

Office of Rail Regulation

Review of Asset Management Best Practice

Summary Report

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Executive Summary

A review has been undertaken of a number of comparator organisations to identify inspection and maintenance best practice. The selected comparators included both British and overseas organisations. They also included organisations from both the rail and non-rail sectors. These organisations were researched and interviewed between August 2012 and November 2012.

The study of Network Rail's position and approach was based on public domain and other evidence produced between July 2011 and November 2012. As a consequence, the assessment was undertaken prior to the publication of the Strategic Business Plan (January 2013) and the emergence of "Project Apple".

A number of common themes were identified and used to structure the review:

- Strategy and Planning;
- Decision Making;
- Asset Knowledge;
- Delivery Planning;
- Organisation and People;
- Review and Improvement.

Good practice was identified from the comparators for each of these themes. These were then compared with Network Rail's current processes, including their announced initiatives, in order to determine the potential gaps.

Few of the comparators have quantifiably evaluated the benefits of this approach, therefore the potential opportunities available to Network Rail have been assessed based on the broad range of available evidence.

The potential benefits available from a risk-based approach are considered in this report for each engineering discipline in turn. The assessment is primarily based on information such as "Network Rail Infrastructure Limited Regulatory Financial Statements" (Year Ended March 2012) and AMCL's report "Review of Asset Information Strategy Phase 2: ORBIS" (September 2012).

The resultant potential efficiency opportunities are as indicated in the table below.

	During CP5	During CP6
Track	Negligible	>5%
Signalling	10%	Normal Improvement
Electric Power & Plant	7%	13%
Civil Engineering	Negligible	<5%
Telecoms	10%	10%

The efficiency assessments are based on a realistic view of the improvements seen in other organisations and an assessment of other initiatives visible to the study team. They assume that:

- Planning schedules can be amended to realise the potential benefits;
- Consolidation of maintenance depots enables benefits to be identified;
- Rapid response coverage required to achieve performance targets does not become the prime driver of maintenance resources;
- Continued mechanisation of tasks will remove manual handling constraint on team size.

Negligible additional savings from adoption of an RBM approach have been identified for track and civil engineering disciplines in CP5 following consideration of the other initiatives already being developed. For track that includes initiatives within the ORBIS project and for civil engineering the BCAM programme.

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1.0 INTRODUCTION

1.1 Background

The Office of Rail Regulation's (ORR) Periodic Review 2013 (PR13) will establish access charges, outputs and the associated regulatory framework for Network Rail for Control Period 5 (CP5) that will run from April 2014 to March 2019. The assessment of Network Rail's planned Maintenance and Renewal (M&R) expenditure and its efficiency in delivering outputs in a sustainable manner is an important input in assessing these access charges.

Infrastructure asset management organisations have adopted a wide variety of business models, ranging from centralised control and command, to devolved (and even individually licensed) field operational and maintenance units. Additionally, there is considerable variation in retained capabilities, from 100% in-sourcing of labour and plant, to varying degrees of 'thin client' contracting out. Similarly, there is a wide bandwidth of staff and operative competency levels.

At the 'coal face', many infrastructure organisations use Risk Based Maintenance (RBM) and Reliability Centred Maintenance (RCM) techniques to improve asset reliability and efficiency. Whilst RCM concepts were first developed by the airline industry in the 1960s, Network Rail had only utilised RCM for approximately 50% of signalling assets and in a basic form for overhead line equipment (OLE) by mid-CP4. Deployment of the revised maintenance schedules continues. Recent evidence indicates that approximately 75% of all signalling assets have now been assessed. The remainder of Network Rail's maintenance is standards-based.

1.2 Scope

The study has reviewed the maintenance organisation, capabilities, competencies and practices of:

- Network Rail;
- Other rail infrastructure managers; and
- Comparators in other industries.

It identifies best practice in order to review the efficiencies that might be available to Network Rail if they adopted best practice, without compromising Health and Safety. Amongst other attributes, the study benchmarks best practice in:

- Maintenance organisational structures, capabilities and competencies;
- Use of approaches such as:
 - Risk-Based Maintenance;
 - Reliability Centred Maintenance;
 - Remote condition monitoring, plus automated inspection and data collection.

1.3 Methodology

The methodology adopted has consisted of a staged approach:

- Identification of suitable comparators;
- Development of case studies for each comparator based on available knowledge;

- Collection of further details from selected comparators through follow-up discussions;
- Supplementary limited desk-top review for identified additional comparators;
- Desk-top reviews of other applicable documentation, particularly the Rail Value for Money Report, Initial Industry Plan and recent studies undertaken by the Independent Reporters;
- Discussions with stakeholders;
- Assessment of Network Rail’s position, based on the information available to study team; and
- Summarising findings and draw conclusions.

The study was based on material produced between July 2011 and November 2012. As a consequence, the assessment was undertaken prior to the publication of the Strategic Business Plan (January 2013) and the emergence of “Project Apple”.

1.4 Comparators

The following comparators have been included within the study:

- Other railway organisations:
 - Heavy and light rail networks;
 - British and internationally-based;
- Utilities:
 - British-based;
 - Internationally-based;

Additionally, desk-top reviews were undertaken on specific aspects of a number of other selected comparators. These represented:

- Manufacturers:
 - Safety critical environment;
 - Mass production;
- Aeronautical.

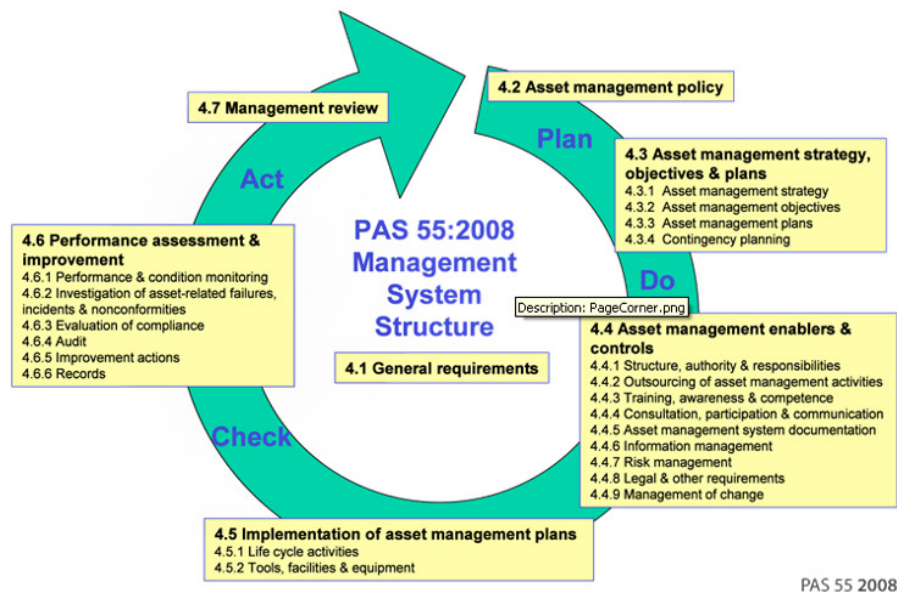
The matrix below indicates the spread of comparators used in this exercise.

	Overseas	British Based
Rail Based	Detailed: 1 Case Study: 2 Desk-Top: 0	Detailed: 1 Case Study: 0 Desk-Top: 0
Other Industry Sectors	Detailed: 2 Case Study: 0 Desk-Top: 3	Detailed: 1 Case Study: 1 Desk-Top: 2

2.0 ASSET MANAGEMENT: INSPECTION & MAINTENANCE

2.1 High-Level Asset Management Frameworks

PAS55 is widely accepted as representative of good asset management practice. The approach that it adopts is based on the Plan Do Check Act (PDCA) model, as shown below. Many of the concepts introduced by PAS55 support the findings of this study.



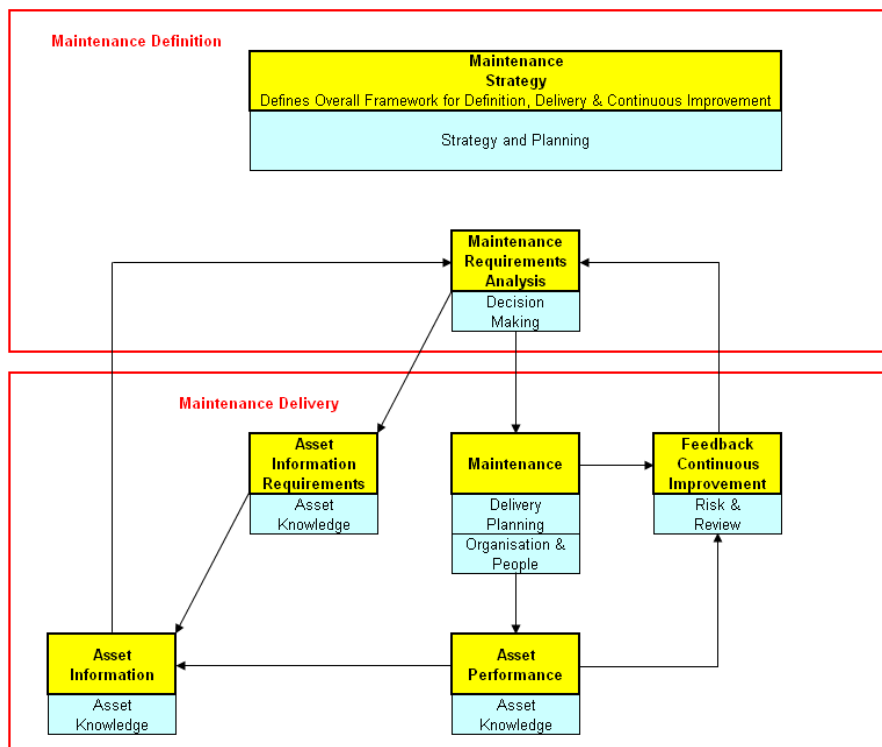
2.2 Identification of Common Themes

An initial assessment of the comparator case studies, taking cognisance of the above model, identified a number of common themes and these have been used as the basis for the structure of this document. These themes are:

- Strategy and Planning:
 - Maintenance strategy (i.e. application of approach); and
 - Consideration of maintenance at all stages of asset life.
- Decision Making:
 - Criticality assessment;
 - Maintenance requirements analysis; and
 - Models and tools such as Failure Mode, Effects and Criticality Analysis (FMECA) and Reliability Centred Maintenance (RCM).
- Asset Knowledge:
 - Determining data requirements and producing suitable data specifications;
 - Data capture, including appropriate use of automated condition monitoring; and
 - Data systems and reliability, e.g. accurate root cause details of faults and failures.

- Delivery Planning;
 - Shutdowns;
 - Safety processes;
 - Resource planning processes; and
 - Management of contracts and out-sourcing.
- Organisation and People:
 - Learning culture;
 - Change management and incentives to improve; and
 - Skill and competence levels.
- Review and Improvement:
 - Feedback loop from delivery;
 - Continuous improvement, including use of lean/kaizen approaches;
 - Standardisation; and
 - Benchmarking (internal and external) with benefit realisation tracking.

The diagram below plots these themes onto a maintenance definition and delivery framework, which is consistent with good asset management practice. It is representative of the general approach used by AMCL and, as such, provides consistency with both the comparator case studies and previous assessments of Network Rail. It has been used as the basis of the assessment and enables easy identification of what has been achieved elsewhere. This is detailed in the remainder of this report.



The consideration of these elements as separate themes in this report is to enable easier understanding of the transferable lessons. However, the power of asset management in delivering an effective and efficient performance is achieved through an integrated approach, whereby each of the elements is linked and coordinated with the others.

2.3 Rail Value-for-Money Study Context

Amongst other issues, the Rail Value-for-Money (R-VfM) Study reviewed the opportunity for cost efficiencies from adoption of best practice inspection and maintenance approaches. In terms of strategy and planning, the R-VfM study noted that:

“Better asset condition monitoring, coupled with a better understanding of asset failure modes and their criticality, can enable the adoption of more cost effective approaches. A move away from calendar based maintenance and renewals can avoid the cost of unnecessary work. Non-critical assets will be fixed when they fail, and critical assets fixed when their condition begins to deteriorate.”

