for CP5’ discussion. RoSE pointed out that to gain benefit from taking RoSE further depends a lot on other factors as well, such as asset information and cultural change which are currently also under discussion.

Network Rail noted that the goal from now on is to avoid changes in maintenance regimes without first updating the FMEA with the new failure mode(s) that are driving the need to update the maintenance standards. This will aid training people on the new failure modes, and furthermore should increase the effectiveness of maintenance to address the failures it aims to fix or avoid.

Trade-off between			Notes
1	Maintenance workload	Asset condition	In some cases improving specific elements of asset condition will allow a reduction in maintenance (e.g. facing point lock tests) and will deliver improved reliability and safety
2	Maintenance workload	Asset reliability	Where a significant element of maintenance is associated with reliability, it may be possible to cut out some maintenance accepting that more failures will occur. However the system effects (increased safety risk, cost of rapid response, effect on customer satisfaction) of this approach need careful consideration
3	Maintenance workload	Asset modification or renewal	In some cases relative minor modifications will allow a reduction in maintenance (e.g. use of specific charger/secondary cell combinations on track circuits). Alternatively it may be preferable to replace the asset with one of a different type (e.g. replace SL17 signal heads with LED heads)
4	Maintenance undertaken by discipline A	Maintenance undertaken by discipline B	Reductions in maintenance undertaken by one discipline may increase the degradation rate of an asset which is maintained by another discipline (e.g. reducing track intervention levels on S&C increases vibration and so increases the need for attention to point operating equipment and point fixings)
5	Manual maintenance	Remote monitoring / automated inspection	Non-manual maintenance may, in some cases, be able to replace manual maintenance. This could be particularly effective in reducing manual maintenance on more rural lines without an adverse impact on reliability.

Table 3 RoSE for CP5 Trade-offs Under Consideration

Network Rail noted that CP5 development will involve evaluating options for CP5 funding, which will include Failure Tolerance (i.e. conditions to allow assets to 'run to failure'). In terms of RCM^2, the CP5 optioneering will include people from maintenance to enable them to not only focus on avoidance of failures but also to develop the capability to predict failures.

These aspirations noted by Network Rail align with many of the main recommendations of this report, including optimising the trade-offs between maintenance and renewals/enhancements. However, there are still a few gaps. First, no specific formal documentation has been produced yet about the Future Plans for RoSE that shows that these are endorsed by the wider Network Rail management and that they will be proactively pursued. Network Rail stated that further discussions are currently taking place around RoSE in CP5 which go even further than the RoSE Future Plans. However, with no other Network Rail documentation available to clarify how these trade-offs will be optimised within the Network Rail organisation and how major obstacles of lack of data/information and culture will be overcome, it is difficult to judge whether this will be possible to be done within a reasonable timeframe. Also, there is no mention of whole-life

system optimisation, i.e. the optimisation of the trade-offs across assets, asset systems (for example signalling, track, rolling stock, E&P, telecoms etc.), as well as across Routes. In addition, the possibility for new innovative or radical designs does not appear to be sufficiently considered, as well as the potential need for R&D to provide solutions to some known problems.

6 RoSE Application to Other Assets

After having focused on signalling first, Network Rail has been considering the application to other assets. In particular, in May 2009 a decision was made by Network Rail to extend RoSE to S&C, E&P, and Telecoms. However, there have been delays in expanding the team to accommodate this. In September 2010 a further request was made to evaluate whether the process would be beneficial to plain line maintenance; this will be undertaken after experience has been gained on the track elements of S&C. The application to 'yellow plant' is also under consideration, albeit as a separate project.

Network Rail mentioned that RoSE will be extended to track assets (plain line) once the 2BC re-organisation is complete. This will involve getting the relevant people trained first. It was also noted that the Professional Head for track has already been involved in the S&C RoSE study, so he has already experienced the process.

Network Rail also pointed out that the slow application of ROSE on other asset groups has been because apart from signalling, which RoSE has focused on, other assets have been being maintained by various maintenance contractors following a different approach to maintenance than the one followed by ROSE, such as Telecoms and Distribution & Plant. In addition, ROSE has not been a system wide project, and because of that there has been no integrated system wide roll out plan across assets outside signalling.

However, there is no Gantt chart or specific forward looking plan for the development and implementation of new RoSE maintenance regimes, even for signalling assets. Network Rail responded that the main reason has been the lack of resources, and hence it could have slowed down the RoSE analysis.

The ex-DU maintenance engineers interviewed as part of this audit seemed to agree that RCM is applicable to all other assets within Network Rail although the benefits may be different to signalling, depending on the asset. Furthermore, the following table summarises the responses obtained from the questionnaire based interviews as part of this audit to the question of rating the potential benefits of implementing an equivalent process on other key asset ground in the DUs. The responses were provided to AMCL on a scale of 1 to 5, with 1 meaning not any benefits, 2 some benefits, 3 same or equivalent benefits to signalling assets, 4 more benefits, and 5 much more benefits. Overall, on average the DU engineers believe that the benefits to other assets may be slightly less to signalling, with Telecoms having equivalent benefits to signalling (average score of 3), while structures having the lowest among all assets with an average score of 2.2.

Asset Group	Potential Benefit (1 to 5)
Electrical Power	2.8
Operational Property	2.4
Plant	2.8
Structures	2.2
Telecoms	3.0
Track	2.8

Table 4 Network Rail DU Engineers' View on Applicability of RoSE to Other Assets

Network Rail highlighted that when RoSE is extended to track, it will be a difficult decision for Network Rail to increase maintenance intervals on points due to their high safety risk, even though this has been done for the FPL testing. However, for FPL testing the maintenance intervals already varied by maintenance contractor, and so it was easier to justify rationalising the testing frequencies within the existing range of frequencies (4 to 13 weeks), with many cases where the new regime should result in doing maintenance more frequently according to the RoSE project team.

RoSE mentioned that, like for signalling assets, asset condition should be used to capture the need for variation in maintenance. For track however, usage will have to be taken into account, in terms of asset criticality (i.e. potential safety and service impact of a failure), but also because in this case is a key driver of asset degradation. However, asset condition will always have to be the main 'driver' for setting intervals. In particular, all the variable factors that should drive maintenance task and frequencies will need to be monitored according to RoSE. However, the RoSE maintenance regimes developed so far for signalling have not yet developed RCM decision rules or processes to allow the DUs to derive optimum inspection/maintenance intervals depending on asset criticality or a cost-risk optimisation exercise. To do so will require RoSE to go a lot further and improve on the work already done.

Furthermore, it was mentioned by Network Rail that telecoms assets have less potential safety risk than signalling, and more potential business impact, i.e. service risk in terms of service delay or operational risk. So, optimising the trade-offs between cost for maintenance and service impact will be easier to be accepted doing within Network Rail than it was for signalling and track that have a lot greater potential safety impact when they fail.

Finally, even though the signalling DUs have a good awareness of the ROSE project as they have been involved and implementing the new maintenance regimes, other disciplines (e.g.

E&P) have limited knowledge to date about the RoSE project. Therefore, there will be a period needed for raising awareness and understanding, as well as providing RCM training.

7 Conclusions and Recommendations

7.1 Conclusions

General Progress

Over the course of the last three years the RoSE project has developed new regimes for the cyclic maintenance of almost 80 percent of Network Rail's signalling asset base, while approximately 50 percent have had RoSE maintenance regimes authorised for implementation by the maintenance Delivery Units (DU). However, with the exception of facing point ends, there are still major signalling assets such as interlockings, points and level crossings that have not been analysed yet by RoSE, which account for a large proportion of the maintenance effort.

Furthermore, the delay in expanding the RoSE team has, according to Network Rail, probably resulted is RoSE being about 20 to 24 months behind where it could be for signalling and S&C, and about 15 months behind where it should be for Telecoms and E&P. The RoSE project team believes that the project is probably about a year behind the assumptions that were included in the workload projections for CP4.

Implementation and Benefits

The main emphasis of RoSE to date has been on delivering workload savings through increasing maintenance intervals, in order to enable Network Rail to meet its CP4 efficiency objectives. Indeed, RoSE has been stated to have already delivered workload savings that have been a major contributor towards a reduction in signalling headcount of about 10 percent during the recent 2BC re-organisation. This has been achieved via the authorised RoSE maintenance regimes which amount to approximately £4m per annum or 34 percent estimated theoretical 'time on tools' workload savings for those assets affected, plus un-quantified yet savings in non-productive time.

However, the actual implementation on the ground may be lower, and it has not been possible to calculate the actual workload changes from Ellipse due to various system changes. In particular, the actual implementation on the ground by the maintenance teams is lower than that reported, as it can take time until the new cyclic maintenance tasks become embedded in the maintenance schedules by the DUs. In addition, there are many cases where a few assets at a site are either in poor condition or they do not qualify in the implementation criteria which minimises the benefits as the maintenance team still have to visit that area, or even hinders all

the other assets moving to the new regimes. However, as the RoSE project addresses a greater proportion of asset types, the poor asset condition is becoming the main constraining factor.