It continues by saying that this approach will provide further benefits such as:

- Improved long-term planning from better asset information, leading to informed decisions on whether to renew or maintain;
- Asset policies that better reflect local circumstances, e.g. rural lines;
- Better understanding of operational and maintenance options and consequences;

2.4 Network Rail’s Route-Based Organisation (Devolution)

Network Rail’s previous organisation had two primary delivery legs:

- Operational management with focus on how to run railway;
- Asset management function with focus on how to keep railway running;

The maintenance organisation was transferred into the Routes a year ago. This was achieved by transferring responsibility for maintenance delivery units to Route MDs. The Route organisations now manage both operations and maintenance activities, developing their own asset management plans that suit their local requirements.

The move to the new organisation was accompanied by a change from “control and command” to one of “service culture” (plus assurance) in terms of relationship between the centre and the Routes.

Devolution has been noted as improving the communication of failure management and reliability issues within the key functions on the Routes, through creation of closer working practices and regular meetings. The inclusion of Schedule 8 costs within the Route budgets has also focused increased attention on improving performance and reducing incidents.

In summary, it is believed that:

- Devolution has been implemented within Network Rail, broadly as envisaged in the R-VfM Report;
- Revised structures are still developing their maturity, particularly with respect to the decision-making process;
- Local optimisation has already started and should support the adoption of a risk-based approaches;
- Relationships between the centre and the routes are still maturing in order to ensure that the possible risks to the implementation of national process and/or technology improvements are mitigated.

3.0 MAINTENANCE STRATEGY

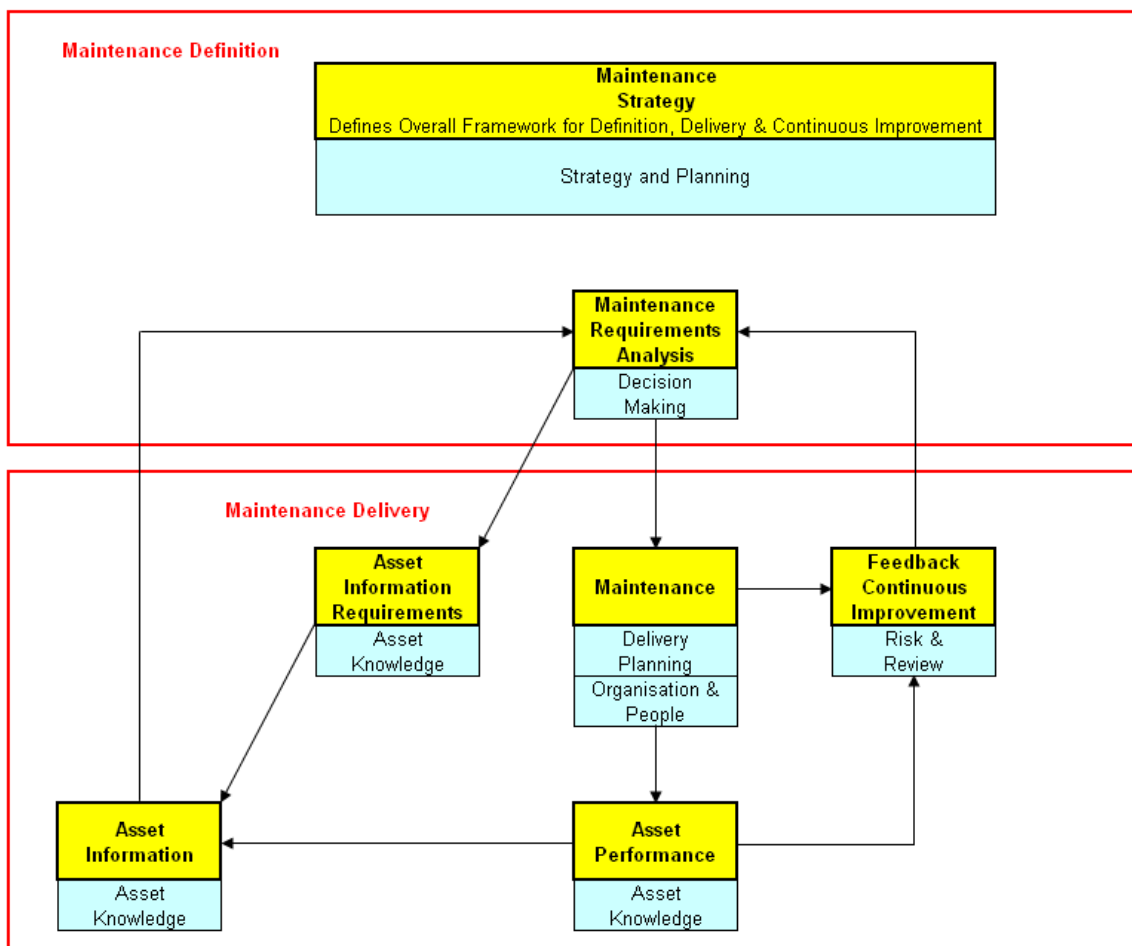
3.1 Overview

Good practice maintenance delivery organisations are able to demonstrate that they have a coherent process for both the definition and delivery of maintenance activities.

Maintenance definition is ‘doing the right thing’, i.e. ensuring that maintenance and inspection activities are clearly defined and focused on achieving desired levels of risk (expressed often as performance or reliability) for a given direct cost, sometimes known as ‘maintenance optimisation’.

Maintenance delivery is ‘doing things right’, i.e. ensuring that the maintenance and inspection activities are delivered efficiently and provide adequate information on the consequential asset behaviour and costs of the maintenance regime.

These aspects are emphasised in the maintenance delivery framework below and are usually undertaken by different parts of the organisation:



The maintenance strategy defines the overall framework for the definition, delivery and continuous improvement of maintenance within the organisation. A risk-based approach to asset management is one that enables achievement of the required performance and acceptable risk levels for least overall cost (sum of direct and performance costs).

3.2 Comparator Good Practice

Appendix A contains details of the identified good practice in this area.

The following areas of good practice have been identified:

- Clear definition of asset owner, asset manager and service delivery roles and responsibilities;
- Development of a maintenance strategy that is based on optimised intervention;
- Task of undertaking the Maintenance Requirements Analysis (MRA) process is the responsibility of a group separate to those responsible for service delivery;
- Align the organisation with the developing maintenance strategy;
- Need for a separate maintenance strategy document is not a prerequisite, but direction is required on how to undertake the MRA process;
- Maintenance costs should be considered at the design and procurement stage;
- Small competent core team required to support implementation;
- Typically, initial rollout programme is 3 to 4 years duration;
- Emerging reliability performance should be reviewed on a periodic (often quarterly) basis.

3.3 Network Rail

The following summarises our understanding of Network Rail's position:

- Network Rail is improving its capability to understand the whole life cycle of its assets, for example by attaching dedicated engineers to major programmes to ensure that through-life maintenance is considered at the development stage, although it still remains a challenge when costs are under pressure;
- Significant work is being undertaken to develop modelling of this approach in preparation for the start of CP5.

4.0 DECISION MAKING

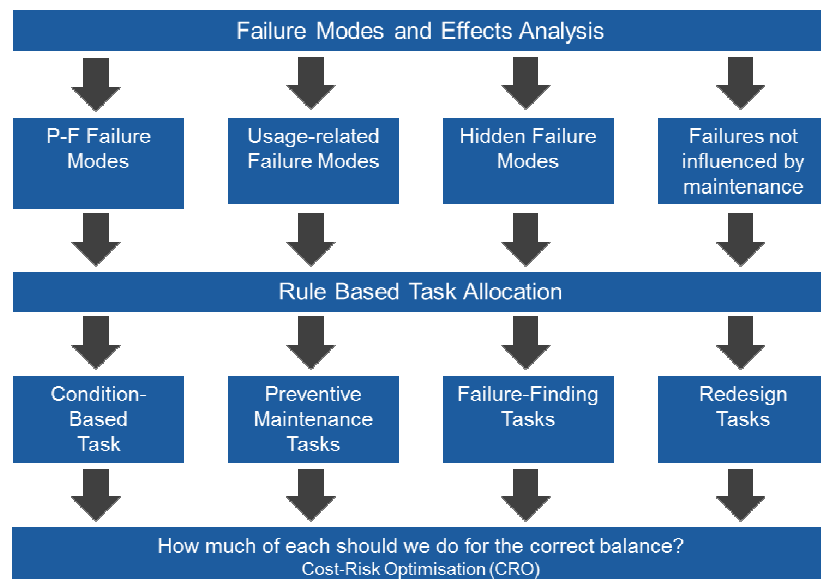
4.1 Overview

The maintenance strategy defines the overall approach to specifying, delivering and continuously improving maintenance activities. MRA is usually the core decision-making approach. The most prevalent MRA methodology is Reliability Centred Maintenance (RCM), which usually differs from Risk Based Maintenance (RBM) in the level of analysis undertaken to define maintenance and inspection intervals.

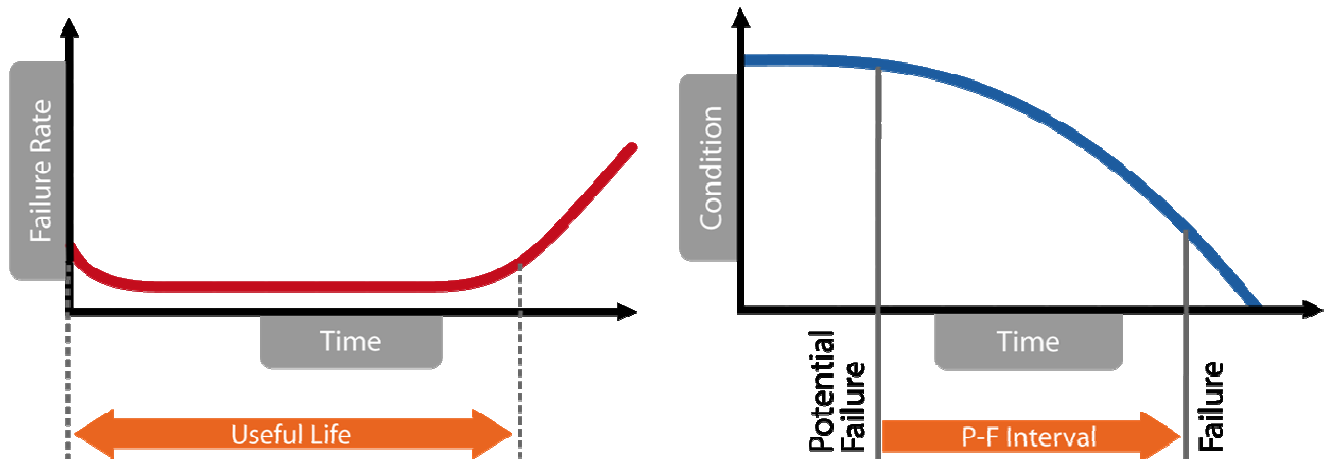
A typical RBM process might involve the following stages:

1. Determine criticality based on an overall ‘total cost of ownership’ of the asset portfolio to prioritise implementation on the top 20% of assets;
2. Identification of maintenance activities for the critical assets;
3. Failure Modes, Effects and Criticality Analysis (FMECA) of the risks inherent in the asset type;
4. Define risk parameters to determine if there is opportunity to vary maintenance and inspection regimes based on an asset type’s risk context;
5. Loss & consequence modelling to determine weighted cost of failure for asset types;
6. Cost/risk optimisation techniques to optimise the interval for maintenance or inspection activities;
7. Draft maintenance specification that will be validated through testing and review;
8. Determine impact of the revised maintenance specifications in terms of reduced operational expenditure;
9. Safety and reliability justification.