The DUs view RoSE quite positively, and believe that apart from the benefits mentioned above there has also been a reduction in the unnecessary time spent on track and so a reduction in safety risk, and potential reliability improvements from using the saved time on one asset type to maintain and improve condition of other asset types when on track. However, due to the way reliability has been monitored and recorded within Network Rail, it has not been possible so far to distinguish the exact impact that RoSE has had among other initiatives on reliability and safety. Network Rail believes though that because the reliability trends have, generally, either continued to improve or have been stable since the introduction of the first RoSE regimes, this indicates that there have not been any adverse impacts.

In addition, the DUs expressed that RoSE has resulted in a reduction in maintenance backlog, and has helped to identify assets that need their condition to be improved or need renewal to enable implementation of the new maintenance regimes. It should be noted that the RoSE regimes have clear exclusion criteria depending on the asset specification within an asset type. Nevertheless, the DUs noted that there are many configurations of equipment within the asset types analysed, which could have reduced or increased frequency based on asset configuration and detail, but so far there is little differentiation. Also, the DUs identified that there has been no consideration of the opportunity arising from Renewals in reducing maintenance which could help justify targeted renewals, even though there has been some consideration by RoSE of installing assets that are low maintenance such as LED signals. The DUs also highlighted the lack of integration of the RoSE implementations with Minor Renewals, which due to lack of dedicated funding to support improving poor asset condition before extending the maintenance intervals, would be an enabler for the new RoSE regimes.

Furthermore, Network Rail and the DU engineers highlighted that RoSE has helped them to look at assets as a system at the local level, for example when poor FPL performance results from poor underlying track condition. However, in these cases RoSE implementation is taking a lot longer time to implement because P-way has been slow to provide the required information. The DUs also mentioned that changing maintenance schedules to release time from longer maintenance intervals is complex and time consuming, which in conjunction with the lack of resources with the necessary skills and other priorities, have resulted in areas where even though implementation is authorised, actual implementation levels are still low. Finally, the data required to assess asset condition against the requirements of the RoSE implementations is not

always readily available and site visits are often required, which further delays the implementation process. However, this process actually results in asset data improvements.

Project Scope

The RoSE project stated that within the last year more emphasis has been given on ensuring that the right maintenance is being done to each asset type to help improve reliability, which can result in either increasing or decreasing maintenance intervals depending on the condition of each individual asset. An example where this has been done already is the new FPL testing frequency rationalisation, which takes into account the recent record of failures and adjustments done to an asset. It is worth pointing out that asset criticality is not used to derive maintenance frequencies by the RoSE regimes, and rather on-condition tasks are preferred. The FPL testing frequency rationalisation appears to require a lot of joint effort by the DU engineers, including analysing and categorising failure data from the FMS, and working together with the P-way engineers to determine the underlying cause of poor condition. The DU engineers have been developing their own spreadsheets to record, assess and monitor asset condition for signalling and P-way assets. It is worth mentioning that the DU engineers have also been locally considering asset criticality, such as line speed, to qualitatively assess the potential consequence of failure in deciding to move points to longer FPL testing intervals.

So far, no specific targets have been set for RoSE for achieving reliability and safety improvements, and no further formal roll-out plan has been defined, as required by the 2010 Asset Management Improvement Roadmap. Also, there is no direct link to the overarching Network Rail targets as set out within Network Rail's Asset Management Strategy and Policy. Most of the emphasis there is on the use of remote condition monitoring, and there is only limited reference to RoSE and the use of RCM to optimise maintenance.

The RoSE Process

RoSE has been following a recognised Reliability Centred Maintenance (RCM) approach, which has primarily been based on engineering judgment to extend maintenance intervals and rationalise maintenance tasks, utilising a standard practice RCM process by John Moubray. Apart from a high level qualitative identification of the merits of the RCM process followed, Network Rail has not produced any documentation of why RCM was preferred over Risk Based Maintenance.

The RCM process is being applied via an RCM workshop involving experienced DU engineers, identifying functions and functional failures, analysing failure modes and failure effects, and

determining the technically feasible inspection, maintenance and failure finding tasks that can prevent or mitigate the effects of failures. The worth doing evaluation of these tasks is being done qualitatively based on the workshop's engineering judgment, which RoSE thinks is appropriate due to the short duration of most of the signalling maintenance tasks analysed to date, and also because it enables the RoSE project to achieve earlier delivery of benefits.. Hence, there is no quantified evaluation of the consequences of each failure mode or a recorded qualitative evaluation of their expected order of magnitude. Finally, there are no references to any performance standards that each asset has to comply with in terms of the required level of the reliability or availability.