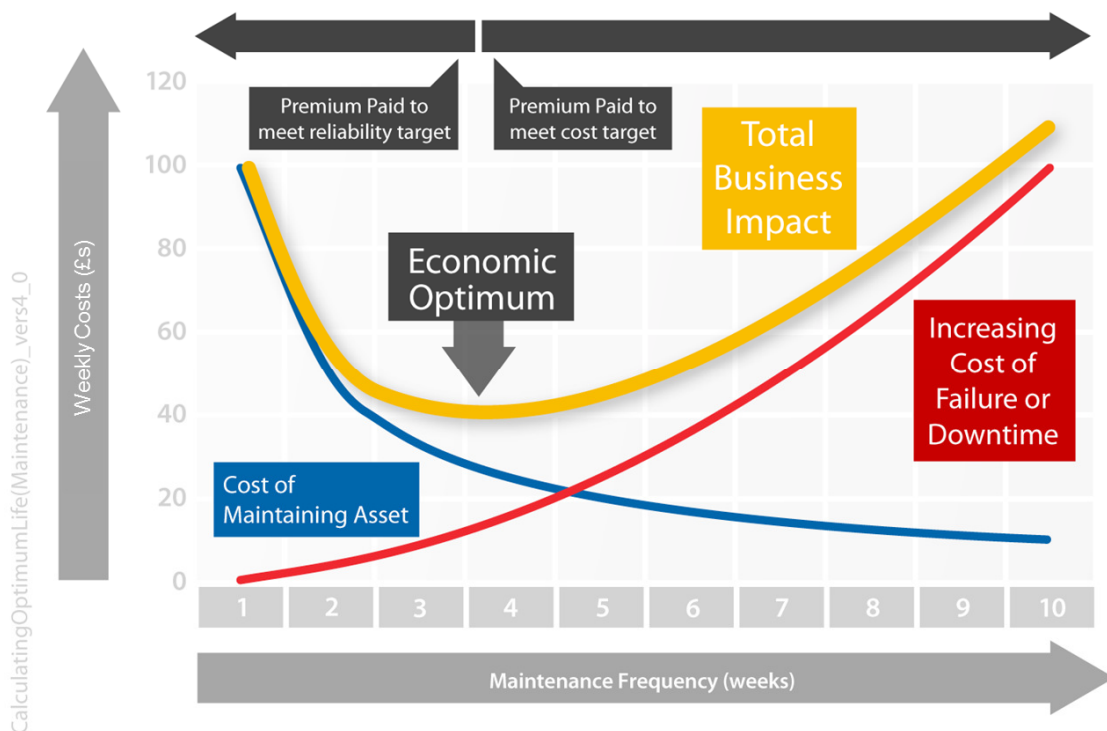
The key concepts that a good practice organisation will exhibit include firstly a structured approach to identifying failure modes. The most appropriate maintenance or inspection tasks for mitigating those failure modes will be evident. This is the core process that underlies any RCM form of MRA. The following diagram depicts the basic logic, often known as ‘decision logic’. The characteristics of the failure modes lead to a specific type of mitigating maintenance task.



The second stage in the process, once the tasks have been identified, is to define a suitable interval or frequency. This can be estimated qualitatively, based on an engineering judgement of the 'useful life' for predictable 'usage-related' failure modes and their 'preventive maintenance tasks'. Alternatively, it is calculated by estimating the 'P-F interval' (as defined in the diagram below) for randomly initiated 'P-F' failure modes and their 'condition based tasks'. These are effectively inspection tasks.



A quantitative analysis of the interval can be completed using 'quantitative RCM' or other 'cost-risk optimisation' software. These seek to identify the optimum frequency at which the sum of the costs and risks of a certain maintenance or inspection task is at a minimum, or at its lowest whole-life cost solution. This approach is summarised in the diagram below.



4.2 Comparator Good Practice

Appendix B contains details of the identified good practice in this area.

The following areas of good practice have been identified:

- Use of total cost of ownership as the basis of criticality analysis is not widespread;
- Use of criticality analysis focused on failure rates or consequences is widespread;
- Criticality assessment of asset types is undertaken to prioritise renewals and performance assessments;
- Criticality of specific assets within an asset type is used to determine maintenance interventions;
- Many comparators are using a MRA process approach as part of a move to condition-based maintenance intervention;
- Implementation is supported, or driven, centrally by a competent core team;
- Tools are available to support deployment of this approach;
- FMECA is the main technique typically used to underpin the MRA process;
- RCM is the most common MRA approach being used;
- Where cost-risk optimisation is incorporated to help tailor maintenance regimes, this is known as risk based maintenance (RBM);
- Loss and consequence analysis is being introduced as part of the process;
- Statutory requirements have little or no impact on the MRA process;
- Reactive work has been reduced to approximately 25% of total maintenance work.

4.3 Network Rail

The following summarises our understanding of Network Rail's position:

- Network Rail has developed a criticality assessment process based on performance impact, although it does not fully take into account the total cost of ownership;
- During a review by the Independent Reporter, criticality was reported as having not been incorporated into the signalling maintenance review process;
- As stated in a recent review by the Independent Reporter (AMCL RoSE Study), Network Rail has already achieved a 10% reduction in direct costs from application of a risk-based approach to scheduled signalling maintenance;
- Network Rail has deployed an RCM approach, under-pinned by FMEA techniques, with significant progress made particularly within the signalling discipline;
- This RCM approach is now the basis for development of an RBM approach;
- This risk-based approach is now being rolled-out across other disciplines' activities, such as track inspection frequencies;
- Risk-based approach is not always appropriate, for example the condition of rail pads is difficult to assess so a cyclic approach is proposed, whilst "plate oiling" is a seasonal activity;
- Work is being undertaken to ensure that Standards support the requirements of the revised industry.

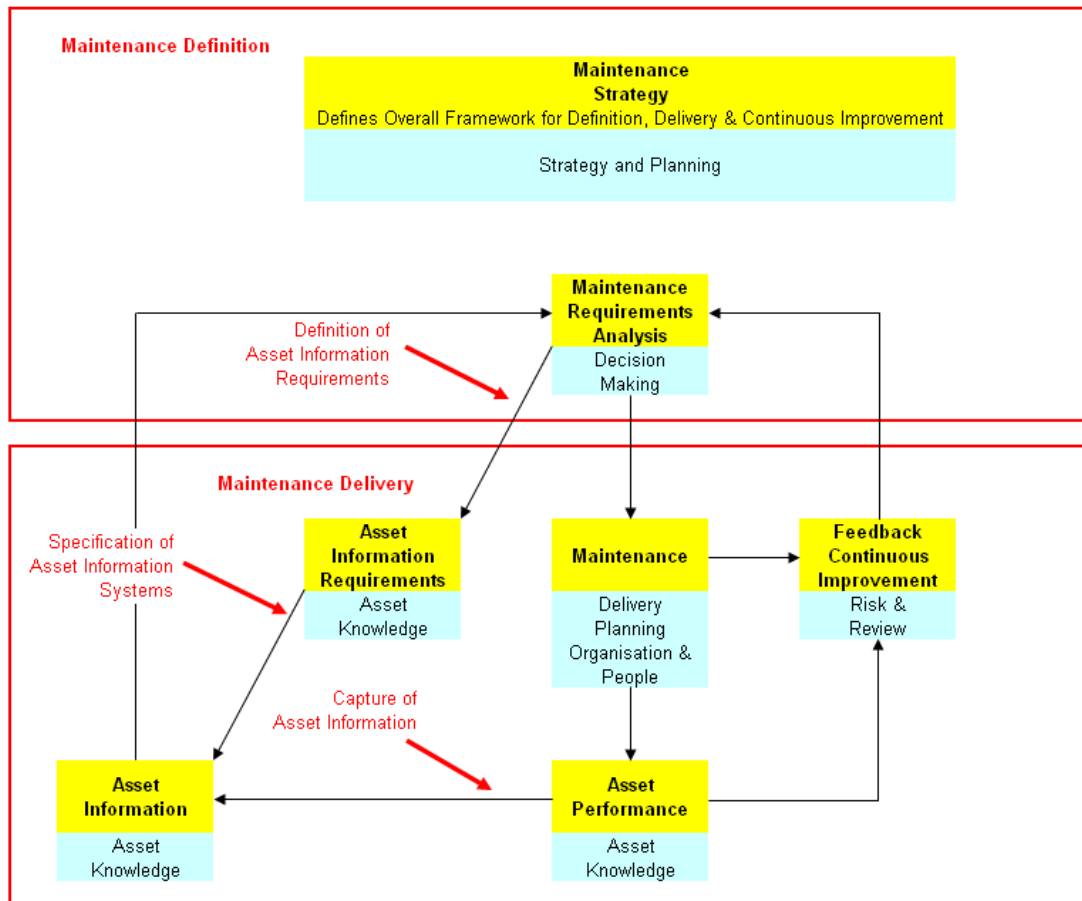
5.0 ASSET KNOWLEDGE

5.1 Overview

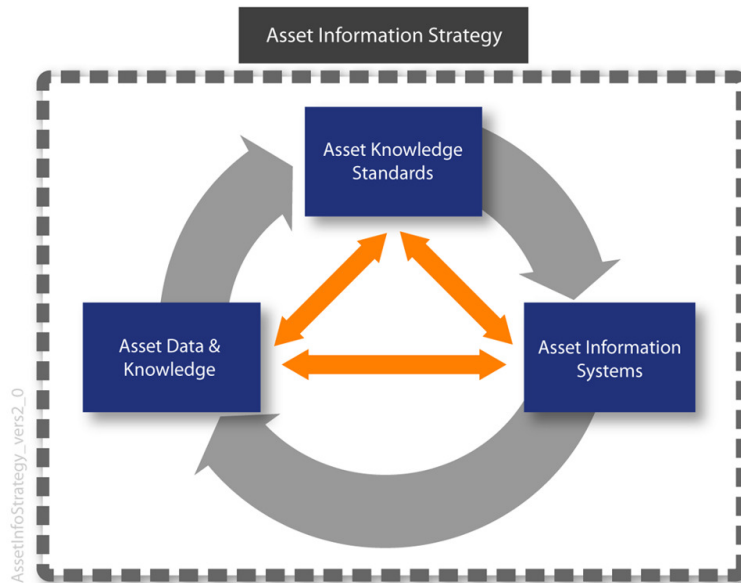
The availability of good asset knowledge underpins the use of the techniques described previously. However, decisions can be made based on fairly poor information as long as this is done within a continuously improving maintenance delivery framework. A good maintenance strategy will ensure that the:

- MRA process identifies what parameters need monitoring;
- Identified parameters are monitored; and
- Information is utilised to support continuous improvement.

This supports the specification and acquisition of suitable technology to capture the data.



Good practice organisations will exhibit clarity over these aspects of asset information. MRA does not exist disconnected from the definition and continuous improvement of asset information, nor from the systems used to collect and manage it. In general terms, the management of asset information can be divided into three parts as the following diagram demonstrates. There may also be an overarching ‘asset information strategy’ in place to coordinate activities and define the framework.



5.2 Comparator Good Practice

Appendix C contains details of the identified good practice in this area.

The following areas of good practice have been identified:

- Data requirements should be identified at the acquisition stage;
- Regular review of the collected data should be undertaken to feed into the continuous improvement process;
- Use clear, consistent definitions of asset condition;
- Use a single system to store information;
- Availability of good failure data underpins the MRA process;
- Lack of suitable information, particularly unit costs, is a constraint;
- An “Owner” of the information is identified who understands the requirements beyond the operational context and can translate the MRA requirements into IT system requirements;
- Automated condition monitoring systems are widely deployed, although on a case-by-case basis;
- Hand-held computers are seen as “business-as-usual” applications;
- General use is made of commercially available software (rather than bespoke systems).

5.3 Network Rail

The following summarises our understanding of Network Rail’s position:

- Formal identification of data requirements is an emerging process;
- Asset information is an area of major investment through the ORBIS programme;
- Industry records need improving, particularly in terms of failure and reliability data to facilitate adoption of FMECA processes;
- ORBIS programme does not appear to include any initiatives to address the current shortfall in accurate root cause asset fault related information;

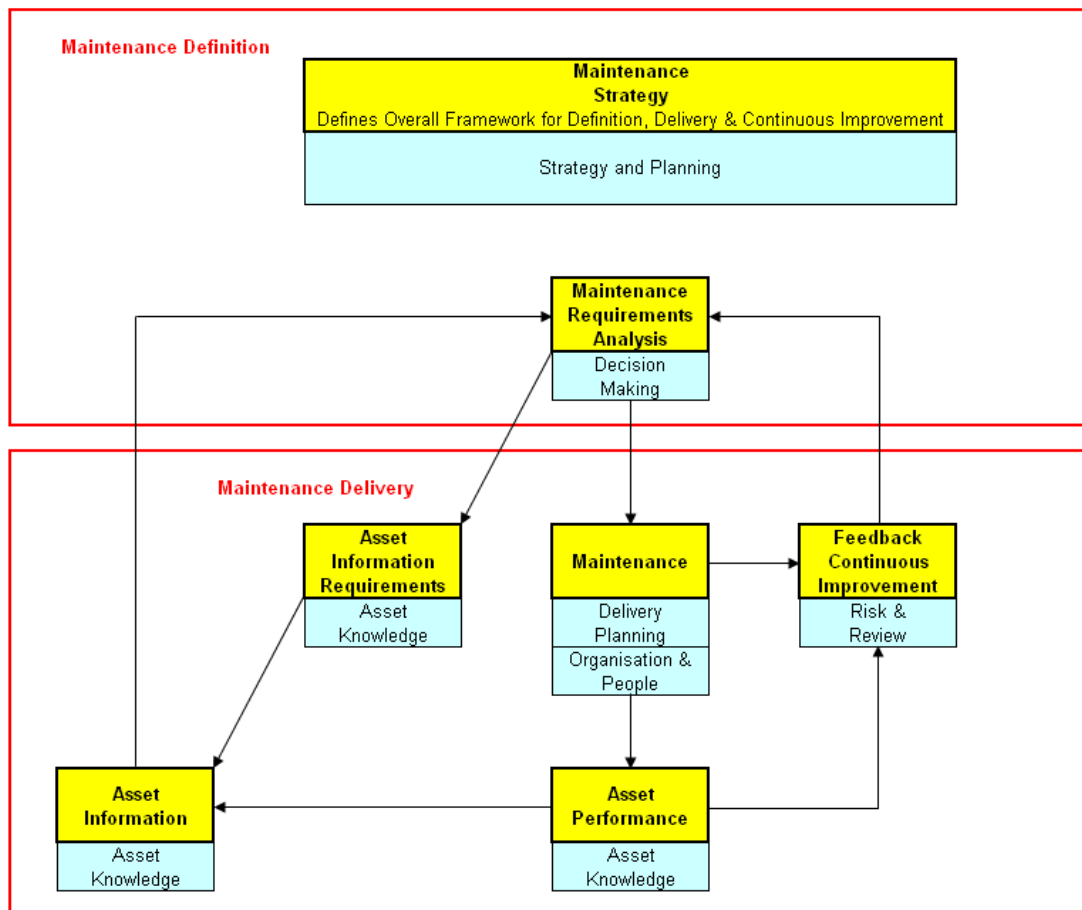
- More detailed data is required to support the move to a risk based approach to inspection and maintenance;
- Opportunities appear to exist to leverage more value from automated condition monitoring equipment;
- Power of mobile computing is being explored, with iPhones and iPads being rolled out that should improve accuracy of asset condition data;
- Clear ownership of asset information yet to be determined.

6.0 DELIVERY PLANNING

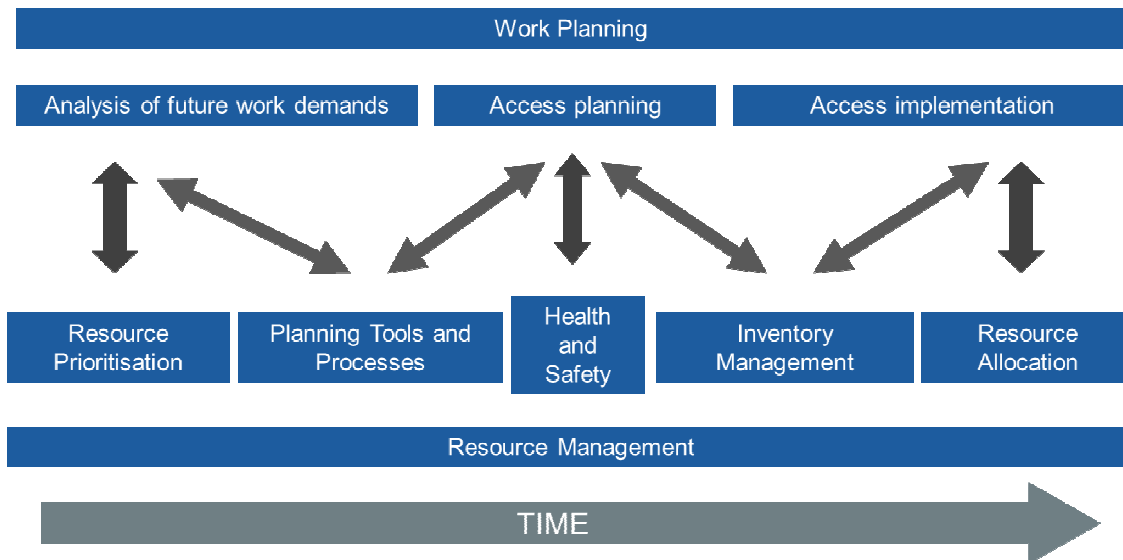
6.1 Overview

Good practice organisations will plan to deliver their maintenance and inspection activities as effectively and efficiently as possible. This section of the review considers the ‘doing things right’ aspect of the maintenance delivery framework. The objectives are to:

- Ensure efficient delivery of the planned work, and to manage exceptions;
- Provide adequate information to monitor and manage efficiency, quality and safety;
- Positively feed back information to continuously improve maintenance and inspection activities.



To achieve these objectives it is essential to create a plan that brings together the resources available with the required work. The resources available include skilled and unskilled labour, access to the asset, plus plant and equipment. The required work will include predictable and clearly identifiable work packages through to emergency items. These plans will be increasingly refined and defined as the delivery date gets closer. Within a rail context, plans are usually first developed at least two years in advance. The diagram below helps to explain this approach.



Another key aspect related to good practice delivery planning is the selection of delivery resource. If this is internal to the organisation, it is assumed there will be effective control and understanding of the skills and capabilities of the resource to ensure efficient and safe delivery to the right quality. If this is external to the organisation, it is essential that requirements are clearly defined and the contract effectively managed in a PDCA cycle.

6.2 Comparator Good Practice

Appendix D contains details of the identified good practice in this area.

The following areas of good practice have been identified:

- Long-range planning enables optimisation of shutdown opportunities;
- Work is clustered to maximise shutdown opportunities;
- All comparators operate within a safety critical environment;
- Clear and well defined processes are used for resource planning;
- Resource planning usually utilises a computerised management system;
- Supply chain should be managed on a (measured) performance basis;
- Clear set of criteria should be in place to understand out-sourcing benefits;
- Majority of maintenance work is undertaken in-house by these comparators.

More detailed work has recently been undertaken on these areas in other reports.

6.3 Network Rail

The following summarises our understanding of Network Rail's position:

- Early planning facilitates safe and efficient access to the infrastructure;
- Early planning needs early visibility of requirements;
- "Seven Day" railway concept increases pressure on inspection and maintenance, with a number of good initiatives being reported as implemented during CP4; and
- Work is on-going to improve resource planning by taking a system perspective, for example the "One Plan" initiative.

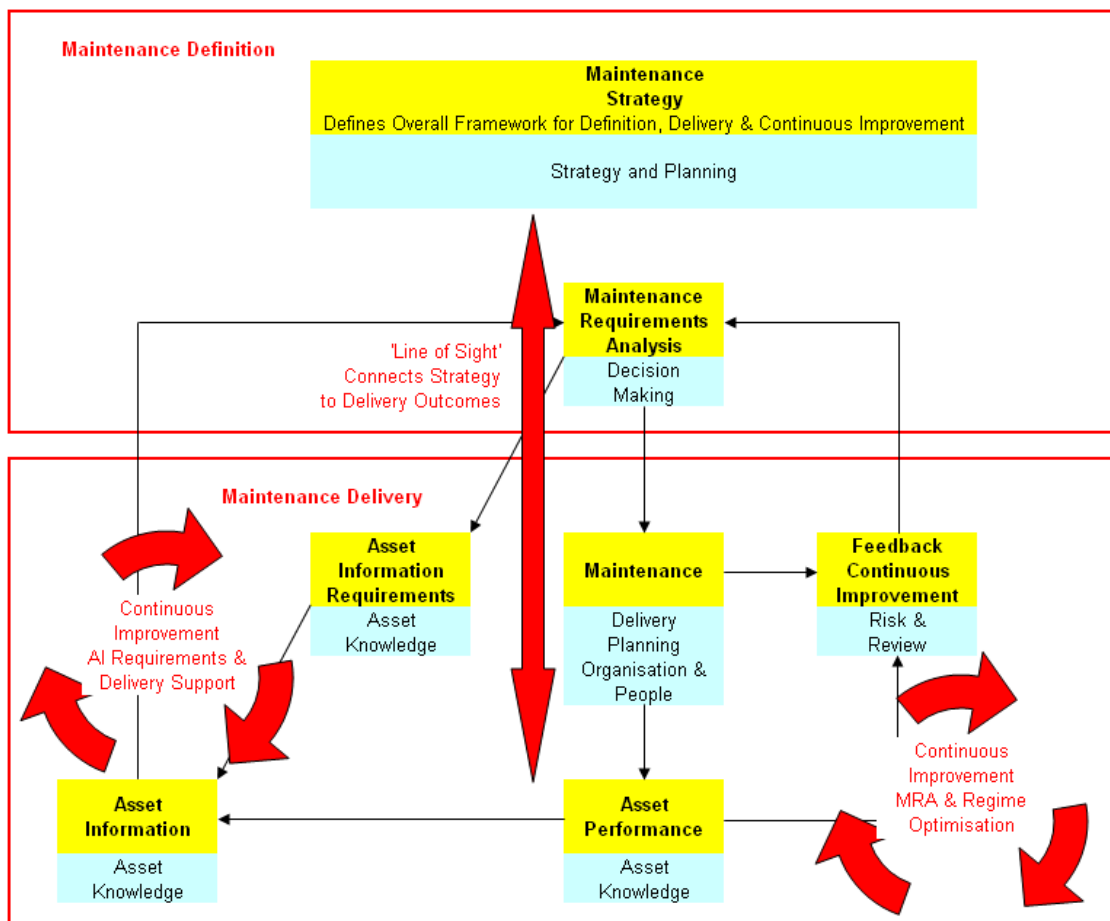
7.0 ORGANISATION AND PEOPLE

7.1 Overview

Definition and delivery of maintenance requires an active learning culture, which is characterised by the following requirements:

- Clear 'line of sight' from the maintenance strategy, through the planning and into the delivery of maintenance activities;
- Active feedback back up the organisation; and
- Active continuous improvement through PDCA style cycles.

The maintenance delivery framework can help place these two requirements into context. Within this framework change is a natural and on-going activity and a good practice organisation will be able to absorb change on a regular basis.



Good practice organisations ensure these requirements are achieved through developing and maintaining a disciplined and focused organisation with experienced people. They will understand their roles and be empowered, such that they are able to competently discharge the roles.

To enable this requirement to be fulfilled, the organisation needs to ensure that:

- It has clearly defined processes to follow which are effectively integrated;
- The roles required to effectively implement these processes are clearly defined;
- The competence requirements which underpin the roles for delivery of the processes are clearly defined, understood, developed and maintained.

7.2 Comparator Good Practice

Appendix E contains details of the identified good practice in this area.

The following areas of good practice have been identified:

- Strong level of leadership and drive is required to implement the changes into the organisation;
- Roles and responsibilities should be defined;
- Regulatory pressure is seen as one of the drivers for improving performance;
- Drivers for change are improving performance and reducing costs;
- Whether present or not, the need to reduce non-availability penalties is not seen as a key driver;
- Cultural change requires a clear decision to be made by staff involved;
- Need to understand the competencies needed to achieve the desired culture.