As part of RoSE analyses undertaken 'redesign' requirements are being evaluated, such as redesign of the asset, new training requirements for personnel, or the use of new tools and information, such as implementing remote condition monitoring for specific failure modes via interaction with the Intelligent Infrastructure project. However, this is at an early stage of development. Furthermore, findings around issues which cannot be addressed through maintenance are being fed to the Reliability Improvement project. In terms of identifying the need for new types of assets and using the RoSE analysis to influence scheme design, this is still under consideration. According to Network Rail, this would enable identifying more radical changes to maintenance, most of which will require equipment modification or the use of remote condition monitoring. However, the DU engineers noted that R&D may be needed to do radical changes to the design of assets to solve some maintenance issues. Finally, levels of spare holding and the interaction with the depot facilities have not been analysed yet by RoSE.

One key finding of the review is that, although Network Rail's Asset Management Strategy and Policy documents require the optimisation of the whole railway system whole-life costs against business risk as a result of failure, including optimising the balance between maintenance and renewals, only limited progress has been made so far in this respect by Network Rail. In particular, the focus in Network Rail and the RoSE project has been so far to develop regimes which minimise asset failures by aiming to prevent them from occurring. Also, the new RoSE regimes do not take into account local asset criticality and the resulting downtime after failure and service redundancy available which can mitigate the consequences of failure. Hence, there has been limited consideration of run to failure conditions for critical failures. This, in conjunction with having developed only one maintenance specification by asset type so far, does not allow relaxation of the maintenance specification or extending the task intervals by location if that was justifiable to do so depending on the required level of Route availability and a system whole-life cost-risk optimisation exercise. However, Network Rail stated that this is a conscious decision

pending the ability to positively link an asset, work order and maintenance specification on the handheld, and hence reduces the risk that the wrong spec will be used. The new RoSE regimes do allow DUs to increase maintenance task frequencies if they judge necessary due to local asset condition, configuration and environment.

In relation to the delivery of the Asset Management Improvement Roadmap commitments, Network Rail has established the guidelines setting out the process for determining the appropriate maintenance regimes for signalling. This process has been applied by the RoSE project, which has produced the business case for the new maintenance regimes, albeit only for 'time-on-tools' savings and only as far as the end of CP4. As noted, no risk-based maintenance and inspection regimes have been developed yet for signalling.

As noted earlier, interlocking, points and level crossings have not been analysed yet by RoSE. For these assets the worth doing assessment will necessitate the quantified evaluation of the consequences of each failure mode, and the optimisation of the trade-offs between the system whole-life costs and risks. For the asset types that have already been analysed by the RoSE project, this approach could have supported the argument that safety risk is reduced to ALARP, as well as exploiting any further opportunities for maintenance cost savings if that was justifiable. The review also found that asset criticality is not currently readily available within Ellipse to enable undertaking a cost-risk optimisation exercise.

Network Rail stated that the RoSE project has not made use of the RSSB Railway Safety Risk Model because it is considered too high level for the purposes of the RoSE analysis, and RoSE can tap into the more detailed risk models available at the depots by the S&T Maintenance Engineers, and via talking to the expert engineers.

Data and Asset Information

Network Rail stated that the main limitation in quantifying the consequences of specific failure modes is the lack of failure data against them. According to Network Rail, failures have been recorded in the FMS database at too high level and without consistency to allow this data to be used by the RCM workshops. Furthermore, there is poor asset degradation data available to calculate average asset age before failure for age/usage related failure modes, or P-F intervals for non age/usage related failure modes. Instead, the expert judgment qualitative approach followed uses the rich experience and knowledge of Network Rail's DU engineers, which has helped to overcome this issue to a certain degree. Also, Network Rail pointed out that signalling assets exhibit few hidden failures and hence failure data are rarely needed to calculate failure

finding task intervals. On the implementation side, the deficiencies in the FMS data do not allow historic reliability trends by failure mode to be produced by the DUs.

An initial improvement has been made to the Ellipse database to enable in the future the recording of FPL adjustments via future handhelds of improved technology when they become available. However, Network Rail has conceded that what is really needed is to improve the recording of failures within FMS by using appropriate failure coding on the handhelds that relates to the RCM FMEA failure modes. This would support both the RoSE analysis and implementation, as well as the RoSE review and continuous improvement.