7.3 Network Rail

The following summarises our understanding of Network Rail's position:

- Changes in the industry are driving the requirement for a different culture and competency set; and
- Rail industry retains a culture that is resistive of change.

Experienced engineers will be required to deliver the changes envisaged. They will be involved in undertaking the FMEA/FMECA assessments, applying the risk-based regimes at a local level and interpreting performance based Standards. Evidence indicates that the shortage of such engineers is being addressed.

8.0 REVIEW AND IMPROVEMENT

8.1 Overview

Good practice organisations will have clearly defined maintenance delivery processes which are continuously improving over time. There are a number of specific items that good practice organisations exhibit in this area, including:

- Feedback loop from delivery to planning;
- Continuous improvement, including use of lean/kaizen approaches;
- Standardisation; plus
- Benchmarking (internal and external) with benefit realisation tracking.

8.2 Comparator Good Practice

Appendix E contains details of the identified good practice in this area.

The following areas of good practice have been identified:

- Assign responsibility for reliability improvement;
- Impose strong governance and a defined process for continuous improvement;
- Impose strong governance to control variation in order to obtain benefits of standardisation;
- Impose strong governance and a defined process for benchmarking;
- An embedded PDCA-based feedback loop is seen as good practice;
- Regular review of reliability and failure data facilitates continuous improvement.

8.3 Network Rail

The following summarises our understanding of Network Rail's position:

- An internal benchmarking approach has been developed that harmonises the structural differences between Delivery Units;
- Identification and spread of track maintenance best practice methods is being rolled-out across Network Rail through use of "Apps" on hand-held devices;
- Opportunities exist to benchmark approaches with HS1 good practice;
- Increased change management support will be provided from the centre to help sustain use of revised methods;
- Benefits of a Lean/Six-Sigma programme have yet to be realised, although work has previously been undertaken in both maintenance and track renewal. It is understood that the LNE Route organisation is deploying lean principles to improve their support activities.

9.0 CONCLUSIONS

9.1 Benefits

The introduction of a revised maintenance strategy based on the principles described in this report is usually undertaken as an overall long-term improvement programme. There has been little quantitative measurement undertaken by the comparators of the specific benefits derived from the individual aspects described in this document.

Tracking the benefits achieved from a particular change within an overall system is not always simple. An example from the rail industry would be the introduction of LED signal heads. This will have provided a train performance improvement (reduction in first filament failures) and a reduction in inspection and maintenance requirements (no bulbs requiring attention). However, achieving visibility of the specific savings from this initiative is not a simple task.

All the comparators have indicated that adoption of a risk-based approach to maintenance and inspection provides significant qualitative benefits. This is seen in terms of better understanding of their assets, their maintenance requirements and the continual improvement in maintenance approach. The type of high-level improvements seen by the comparators following introduction of this approach include:

- Introduction of performance-based maintenance reduced costs by 25%;
- Introduction of risk-based maintenance reduced costs by 20%;
- Introduction of a risk-based asset management process reduced costs by 20% and increased asset availability by 20-25%;
- Introduction of a risk-based asset management process reduced system failures by 30%;
- Incorporating an objective to reduce maintenance requirements during the design phase reduced costs by 15%;
- A programme to implement an integrated management system provided savings of 20-25%;

It is also accepted from studies that have been undertaken that a risk-based approach to maintenance will provide a potential 20-30% reduction in overall maintenance costs.

9.2 Benefit Realisation

As already noted, implementation of a risk-based maintenance approach in the comparators has been part of an overall improvement programme. In a similar way, Network Rail already has a number of supporting initiatives. The “Intelligent Infrastructure” initiative is improving knowledge of asset condition by rolling out automated condition monitoring equipment. This is being supported by the use of reliability engineering to facilitate moving the use of this equipment away from just the early indication of faults.

The ORBIS project includes a number of initiatives that are comparable with the introduction of the approach described in this report. The published savings predicted from the ORBIS project are considered in the Section 9.4 below as part of the assessment process. It has been assumed that the cost of improving the available information and associated systems are also already included within this programme.

There may be other relevant initiatives that Network Rail intended to implement, but that have not been visible to the team during this study.

Building on the experience gained by the comparators, a programme length of three to four years is typical. However, Network Rail has already undertaken work in this area, particularly

for the signalling discipline. The degree of maturity achieved by each discipline is considered in the assessments in Section 9.4 below.

Realising the identified potential benefits is a key part of the implementation programme. A series of constraints were identified that could result in the theoretical benefits not always translating into actual savings. The primary concerns are indicated in the table below, together with mitigating actions that can facilitate realisation of the potential benefits.

Constraint	Mitigation
Reduction of inspection and maintenance frequencies do not always remove the need to visit a particular location as other assets still require attention	Improved understanding of asset condition and degradation mechanisms will enable planning to be improved to harmonise job schedules
Calculated savings can result in theoretical reductions that cannot be achieved at a particular location	Consolidation of Network Rail’s maintenance teams into larger units will reduce the impact of this constraint
Increasingly, the driver for the number of maintenance staff is the level of rapid response coverage required to achieve the stipulated performance targets	Increasing feedback of better reliability data will improve asset performance, reducing the level of incidents requiring rapid response
Minimum team sizes need to be maintained to facilitate the manual handling aspects of specific tasks	Continual improvement and mechanisation of tasks will reduce the manual handling requirements

9.3 Enablers

It is understood that Network Rail already has a number of the key enablers in place that support the introduction of a risk-based approach to inspection and maintenance.

The ORBIS project is addressing the asset knowledge issues that have been identified from comparison with good practice from elsewhere. There is also a significant investment being made in enhancing the equipment used to automate collection of asset condition data. The collection and provision of good information underpins a risk-based approach.

A central reliability team has already been formed and is providing support to the Routes. It is understood that there is a quarterly session involving the discipline asset managers from the Routes and the centre to review the emerging reliability and failure data.

Based on good practice identified in the comparators, it is expected that there will be a core team to facilitate implementation. It is anticipated that a core team of six to eight (factored up from experience of comparators on the basis of employee numbers) will be required for the three to four years long programme. Allowing for a suitable level of expenses and training of this team, this is estimated to equate to £1m to £1.5m per annum for the programme length.

Review of the implementation processes adopted by the comparators indicates that some have also employed consultancy support. An indicative estimate of these costs is again £1m to £1.5m per annum for the programme length. It is assumed that the evaluation of the data and subsequent changes to maintenance interventions will be undertaken as “business as usual” activities within the existing organisation.

The general changes in policy towards life extension through refurbishment rather than asset renewal will increase the scope of potential activity affected by the move to risk-based maintenance. However, at this stage no data has been received indicating the predicted impact of this change in policy or the guidance to engineers on the application of the policy.

Network Rail's recent organisational change that has resulted in devolution of control to ten route-based organisations can also provide impetus to the adoption of a risk-based approach. The local engineers will have a better understanding of their assets and the specific performance challenges. The enhancement of localised Route Asset Management functions provides a focus for the implementation of these concepts.

There is a risk to be mitigated that the devolution process will impede the introduction of any national programme, particularly as it is understood that it is up to each Route to decide whether or not to accept the "support" on offer from the centre. Implementation of the concepts described should be undertaken within a clearly defined common framework. This will ensure that the parameters governing and constraining the MRA output are fully understood by everybody. It will also ease the process of identifying and spreading best practice.

It is believed that Network Rail is developing two core documents that will describe:

- Optimising Maintenance Requirements/Regimes ("the WHAT");
- Optimising Maintenance Delivery ("the HOW").

Although not reviewed, these documents may provide the controls necessary to ensure the continuation of the development work already started.

9.4 Opportunities

The potential benefits available from a risk-based approach are considered for each engineering discipline in turn. The assessment is based on public domain information, primarily "Network Rail Infrastructure Limited Regulatory Financial Statements" (Year Ended March 2012) and AMCL's report "Review of Asset Information Strategy Phase 2: ORBIS" (September 2012) undertaken as part of its role as an Independent Reporter.

9.4.1 Track

Annual core maintenance costs for track are £481m.

The track savings from implementation of ORBIS are quoted as 5%, or £60m per annum by the end of CP5. The review also notes that Network Rail has identified that 35% of its tamping is currently ineffective and 33% of Level 2 defects are repeats.

It should be noted that £60m is approximately 12% of the quoted maintenance spend.

There are a number of other initiatives being undertaken within the track discipline that are related to the adoption of a risk-based approach:

- Introduction of a visualisation and decision support system to enable engineers to improve their decision making (Linear Asset Decision System – LADS);
- The infrastructure monitoring fleet is being enhanced with five new vehicles that will be fitted with pattern recognition software to replace the plain-line basic visual inspection of 15,000 miles of track;
- An inspection vehicle has been under development for several years that will enable the routine inspection of S&C to be undertaken;
- Increasing automation of rail testing/inspection process;
- System engineering approach to planning of S&C inspections to reduce number of annual visits required;
- Rollout of iPhones/iPads to standardise collection of condition information and validate actual asset configuration (e.g. S&C details);

- Changes to the applicable Standards facilitate a risk-based assessment of track inspection frequencies to be undertaken. It is understood that this potentially enables CWR inspection frequencies to be extended from 2-weekly to 26-weekly.

There is a good fit between these initiatives and those typically introduced in the comparator organisations. Although full details of the anticipated savings are not visible, the declared range is comparable to those seen elsewhere. As a consequence of this validation, there is probably limited opportunity to realise further benefits from the adoption of a risk-based approach during CP5.

The accumulation of experience and knowledge gained during CP5, performance improvements from continued application of continuous improvement from reliability engineering, plus the impact of the factors detailed above should provide the opportunity to achieve further savings in CP6. Access to good information will enable a move towards FMECA (rather than FMEA) as the basis for determining the maintenance requirements. In particular, more accurate recording of the root causes of failures and unit costs will facilitate better analysis.

The potential changes in environment before the start of CP6 make it difficult to estimate the size of the potential savings, but the experience from elsewhere indicates that a further 5% could be available.

Opportunities also exist to use the knowledge gained to improve the maintenance input into the design process. The case studies identified from both within GB Rail and other industry sectors show that further savings are available. These maybe at the component level (through design of “fit and forget” items) and the system level (by minimising the use of high maintenance items such as switch diamonds).

9.4.2 Signalling

Annual core maintenance costs for signalling are £167m.

The signalling savings from implementation of ORBIS are quoted as 3% on the CP5 exit rate. As Independent Reporter, AMCL recently reviewed Network Rail’s RoSE ((Reliability of Signalling Equipment) programme, Review of RoSE (July 2011). This indicated that 78% of the signalling asset base had been assessed and 48% of the revised maintenance schedules had been approved. However, it is understood that the implementation rate is around 30%. This is due to a variety of issues such as asset condition and maintenance schedules. This has been stated to have supported a saving of 10% to date, or 34% “time on tools” for the affected assets.

Although there have been a number of external factors that have delayed progress on completing the RoSE programme, it has been running for over 10 years. It is believed to be currently focused on scheduled inspection and maintenance interventions (understood to be estimated as 10% of the total cost of ownership). A risk-based strategy is applicable to all inspection and maintenance requirements and not just the scheduled elements. As such, it is anticipated that a further 10% savings should be available by the end of CP5.

Realisation of such savings in this discipline in particular will be reliant on being able to reduce the requirement for rapid response resource levels. As already noted, experience in other sectors has indicated that there is an associated improvement in asset reliability with the introduction of a risk-based maintenance approach.

During the next two Control Periods there is anticipated to be a movement towards introducing an ETCS-based train control system, with an associated continual move towards fewer control centres. Overall, this will result in a different set of assets. However, the interim asset policy indicates that there will be less system renewal and more life extension activity. There has been no visibility of the impact of these changes.

9.4.3 Electrical Power and Plant

Annual core maintenance costs for electrification are £47m, with a further £37m for plant and machinery.

The electrical power savings from implementation of ORBIS are quoted as 5-10%, although a concern is expressed that this saving is double-counted with declared efficiencies from changes in asset policy.

Traditionally, this discipline has adopted a time-based approach to inspection and maintenance. It is understood that an element of a risk-based approach was incorporated in the past. It has been stated that electrical power will be the next discipline to be the focus of attention for the reliability/RoSE team.