Training

In terms of training, RoSE undertakes three levels of training courses that are appropriate to each RCM workshop participant. Also, RoSE has assigned the role of the 'RoSE Champion' to one senior engineer at each DU, who has received RCM2 training and proactively manages the RoSE implementations and the regular briefings and progress reviews. However, the RCM training for Champions and the training provided to DUs as 'background' has been paused since April 2010 due to the recent 2BC re-organisation, although a number of courses have been undertaken over this period to support the RoSE analysis workshops. The general response from the DUs is that the training is sufficient and well done. However, understanding and perceptions about RoSE within DUs is considerably influenced by cultural factors, and the continuing belief of some technicians that RoSE is a cost cutting exercise.

Monitoring and Review

The RoSE project team is regularly sharing progress reports, which show the status of the RoSE analyses and implementations. A reliability report is also under preparation, but as noted earlier, the impact of RoSE cannot be distinguished, while there is no reporting of reliability by function or failure mode to assess the impact of RoSE and provide feedback for improvements. Finally, the DU engineers pointed out that not all assessment documentation has been produced for approval by some DUs, even though Ellipse shows they have.

The DUs pointed out that, apart from the three monthly local reviews at the depots, there has not been yet any formal review after the RoSE implementations, even though this is required by the RoSE standards. Also, the standards do not provide any guidance on forms or formats, or the key factors to consider as part of the review. For that reason they believe that there is no evidence that any formal review at DU level has been done so far, and when it has happened, their value will be different in each DU. However, RoSE has been developing a review process

with one of the DUs which has recently been shared with other DUs and is going to be published in the next update of the RoSE maintenance regimes standard. The DUs also suggested using a nationwide system to report the technical details about the RoSE implementations, which would assist following up assessment issues and monitoring progress. Currently, the implementation process does not include following up or reviewing actions prior to the assessment for implementation, and neither it includes tracking them after approval is given.

Application to Other Assets and Future Plans

Finally, the review has concluded that the RCM process is fully applicable to cyclical maintenance regimes in other Network Rail assets groups, such as Track, E&P, Operational Property, Plant, Structures, and Telecoms, and even though the benefits may vary by asset type, there should be considerable benefits to be made similar to those achieved and still further possible for Signalling. Also, Network Rail is currently reviewing the gaps and opportunities around RoSE and the other related initiatives as part of the CP5 discussion. This discussion is around issues such as asset information, cultural change and whole life trade-offs.

7.2 Recommendations

The recommendations from the review of the RoSE project are as follows:

Current RoSE Programme

1) Given the strength of the business case, Network Rail should complete expanding the RoSE project team to enable accelerating the development of new maintenance regimes for the remainder of the signalling assets to complete the current RoSE programme and to enable recovering some of the delay incurred in the project. (by January 2012)

Improvements to the RoSE Analysis Process

2) Network Rail should make the following improvements to the RoSE analysis process:
    a. The RoSE analysis process should include a sufficiently thorough and detailed evaluation of the magnitude and criticality of the consequences of each failure mode identified by the FMEA, either qualitatively or quantitatively as appropriate, to ensure reduction of safety risks to ALARP is achieved and documented, as well as to support optimising costs versus risks; (by January 2012)
    b. The RoSE analysis process should include the appropriate consideration of run to failure conditions at the local level where this is justified depending on the asset criticality, the potential downtime after failure and the available service redundancy; (by January 2012)
    c. The RoSE project should develop and implement a process for predicting the expected impact on reliability and safety by asset or failure mode as a result of the new maintenance regimes; (by January 2012)
    d. The RoSE analysis process should include an evaluation of the level of spares holding in conjunction with the available depot facilities. (by March 2014)

Improvements to Data and Asset Information

3) Network Rail should improve the data and asset information used to support the RoSE analysis process as follows:
    a. The recording of failures within FMS should be improved, with the use of failure coding that better matches the most critical failure modes as identified by the FMEA; (by January 2012)

b. The process of recording asset condition should be improved which will enable an improved estimation of asset degradation or P-F intervals to be undertaken. (by January 2012)