As such, it is believed that the overall savings achievable should be at least 20% based on that seen in the comparator organisations. Based on experience elsewhere, the implementation programme will take 3 to 4 years. As such, most of the savings will be realised during CP6.

The scope of the electrification assets under maintenance are expected to change considerably during CP5 as a result of the enhancement schemes included within the HLOS. There is also a pilot scheme to convert an existing 3rd rail traction system to OHLE.

The introduction of a considerable length of new electrification assets provides a good basis to start a risk-based approach. The impact of introducing new assets on reliability has not been considered, nor the increase in maintenance in real-terms due to the increased asset population.

The use of a new system also provides the opportunity to introduce a design that has fully incorporated consideration of maintenance requirements. As already noted, this has been shown to provide the opportunity to reduce maintenance costs by 15% through use of maintenance-free components plus access improvements that ease inspection and maintenance. Specific opportunities that were identified included:

- Use of remote operated systems that enable quick safe isolation and earthing of OLE sections, removing the need for staff to be trackside and decrease time lost mobilising possessions;
- Standardised provision of single UPS at a system level, removing duplication.

The introduction of a considerable length of new electrification assets provides a good basis to start a risk-based approach.

9.4.4 Civil Engineering (Structures and Geotechnical)

Annual core maintenance costs for structures are £39m, with the cost of structural examinations quoted as £37m. A further £375m was spent on structure renewals.

Only minor savings from implementation of ORBIS are expected from civil engineering at this stage. There is a major improvement programme being implemented in this area that addresses a number of asset management related issues.

A report by the Ove Arup and Partners in their role as Independent Reporter “Review Asset Management, Stewardship and Management of Structures” (March 2011) sets out the issues with this asset group and provides a comprehensive set of recommendations. These are based on the implementation of an asset management strategy similar to that described in this document.

It is understood that these recommendations were accepted and are being implemented through the programme. However, concerns have been raised as to whether Network Rail’s devolution process has had a negative impact on the programme. In particular, the

movement of engineers into the new organisations is perceived to have slowed the momentum of the programme.

On the assumption that the programme will be delivered as planned, it is anticipated that there will be little additional efficiency savings during CP5 from this discipline. However, the improved availability of information and a mature risk-based approach to inspection and maintenance offers the opportunity for savings during CP6.

In terms of quoted expenditure, most is spent on structure inspections (95%). There is an opportunity to apply a more structured risk-based assessment of inspection frequencies. However, particularly in this area, it is difficult to estimate the potential efficiency saving without a clear understanding of the existing reported backlog of structure inspections.

The structural examination process will benefit from the opportunity of better access to the infrastructure from remote isolation processes noted above. It appears reasonable to anticipate at least a 5% reduction in inspections, without changing the risk profile.

It is anticipated that better modelling of assets will enable improved structure renewal decision making. This is likely to reduce the renewal costs, but this move is outside the scope of this study.

9.4.5 Telecoms

Annual core maintenance costs for telecommunications are £22m, with a further £55m classified as “Controllable Opex”.

The telecom savings from implementation of ORBIS are quoted as 10% (or £0.8m) from the introduction of hand-held technology. It is noted that the 10% savings quoted is not being calculated using the published annual core maintenance cost.

The traditional approach to telecom inspection and maintenance is similar to that used by the signalling discipline. As such, the savings that should be available from this discipline are similar as those for signalling, but recognising that the process is not yet developed in telecoms, i.e. 10% for each Control Period.

However, there is an on-going investment in new technology that is likely to have a significant impact on the maintenance requirements.

9.4.6 Other Improvements

Introduction of an asset management approach as identified in this document brings other improvements as a consequence of the better information flows and integration of processes. For example, the asset management related continuous improvement process will be able to feed improved insight into the business of the issues based on good data.

It is a general view that any business should be able to improve its cost base by between 1% and 3% per annum through normal business improvement initiatives. This is validated from the review with one of the organisations identifying that they were saving 2% per annum from the application of Lean/Six Sigma techniques.

Early discussions with Network Rail indicated that the organisation may not yet be ready for Lean/Six Sigma techniques across all activities, as there is a need to provide a stable base from which to introduce incremental improvements and the regular use of the same activities. It is noted that the track renewals team report good use of these techniques to improve their operations.

The introduction of regular benchmarking of similar organisations to identify best practice provided more than 1% saving per annum in another industry sector. It is understood that Network Rail has identified a series of peer groups that enable each Delivery Unit to be benchmarked against similar units.

Improvements in asset reliability achieved from a better understanding of asset condition and degradation mechanisms will result in a reduction in Schedule 8 payments. Schedule 4 payments due to maintenance should also reduce with improved capability to predict intervention requirements at an earlier stage in the planning process.

It has also been noted that the introduction of good information systems will provide significant benefits in the development of annual and control period asset plans. The potential benefit could be a 50% reduction in the cost of the planning exercise.

Consideration of these incremental improvements has not been included within the above assessments as there has been no verification undertaken to ensure that these benefits are not already included in other Network Rail initiatives.

9.5 Summary

Having considered the impact of other initiatives that Network Rail has already announced, the potential efficiency opportunities are as summarised in the table below.

	During CP5	During CP6
Track	Negligible	>5%
Signalling	10%	Normal Improvement
Electric Power & Plant	7%	13%
Civil Engineering	Negligible	<5%
Telecoms	10%	10%

The efficiency assessments are based on a realistic view of the improvements seen in other organisations and an assessment of other initiatives visible to the study team. They assume that:

- Planning schedules can be amended to realise the potential benefits;
- Consolidation of maintenance depots enables benefits to be identified;
- Rapid response coverage required to achieve performance targets does not become the prime driver of maintenance resources;
- Continued mechanisation of tasks will remove manual handling constraint on team size.

Negligible additional savings from adoption of an RBM approach have been identified for track and civil engineering disciplines in CP5 following consideration of the other initiatives already being developed. For track that includes initiatives within the ORBIS project and for civil engineering the BCAM programme.

APPENDIX A: MAINTENANCE STRATEGY

A1: Evidence from Comparator Case Studies

A1.1 Maintenance Strategy

A focus on roles is seen in several of the comparators. In one of the rail organisations it is clear that:

- Asset owners and users (government and train operators) set the strategy in terms of what is required;
- Asset manager (railway comparator) set the tactics by planning the “how”; and
- Delivery units deliver the “do” through operational plans.

The focus on Asset Management processes, and the concept of ‘Asset Owners’ operating within a common Asset Management system are acknowledged good practice in this area.

Twenty years ago, one of the comparators undertook maintenance based on a planned repetitive basis. This was based on an extremely rigid and structured policy of conducting maintenance. This type of maintenance can be thought of as being very traditional, top-down, and hierarchical. This approach was regionalised as well, which meant that different maintenance policies existed in different regions.

The process of introducing a revised maintenance strategy was as follows:

- Maintenance planning being centralised with one maintenance plan that covered the whole country (i.e. there were no longer any regional variances and all areas followed a common framework);
- Common framework achieved by conducting a large maintenance review across all asset families, with maintenance frequencies changed to try and group different asset interventions together;
- Application across the country did not account for regional variation in asset condition, life, or usage;
- Development of a more sophisticated framework with an underlying structure of fairly rigid maintenance frequencies, but with added flexibility, regional variation;
- Increasing focus on using a risk and criticality approach.

A similar development process has been seen in another of the comparators. The planning process is fairly complicated as they initially begin by looking at a 10-20 year timeframe where forecasted levels of required output are forecasted. Eventually, a 3 year outage plan is created which becomes increasingly fixed in time as it gets close to time zero.

Initially this was undertaken regionally with each district having knowledgeable engineers who understood the condition of all their assets. However, the policy procedure and monitoring in one region was conducted completely differently to that of the next region. This made it much more difficult for the central body to collate and compare all the results together.

Now a more fluid asset management approach is adopted. Failure events are qualitatively and quantitatively assessed with proactive measures applied across the entire asset population. Updated scenarios are fed back into the long range plans; which have more flexibility. This means is that there is a continuous feedback process in order to better develop maintenance strategies and plans to a continually changing environment.

The maintenance strategy for another comparator is reflected in their organisational structure. The principle is to split maintenance into three main elements:

- **First Line Maintenance**

They are responsible for keeping systems available for service. The teams are multi-skilled personnel and line-based (i.e. customer focused). Their day-to-day work involves maintenance, inspection, minor corrective maintenance and identification of potential future maintenance or renewal requirements.
- **Second Line Maintenance**

They are responsible for enhancing system reliability, availability, maintainability and safety. This provides a more effective service. The teams contain functional 'subject experts'. They support the first line organisation with technical expertise, plus the collection and analysis of asset information to improve RAMS.
- **Support**

They are responsible for ensuring that the first and second line organisations can function efficiently. This element contains planning and control, system support, and resource development.

An organisation has a simple approach to determining the optimum interventions using a risk based approach. Objectives are valued and a life-cycle cost model used to identify unacceptable risks. A risk matrix is then developed and mitigating actions identified. These are then prioritised on the basis of greatest risk reduction achieved per unit cost investment.

Another organisation deploys two types of maintenance to support the system:

- Preventive maintenance; and
- Corrective maintenance.

Preventive maintenance is undertaken to keep an item in a specified operating condition through regular maintenance tasks and through systematic examination to detect and prevent potential failures. The latter comprises surveillance examinations, condition monitoring and functional checks. A maintenance plan is developed that details the periodicity at which preventive maintenance is performed.

A1.2 Through-Life Maintenance Considerations

Broadly in line with Britain's CDM Regulations, one of the comparators has made its design engineers responsible for ensuring that maintenance requirements are reviewed for all configuration changes. Confirmation that this has been done is a necessary part of the design verification process leading to design approval. The scope of the review ensures that the revised maintenance requirements properly reflect the changes made to the design.

Another comparator has a process to ensure that assets are planned, acquired, operated, maintained, upgraded and disposed in a systematic manner that meets the agreed needs of nominated stakeholders at minimum lifecycle cost. Risk management techniques are applied across the asset's life cycle to ensure specified levels of service quality, safety, environmental risk, and economic outcomes are achieved in a timely manner.

Another comparator was able to achieve a reduction in through life maintenance costs of 15 percent when introducing a new range through design improvements and improved documents and training. The types of changes that were made to lower maintenance costs included:

- More common parts;
- Fewer parts (30% reduction);

- Easier access for maintenance teams; and
- Built-in monitoring equipment with improved user interfaces (reducing time and errors during fault finding).

Maintenance is a key consideration throughout the Asset Lifecycle for one of the utility comparators. The framework is summarised in the table below.

Lifecycle Phase	Approach / Deliverables	Notes
Planning	Maintenance and Support Concepts (linked to Operating Concept)	Includes consideration of: <ul style="list-style-type: none"> ▪ Available maintenance windows; ▪ Ownership of spares and other support facilities; ▪ Form and period of any support contract; and ▪ KPIs for measurement of contract performance.
Acquisition	Support(ability) Analysis Establishment of Asset Identification and Coding	Develops Asset Specification in terms of: <ul style="list-style-type: none"> ▪ Reliability and maintainability analysis; ▪ Failure Modes, Effects and Criticality Analysis; ▪ Maintenance Requirements Analysis; ▪ Spares Requirements Determination; and ▪ Training and Documentation.
Use & Maintain	Asset Configuration Asset Identification and Coding MRA and Maintenance Plans	Implementation and delivery of specification from Acquisition phase. MRA continues throughout asset life. Changes made to asset configurations will be reflected in updates to asset maintenance regimes. Maintenance plans summarise the programmed maintenance requirements.
Disposal	Continuing Maintenance and Support obligations	Capture any ongoing requirements while assets are being disposed of.

“Use & Maintain” is the main step in the framework. This covers continuous maintenance improvement through reliability engineering activities to develop engineering changes that either enhance asset performance or reduce costs.

A1.3 Comparator Good Practice

The following areas of good practice have been identified:

- Good practice is seen as clear assignment of asset owner, asset manager and service delivery roles;
- Development of a maintenance strategy that is based on optimised intervention;
- Align the organisation with the developing maintenance strategy; and
- Maintenance costs must be considered at the design and procurement stage.