Improvements to the RoSE Implementation Process

4) Network Rail should make the following improvements to the RoSE implementation process:
   a. The monitoring and reporting of actual implementation of the new maintenance frequencies within the maintenance schedules by the DUs versus authorised implementations should be improved to enhance visibility; (by January 2012)
   b. A formal review process should be developed for the RoSE implementations, specifying the key factors to consider; (by January 2012)
   c. Network Rail should establish appropriate monitoring and analysis of the realised reliability by asset or failure mode after implementing the new maintenance regimes against the expected impact, to enable the effectiveness of the new RoSE regimes to be assessed and to provide feedback to the RoSE project to allow further improvements to the analysis; (by January 2013)
   d. Network Rail should establish an appropriate process for developing maintenance schedules, to make it easier and less time consuming for DUs to realign schedules when inspection/maintenance intervals change; (by January 2013)
   e. The process of managing implementation issues should be improved and formalised, including capturing key technical details on an asset by asset basis, to allow following up on assessment issues, monitoring of progress, and tracking of performance post implementation approval within the DUs. (by January 2013)

Strategic Approach to Risk-Based Maintenance

5) To deliver further benefits in CP5 and beyond from improved maintenance regimes, Network Rail should develop its strategic approach for the development of RoSE and risk-based maintenance as follows:
   a. Network Rail should develop an RCM or risk-based maintenance strategy and decision support framework to manage business cost and risk that aligns with Network Rail's Asset Management Strategy and Policy; (by January 2012)
   b. Network Rail should set up specific targets for the development and implementation of new maintenance regimes by RoSE or risk-based

maintenance across the whole of the Network Rail asset base, on an asset criticality and cost basis; (by January 2012)

c. Targets specific to the implementation of new risk-based maintenance regimes should be developed for achieving cost savings and improvements in reliability, safety or availability; (by January 2012)

d. The RoSE project should be more closely and formally integrated with all other RCM initiatives, such as the Reliability Improvement and Intelligent Infrastructure projects, and a formal RCM framework should be developed to govern the joint application of RCM across the business; (by January 2012)

e. Network Rail should follow a quantified cost-risk optimisation approach to justify the selected maintenance task intervals on an economic basis, and also to evaluate the business opportunity for further reduction or increase of maintenance at local level depending on the asset configuration within an asset type, asset condition and criticality, the potential downtime after failure, and the available service redundancy; (by January 2013)

f. RoSE should be integrated with Renewals and Enhancements to enable investigating opportunities to radically reduce maintenance or install 'low-maintenance' assets via targeted renewals; (by January 2013)

g. Network Rail should establish appropriate planning of Minor Renewals on a location by location basis, through a justified business case that takes into account the local asset condition and the fact that it is the major enabling driver for the new RoSE regimes and subsequent benefits; (by January 2013)

h. Network Rail should explore the benefits and if appropriate pursue integrating RoSE with SICA. (by January 2013)

6) Network Rail should improve its whole-system whole-life cost-risk optimisation capabilities, which should assist pursuing further value for money improvements. This should involve the following activities:

a. Balancing preventive versus reactive maintenance at the local level for each asset type/configuration, following a cost-risk optimisation approach; (by January 2012)

b. Whole life cost-risk optimisation at local level for each asset type/configuration, aiming at balancing capital expenditure (Renewals and Enhancements) versus maintenance and risk (safety and service expressed as revenue) throughout an asset's life; (by January 2013)

c. System-wide whole-life cost-risk optimisation, which involves optimising whole life costs and risks for all assets as a system, taking into account the assets' and sub-systems' criticality in terms of their contribution to the system whole life costs and risks; (by March 2014)

d. The above optimisation activities should be applied at Route level based on a whole-life system-wide Route business case optimising the trade-off between costs, revenue and risks to deliver the required level of service for that Route. (by March 2014)

Appendix A: Interviews

Name	Role
Deanne Haseltine	RoSE Project Manager
Mike Sowden	Director Infrastructure Maintenance (Reliability)
Barney Daley	Head of Infrastructure Maintenance Reliability
Steve Hailes	Professional Head, Signalling & Telecoms Engineering
Dan Boyde	Strategic Planning Manager, Policy & Modelling
Iain Tankard	Asset Information Strategy Manager
Steve Franklin	Senior Policy & Standards Engineer
Andy Butt	Senior Maintenance Support Engineer (Level Crossings)
Dave Grant	Special Project Manager RCM
Chris White	Senior Maintenance Support Engineer (Lineside Signalling)
Iain Clement	Senior Maintenance Support Engineer (Lineside Signalling)
Newcastle depot	
Steve Collins	Senior Maintenance Support Engineer [Interlockings & Systems]
Martin Errington	S&T Maintenance Engineer
Sean Cook	Team Leader (Signalling Maintenance)
Franco Fraterrigo	System Support Manager
Edge Hill depot	
Martin Hart	S&T Maintenance Engineer
Johan Strydom	Infrastructure Maintenance Engineer
Philip Swindell	Technical Support Engineer (RoSE Champion)
Lawrence Carabine	Performance and Assurance Engineer
Ipswich depot	
Bill Fordham	S&T Maintenance Engineer
Dave Deeley	Infrastructure Maintenance Delivery Manager
Mick Askew	Infrastructure Maintenance Engineer
Steve Carpenter	Performance & Assurance Engineer (previous SSM)

Appendix B: RoSE FPL Testing Frequency Rationalisation

According to the RoSE analysis for the FPL Testing Frequency Rationalisation, repeated FPL adjustments or component failures highlight an underlying problem and hence risk. So, whilst increasing the frequency of FPL testing would help to mitigate the risk it **does nothing to rectify the underlying problem** and so may mask increased stresses and increased risks. The RoSE analysis for FPL notes that previous means of capturing FPL adjustment is not robust in many depots, and several options existed for capturing adjustment and the need for further investigation. Also, traditionally, maintenance frequencies, once set, were rarely changed. The RoSE analysis identified that in order to manage the risks associated with deterioration of points, there is a need for a periodic review and, if necessary, an adjustment of the FPL testing schedule. Equally, it should be a simple matter to extend the testing interval when remedial action is completed.

As found as part of the site visits, initial implementation and ongoing management of the FPL testing frequencies is very much dependent upon the S&TME or Signal Section Manager devoting the necessary time and effort to assess the current FPL condition and when the key factors change.

According to one of the sample briefing exercises for FPL testing[34], many depots already have a repeat failure process for points, and the new FPL maintenance regime is extending this to ensure that adjustments or failures are investigated and understood. The briefing material highlights that this does mean that **all adjustments need to be recorded from now** on by the maintenance teams, and to facilitate this, the handheld recording process in the Ellipse database has been made a little easier to enable in the future the recording of FPL adjustments via future handhelds of improved technology when they become available. Finally, it mentions that every 3 months, the DU teams will have to review failures and adjustments and decide whether points need to move frequency. They will also have to check corrective actions to see what impact they have on the testing frequency.

In the longer term, according to the RoSE analysis, recording FPL adjustments will also enable undertaking trend analysis. To facilitate that, Ellipse has a ‘condition monitoring’ module which could be used to capture this information as an ad hoc tool to the existing processes. During the site visits we undertook as part of this audit, the Ellipse operators demonstrated this capability, which showed that Ellipse can relatively easily handle a lot of data for each individual asset. This data can be captured via the handhelds during maintenance. However, as identified by RoSE earlier, no data has been captured in this way so far to support monitoring asset

[34] FPL testing v2.briefing.pdf

condition, and most fields that have already been set up in Ellipse are empty. Network Rail agreed that although not planned at the moment, using data collected via handhelds would be a valuable addition, but may require improved handheld technology. For the moment, RoSE maintenance specs are being presented via the existing handhelds.

What was found about the new FPL testing regime during the site visits at maintenance depots as part of this audit is that DUs have been relying on using their own bespoke spreadsheets[35] to capture data and apply the selection criteria and decision logic as per NR/L3/SIG/10665. These spreadsheets are usually being created by one of the RoSE Champions as part of the initial RoSE implementations, and then are being shared across DUs as 'best practice'. Examples were provided by the three DUs visited (two of which were identical in format), which included a table developed by the S&TMEs to record, assess and monitor performance and asset condition for the signalling and P-way assets affecting the point ends. It is worth mentioning that in assessing points with the new FPL testing regime the DU engineers have further broken down the criteria required by NR/L3/SIG/10665, as shown in the following table (the one used by two of the three DUs visited), and in addition, they have been considering asset criticality such as line speed to assess the potential consequence of failure in deciding to move points to longer FPL testing intervals. According to Network Rail, the RoSE champions develop and share these regularly as they identify the need or opportunity.