A2: Evidence from Follow-Up Discussions

A2.1 Maintenance Strategy

In general, all the comparators have a clear separation in the responsibilities of asset owner, asset manager and service delivery. The functions of asset owner and asset manager are usually undertaken by a central team. Service delivery is managed at a lower level, whether using in-house or external resources.

A typical organisation structure consists of:

- Engineering group responsible for policy, strategy, defining the criteria for renewal and maintenance decisions plus engineering standards;
- Network Development team who are responsible for development of the asset management delivery plan plus provision of design and project management services for projects;
- Operations team who are responsible for the delivery of maintenance, renewals and projects.

A clear split is also seen in the responsibility for undertaking a maintenance requirements analysis (MRA) and delivery of the maintenance activities. In terms of the typical comparator organisation described above, the MRA is undertaken by the engineering group and delivery by the operations team.

The details of determining “doing the right thing” generally do not sit in a separate maintenance strategy document, but as part of a broader asset management manual. The discussions identified that these typically set out the strategy for developing a risk and condition based approach to determining maintenance requirements, i.e. how to undertake the MRA process.

The approach to implementation has varied across the comparators, although generally external support has been sought at the start. The success factor is seen as ensuring that there is a competent core team who are trained and able to provide support across the organisations

Reviewing across the comparators has not identified that there is a need to train people throughout the organisation in the techniques. This approach is supported by the conclusions from above that the MRA process is usually undertaken by a central engineering team.

Initial implementation of this type of maintenance strategy was reported to have been implemented by a small team of 2 to 10 people. An initial timeframe of 3 to 4 years has been seen for completing the first cycle of assessments. A typical response was:

“External expertise was used for facilitation in the early years but they then employed an external person to run the process internally. All other resources came from within the business or from existing contract staff. It was estimated that a central team of two people was necessary to run the process over 2 to 3 years, with appropriate input from the engineers within the business.”

This organisation employs approximately 5,500 as a comparison in size.

A2.2 Through-Life Maintenance Considerations

Most of the comparators identified that they undertake regular reliability analysis sessions to identify issues that require actions.

A typical approach involves review of service delivery in terms of reliability, safety and quality. Any areas where reliability is identified as being outside the anticipated parameters are reported to the Strategy Division for resolution. Where local circumstances are causing a reliability issue, this would typically be addressed by the service delivery group

and the Strategy Division would be informed. The frequency at which these meetings are held varies from monthly through to annually, but are typically 3-monthly.

A2.3 Summary of Further Good Practice

The following areas of good practice have been identified:

- Clear definition of asset owner, asset manager and service delivery roles and responsibilities;
- Task of undertaking the MRA process is the responsibility of a group other than those responsible for service delivery;
- Need for a separate maintenance strategy document is not a prerequisite, but direction is required on how to undertake an MRA;
- Small competent core team required to support implementation;
- Typically, initial rollout programme is 3 to 4 years duration; and
- Emerging reliability performance should be reviewed on a quarterly basis.

APPENDIX B: DECISION MAKING

B1: Evidence from Comparator Case Studies

B1.1 Criticality Assessment

Many comparators do not utilise an overall criticality analysis to differentiate between different assets within an asset type. Within an asset type, different designs may be treated in different ways, but this is a consequence of the way interventions are assessed and optimised, rather than a ‘drill down’ through an overall total cost of ownership criticality analysis.

Examples have been identified in several comparators of the use of a FMECA based approach to determine asset criticality. Generic industry categorisations have also been used to define criticality, although this approach does not differentiate between different levels of risk for different asset types.

Another risk management process that has been seen is to determine how to efficiently split resources between planned maintenance and unplanned maintenance. This approach prioritises maintenance activities in terms of risk criticality, i.e. probability of occurrence multiplied by consequence.

The risk and criticality approaches seen in another comparator uses a combination of historical data and ‘on ground’ local knowledge to decide which are the critical assets that need to be seen to and which ones can be left to be dealt with at a later date. This local inspection and assessment process is checked by the overseeing individuals in the central office to see if that is the right move for the company as a whole. There is good feedback from top-down and bottom-up aligned alongside the business objectives.

B1.2 Maintenance Requirement Analysis

A good high-level maintenance strategy integrates capital maintenance and renewals, with links to strategic objectives and overall serviceability requirements. A utility has been reviewed that approached this by:

- Translating the objective into quantifiable service measures;
- Assessing the impact on these measures of the performance and risks associated with individual components;
- Developing investment plans that address each item based on its contribution to achieving the objective.

This requires an in-depth knowledge of each item’s condition and performance to enable a robust risk assessment to be undertaken. The utility in question also considers the system-level redundancy in order to identify items that may be allowed to fail (i.e. lower proactive maintenance expenditure) without impact on system performance.

Another comparator has systematically analysed and modified its maintenance and inspection standards using formal techniques in order to specify its minimum requirements that will meet safety and output requirements. It utilises preventive, corrective, clock/age-based maintenance, inspection and monitoring strategies dependent on asset and condition.

Elsewhere, a central team provide a centre of excellence for MRA services. MRA is carried out using a bespoke software tool in which the results of analyses are also recorded. This provides a traceable record of decisions as well as a database of potential failure modes and current information on failure rates used as part of the analysis.

For one off unplanned failures, the attitude is a “fix on fault” approach but with information being fed into a central information system. The information in the database can then be analysed in an asset health review process (usually once a year) whereby teams of experts

look of the data and make decision on whether the maintenance strategy is correct. This approach ensures limited resources are not wasted on every type of failure mode in existence within the asset system. Information is continuously collected which means that any emerging patterns can be analysed and used for predictions to better prepare for future events.

The comparator has identified the following benefits from adopting this approach:

- Improved reliability and maintenance.
- Completing projects ahead of schedule
- More money to spend on other resources and areas requiring maintenance,
- Achieved record transmission system reliability of more than 99%

Another comparator has developed processes that ensure an effective maintenance regime can be established that increases efficiency and profitability. The approach has moved from defined maintenance schedules and inspections to one based on condition monitoring. This has extended the installed service life of components without impact on safety or performance by eliminating the renewal after specific time periods had elapsed, regardless of condition.

Use of this approach provides the following benefits:

- Provides maintenance teams with prior notice of defects enabling quicker and more effective repairs to be undertaken;
- Enables defects to be fixed before a failure occurs;
- Reduces downtime.

The MRA approach uses a statistical analysis process that assesses data from every aspect of the systems lifecycle. It uses a series of algorithms and advanced statistical analysis techniques to identify the optimum maintenance intervals for maintenance inspections. The analysis is based on reliability and cost-management models that allow for an optimum interval to be determined.

An organisation has developed condition based maintenance where the condition of equipment by is monitored by periodic or continuous (on-line) equipment monitoring. The goal is to perform maintenance at a scheduled point in time when the maintenance activity is most cost effective and before the equipment fails. This is in contrast to time and/or operation count based maintenance where a piece of equipment gets maintained whether it needs it or not. Time based maintenance is labour intensive, ineffective in identifying problems that develop between scheduled inspections, and is not cost effective.

Predictive maintenance uses principles of statistical process control to determine at what point in the future maintenance activities will be appropriate. Techniques such as infrared, acoustic (partial discharge and airborne ultrasonic), corona detection, vibration analysis, sound level measurements and oil analysis are used to determine the optimum intervention point.

The management of requirements through the application of RAMS and the Systems Assurance Process is acknowledged best practice. A railway-based comparator has based its lifecycle approach on BS/EN50126. The focus on reliability improvement and root cause analysis provides an effective mechanism for managing asset performance risk.

A comparator utilises two main techniques to help establish failure mode risks, and the most appropriate mitigation strategies:

- For 'low volume, high risk' assets 'Asset Risk Models' have been developed which model the anticipated deterioration, failure rates and consequences of failure to determine optimised work volumes to maintain 'steady state' risk profiles.

- The approach adopted for 'high volume, low cost' assets is a form of Reliability Centred Maintenance (RCM) which includes a quantitative probability analysis of failure to determine the most appropriate maintenance strategy based on risk.

Detailed loss and consequence analysis is not undertaken, however, an overall understanding of the costs associated with failure are understood and applied, either within the 'Asset Risk Models' or in consideration of the maintenance intervals determined in the final stage of the quantified RCM analyses.

Quantified RCM techniques are applied on some assets, which have been identified as 'high volume, low cost' and which represent a significant overall population-level risk to the business. Where it has justified the approach, a form of quantified RCM to identify capital maintenance replacement intervention frequencies based on a cost-risk trade-off has been used.

B1.3 Models and Tools

The following areas of good practice have been identified:

Typical assessment tools, as seen in the comparators, used to determine optimum interventions include:

- FMECA assets;
- Network modelling;
- Loss and consequence analysis, aligned to risk management framework;
- Risk based modelling to determine the probability of asset service failures, linked to service measures and calculated as a financial value;
- Deterioration models validated and calibrated statistically against actual failure data;
- Investment intervention models and cost-risk optimisation techniques for optimising maintenance and inspection intervals.
- Collecting and using failure information to support maintenance requirements analysis;
- Remote condition monitoring to support maintenance decision-making;
- Both corrective and preventive action processes for continuous improvement.

Competence in using these tools is achieved by either developing a strong group or a comprehensive training programme. A railway comparator has recently completed a large-scale refresher training programme that has delivered a strong competence within the organisation. Their training and implementation programme took three years, but only resulted in a limited number of changes in maintenance and inspection intervals.

As well as the comprehensive training programme, the comparator has a centre of excellence for reliability centred maintenance work. This development work is undertaken as an off-line activity. A pragmatic approach has been taken and they have adopted a steady rollout to extend the use of condition monitoring.

One of the comparators has used the assessments to produce a series of simple maintenance tools. These enable local staff to make risk-based decisions depending on condition and line category.

Reliability centred maintenance models from the defence industry have been seen being used by other railway organisations. This involves the application of the principles of reliability theory within a structured process designed to identify effective maintenance and inspection tasks that will detect or delay failures of the equipment.

B1.4 Comparator Good Practice

The following areas of good practice have been identified:

- Use of criticality analysis is not widespread;
- Many comparators are using a maintenance requirements analysis approach as part of a move to condition-based maintenance intervention;
- Implementation is supported by a competent core team; and
- Tools are available to support deployment of this approach.

B2: Evidence from Follow-Up Discussions

B2.1 Criticality Assessment

Most of the identified comparators undertake criticality assessments of different asset types, but the output is generally used either for prioritising assets for review or making renewal decisions. In general, criticality is assessed on selected criteria rather than total cost of ownership. For example, one comparator uses the following criteria:

- Modelling of redundancy within the system;
- Impact of loss of network availability;
- Impact on performance schemes.

Criticality assessment of different assets within each asset type is more widely seen across the comparators. The identified risks associated with particular locations are seen to influence the maintenance requirements.

B2.2 Maintenance Requirement Analysis

The use of FMECA as part of the MRA process was common across all the comparators. Several had already completed several cycles of FMECA analysis of their main assets. The output from the FMECA analysis feeds into the RCM processes. RCM is seen as being an embedded technique used as part of the MRA process.

Use of cost-risk optimisation techniques is seen as good practice in determining the required inspection and maintenance intervals. One of the comparators described their approach as follows:

“Cost – risk analysis is undertaken at failure model level and then at equipment level by summing all the risk curves. The maintenance periodicity is set at the minimum total business impact with the tolerances for this periodicity being the time (+ or -) that equates to minimum total impact plus 10%. This allows schedulers to fine tune the periodicities. This is also done for assets in different criticality bands, but sometimes the periodicities still end up the same, e.g. the risks are higher but the system design has more redundancy built into it so these factors cancel out.”

Loss and consequence analysis is used by some of the comparators, but this is a developing approach that has yet to be fully incorporated into the MRA process. However, failure consequences are used, generally being identified by engineering judgement.

Little or no specific legislation constraints on the MRA process were identified by the comparators. The main exception being the requirement to undertake some statutory inspections at fixed intervals.