FPL Testing Frequency Rationalisation	
RoSE Criteria within Network Rail/L3/SIG/10665	**Breakdown of Criteria (some added by the DUs)**
n/a	Through Line Speed (e.g. 60mph)
Scope	Within scope (yes/no)
Other	Other reasons for visit
Repeat Failure, Adjustments & condition of S&T Equipment (2 year data range required)	Number of failures (FMS) Number of failures (FMS) requiring Adjustment Number of Adjustments (in Ellipse) from maintenance and inspections Number of faulty stretcher bars (FMS) Condition of S&T equipment (e.g. good) Cause known and risk mitigated (yes/no/NA)
FPL Adjustments (2 year data range required)	Number of Adjustments Cause known and risk mitigated (yes/no/NA)
Track issues and condition of P-way	Last gauge measure (mm) 100mm from toes

[35] FPT Exercise Morpeth SB 2009.xls, FPL Test pilot implementation at Newcastle area – paper copy

	Bearer type (e.g. W, C) Bearer condition (e.g. OK, AV) Track condition issues (qualitative comments) Cause known and risk mitigated(yes/no/NA)
Dynamic Gauge Widening	Gauge stable (yes/no) Point machine secure (yes/no)
FPL Frequency Output	Output (new FPL frequency)
-	Comments from Assessment
-	Apply RoSE? (yes/no)
-	Batch for Implementation (usually assets within one section of the railway)
-	Implementation Date

Table 5 Facing Point Test risk assessment

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Appendix D: Glossary

Abbreviations	Description
DQUIP	Network Rail's Data Quality Improvement Programme
DU	Maintenance Delivery Unit (also referred to as MDU)
E&P	Electrification & Plant
Ellipse	Network Rail's maintenance management system
Failure Mode	An event that causes a functional failure
FMEA	Failure Mode and Effect Analysis
FPL	Facing Point Lock
Functional Failure	The inability of an asset to fulfil a function to a standard of performance which is acceptable to the user
MESD	Network Rail's website for Maintenance Engineering & Support Data
PF Interval	The time between being able to detect that a failure is starting to occur and the failure occurring
RAM	Route Asset Manager
RCM	Reliability Centred Maintenance
RCM2	Reliability Centred Maintenance 2 – a widely used derivative of RCM developed by Aladon Ltd
RCM^2	Reliability Centred Maintenance (RoSE) AND Remote Condition Monitoring (Intelligent Infrastructure)
RIS	Reliability Improvement Specialist
RoSE	Reliability Centred Maintenance of Signalling Equipment
S&C	Switches and Crossings
SMS	Signalling Maintenance Specifications issued as NR/L3/SIG/10663
SSM	System Support Manager
S&TME	Signal & Telecom Maintenance Engineer
'Worth Doing'	RCM term as per Moubray (2000): 'A proactive task is worth doing if it reduces the consequences of the associated failure mode to an extent that justifies the direct and indirect costs of doing the task'

Appendix E: RoSE Progress and Workload Savings

The following two tables have been produced based on the workbook ‘Signalling Analyses workload savings 110124.xls’ provided by the RoSE project.

	'Real' Signalling Assets	**RoSEable assets**	**RoSE Analyses Authorised**	**RoSE Analyses in progress**	**RoSE Analysis Planned by end of CP4**
Cable route	-	-	-	-	-
Interlockings	1,584	1,551	-	-	1,343
Location Case	70,318	70,318	70,318	-	-
LX	7,561	1,849	-	475	1,094
Mech Sig	2,308	1,387	-	-	1,387
Plant	-	-	-	-	-
Relays	-	-	-	-	-
S&C	22,520	21,495	-	16,891	4,535
Semaphore	3,998	3,299	265	-	2,731
Sig Control	-	-	-	-	-
Signal	31,883	31,786	29,925	-	36
Signalling	7,939	7,566	757	6,779	30
Signalling other	499	499	499	-	-
TD	250	203	-	-	-
Telecoms	7	-	-	-	-
Train Detection	65,026	64,247	51,282	6,502	6,200
Train Protection	40,901	40,901	40,235	99	-
	4,450	4,295	-	-	4,295
TOTAL	**259,244**	**249,396**	**193,281**	**30,746**	**17,356**

	RoSEable assets	RoSE Analysis Authorised for Implementation	
	WORKLOAD - Baseline (hrs)	**WORKLOAD - Baseline (hrs)**	**WORKLOAD - RoSEd (hrs)**
Cable route	(not yet analysed)		
Interlockings	(not yet analysed)		
Location Case	116,025	116,025	92,820
LX	7,726	-	-
Mech Sig	(not yet analysed)		
Plant	(not yet analysed)		
Relays	(not yet analysed)		
S&C	134,207	-	-
Semaphore	2,714	530	212
Sig Control	-	-	-
Signal	93,687	89,971	60,821
Signalling	10,042	121	121
Signalling other	1,248	1,248	536
TD	(not yet analysed)		
Telecoms	(not yet analysed)		
Train Detection	188,286	147,353	94,706
Train Protection	67,299	66,937	30,343
(other)	3,510	-	-
TOTAL	**633,557**	**422,185**	**279,559**