The use of these techniques has resulted in a reduction in reactive work. The proportion of planned and corrective (condition-based) work has increased to 70% to 80% of total maintenance workload. This enables more efficient use of resources with higher utilisation rates being achieved.

B2.3 Models and Tools

No further evidence was obtained for this area.

B2.4 Summary of Further Good Practice

The following areas of good practice have been identified:

- Criticality assessment of asset types is undertaken to prioritise renewals and performance assessments;
- Criticality of specific assets within an asset type is used to determine maintenance interventions;
- FMECA is base tool used for MRA process;
- RCM is an integral part of the approach being used;
- Cost-risk optimisation is incorporated into the MRA process;
- Loss and consequence analysis is being introduced as part of the process;
- Statutory requirements have little or no impact on the MRA process; and
- Reactive work has been reduced to approximately 25% of total maintenance work.

APPENDIX C: ASSET KNOWLEDGE

C1: Evidence from Comparator Case Studies

C1.1 Data Requirements and Specifications

Good practice identified from review of the comparators is that information that needs to be captured about assets is defined during the acquisition phase and then through the MRA process. Failure Modes are defined in the FMECA process so that throughout the life of the asset any failures and incidents can be logged.

There is a clear need to include cost information in these processes:

"Cost information relating to individual assets is a key element in the ongoing analysis of performance and forms an integral part of the organisation-wide continuous improvement process."

In many cases SAP tools are used to fully integrate costs into the asset information records.

The comparator reported it has all maintenance costs specified and stored within a central database, which is monitored and updated regularly. The comparator was able to demonstrate most clearly the effectiveness and coverage of its asset information systems and clear definition of knowledge standards. Its asset register is stored in SAP, clearly defined, and reported to be fully populated. This supports the production of comprehensive strategic plans. Two factors have made this possible:

One of the comparators has regular workshops with key experts (such as specialists, designers, people involved in construction) for a particular asset to review the asset population and failures in the last year or so including any trends to see what can be learnt and applied for the future. All this knowledge and information is put into a review process that is used to help determine different priority levels for different populations to determine replacement priorities. For example, power transformers were thought to have a life of circa 40 years but now typically have a life of circa 35-80 years. This demonstrates how the strict assumption of single life for transformers has now been pushed out into a huge band and this applies to all different asset types across the entire population.

A popular approach among the comparators reviewed was the pragmatic development of asset information systems, often linked into the need to improve asset performance and reliability. For example, a European water comparator has a long history of developing its Asset Information Systems using an iterative 'continual improvement' model as opposed to large transformational type projects. It has worked with SAP to develop its core systems over an extended period.

Through its strong partnership with SAP and the integrated approach to defining systems that meet the requirements of its asset management process, the comparator was able to demonstrate the link from individual asset through to the high-level evidence supporting board decisions. The specification, capture and analysis of data within these systems is regarded as world class, along with an impressive front end to present management information in a clear, usable format.

This approach emphasises the concepts of clearly defined structure, process, and 'line of sight' throughout the organisation, underpinning the effective implementation of Asset Management, including maintenance delivery.

C1.2 Data Capture

A comparator is moving towards automated condition monitoring systems, with a view to fitting these to operational trains in order to improve performance and more effectively manage corrective maintenance. This builds on previous success.

A recent innovation within another comparator has been the introduction of the Condition Monitoring Centre. The priority in setting up the Condition Monitoring Centre was to focus on the highest cost equipment and plant, and that which had the highest performance impact. The next steps in its development will be to provide remote vision functionality, and to begin to integrate the system together, including potentially into its CMMS.

Conversely, a different comparator has a more structured and strategically embedded approach. They remotely monitor the condition of systems and objects like points, train detection and railway crossings on a systematic basis. The system compiles the data in the cloud and enables:

- Monitoring of points, rail temperature, level crossings (closure times, central sections), axle counters, wheel/rail contact tensions and interference currents, train detection, axle short circuits, and points heating;
- Maintenance teams to perform condition-based maintenance (reducing costs);
- Monitoring of the quality of rail infrastructure.

Another comparator uses condition monitoring to support maintenance decision-making by carefully inspecting the deterioration rates of the assets. This deterioration and condition monitoring on a wide range of assets is an area that the comparator understands well. This includes knowing which assets need condition monitoring and which assets can actually be monitored in a condition monitoring fashion. Specific criticality analysis is conducted to work out which assets are the most critical ones. A subset is chosen and systems developed to understand how they deteriorate. The comparator has an overlay which means that all the assets are given a priority assessment.

This is a common approach with condition monitoring only applied if the asset is exhibiting the appropriate signs that warrant condition monitoring. This is particularly valuable where the asset population is large as condition monitoring can be expensive. The premise here is that assets are only replaced when their condition dictates that they should be replaced. Condition monitoring facilitates this as the decision can be quantified.

There is an increasing level of sophistication with regard to condition monitoring; so for example power transformers can have an online oil analysis system installed that dials up if it notices an adverse trend. The information would be transferred to a team who are responsible for condition monitoring centrally. Here an asset can be taken out of service (but declaring it to be failed) before a catastrophic failure occurs based on this process of remote condition monitoring.

Overall, this knowledge and information flows into the models and systems that give an estimate of how many of a particular type of asset should be replaced, inspected or maintained at what frequency at a system level. This analysis process is then verified by independent experts (including modelling, data acquisition, etc.).

A comparator has made use of its existing SCADA system to improve data capture. A range of information is provided including many of the KPIs that make up the 'Balanced Scorecard'. They have responsibility for a business-intelligence 'front-end' that takes inputs from the SCADA systems and converts these into easily accessible real-time or historic asset information on condition and performance. This is increasingly seen as a key enabler for decision-making and is extending its functionality to include a wider range of existing information systems. This expansion is a direct result of MRA processes within the comparator identifying further information that would be of use in refining maintenance requirements.

C1.3 Data Systems and Reliability

A comparator utilises a range of asset information systems which fulfil most of the roles expected within an organisation of this type. These systems are effectively utilised and generally contain accurate and consistent information. Financial systems are linked to asset definitions at an appropriate level in the hierarchy.

Another comparator was observed to have good systems for the capture and sharing of asset information. One example within this comparator was for Defining Condition Information which grades the state of a component using a catalogue of 'reference damage pictures'. The catalogue captures degradation under varying conditions and they are able to assess the residual life expectancy. Cost saving potential has been estimated to be at least 10% of annual renewal volume

This comparator has developed an approach such that when a disruption occurs, workers send disruption reports to the comparator's control and reporting centre which is then distributed among the three regular maintenance contractors. The previous method was message based, and involved lots of phone calls, emails and notes to pass on the status of the disruptions.

Modernising the message exchange process enables faster communication, makes the cooperation with contractors more effective. It improves performance in terms of reliability, availability, maintenance and safety. Disruptions have been reduced by 20%.

A comparator operates a number of information and work management systems, which are typical of those seen in many comparators:

- Asset registers and work management systems;
- GIS;
- Document management system;
- SCADA system;
- SAP;
- Fault management system;
- Modelling predictive system tools; and
- Business reporting tool.

Multiple asset databases have been replaced by another comparator so that, for the first time, all 95 million asset records are located in the same place. Information is pooled from:

- Handhelds;
- Public reports;
- Manual inspections; and
- RCM installations

Each asset can be chosen from a hierarchy and other fixed menu drop down options (based on engineering knowledge but with constant review). This leads to consistency in data recording and makes searching easier across the entire system. Once appropriate work orders have been created, the input data is reviewed and fed into a single central repository (ELLIPSE) to get a national picture for the assets in case the failures are repeated and patterns start emerging which need to be dealt with proactively.

ELLIPSE is used for condition monitoring, asset deterioration data, maintenance planning and FMS. ELLIPSE is the prime/master data source that is being fed into with other data interfaces. This eliminates problems such as duplicate data entry and uploading data separately onto ELLIPSE when it is already on Intelligent Data Capture (as the data transfer is done dynamically).

The comparator has recognised that ELLIPSE is not very good at linking to external data sources for presenting information, so web based applications are being built as attachments to ELLIPSE to present the information to the user in a more useful manner.

A manufacturing comparator builds a detailed inventory of all components that is documented in electronic format. It has a project that focuses on maintenance planning for its customers that requires capture of those customers' actual experience with replacing failed parts and scheduled maintenance.

Within another comparator most of its facilities have predictive maintenance databases. It has determined that, to track the necessary trends, such a database system should include:

- List of critical equipment
- Maintenance and measurement procedures for each type of equipment
- Maintenance schedule
- History for each measurement
- Limits for each measurement (maintenance alarm trigger)

C1.4 Comparator Good Practice

The following areas of good practice have been identified:

- Data requirements should be identified at the acquisition stage;
- Unit cost information is a key part of the information set;
- Regular review of the collected data should be undertaken to feed into the continuous improvement process;
- Automated condition monitoring technology is widely available;
- Proactive decisions need to be made about which assets to fit with condition monitoring equipment;
- Use clear, consistent definitions of asset condition; and
- Use a single system to store information.

C2: Evidence from Follow-Up Discussions

C2.1 Data Requirements and Specifications

A critical input into the process has been identified as the availability of good asset failure information. This is used to support the MRA process, reliability analyses and thus the continuous improvement.

One of the comparators collects information at failure mode level within their SAP system. This is fully aligned with the FMECA analysis. It is marked as mandatory within SAP, but the comparator simplified the process for the operatives so it can be entered by using drop-down check lists. Each failure is recorded by component, defect and cause. Statistical analysis is undertaken to identify any 'rogue' areas and additional training / briefing is undertaken where this is found. There were some early issues with data quality, but most problems have now been eliminated.

Provision of cost information to support the MRA process is seen by all comparators as important. However, it is also generally recognised as an area that requires further improvement to correctly determine relevant unit costs.

A clear business owner of the information is seen as good practice across all the comparators. This owner is responsible for ensuring that the information requirements are defined and suitable systems available. Information requirements should be set outside the operational service delivery teams to ensure that the input into the MRA process is adequate.

As a consequence, there is a general alignment seen in responsibility for undertaking the MRA process and ownership of the information.

C2.2 Data Capture

Automated condition monitoring is widely used to support maintenance decision making. However, a clear cost benefit decision is required to ensure that the equipment is installed on assets where they provide a benefit, especially with large asset numbers. This is particularly the case if the monitoring equipment is being retro-fitted.

Hand-held devices are widely used to support the collection of information and seen as a “business as usual” part of the maintenance toolkit. The most common type of technology in use is Apple products (iPhones and iPads). These typically directly interface with the maintenance systems, hence mitigating the risk of data corruption.

C2.3 Data Systems and Reliability

Information systems are used to support:

- Maintenance requirements analysis;
- Maintenance management;
- Failure and incident management; and
- Performance reporting.

In general, the trend seen across the comparators is to use commercially available “off-the-shelf” systems.

C2.4 Summary of Further Good Practice

The following areas of good practice have been identified:

- Availability of good failure data underpins the MRA process;
- Lack of suitable information, particularly unit costs, is a constraint;
- “Owner” of the information is identified who understands the requirements beyond the operational context;
- Automated condition monitoring systems are widely deployed, although on a case-by-case basis;
- Hand-held computers as seen as “business-as-usual” applications; and
- General use made of commercially available software (rather than bespoke systems).

APPENDIX D: DELIVERY PLANNING

D1: Evidence from Comparator Case Studies

D1.1 Shutdowns (Possessions)

A comparator uses a centralised system for the booking, granting, notification, implementation and review of possessions. The system provides support for the entire engineering works management process. It provides proposed, optimised, weekly possession plans for consideration by the weekly Engineering Works Management meeting and facilitates interactive re-scheduling during that meeting. It also provides electrical works planning (for outages, if required) and facilitates the execution of possessions, engineering and electrical works, as well as management review of performance.

The comparator employs the system to help plan and manage possessions and electrical outages. On the night of the possession, the OCC will coordinate the taking of the possession and the implementation of any required outages. The comparator typically closes down the entire line on which five or six worksites might be set up. The electrical isolation is taken for the whole line in accordance with pre-defined switching instructions implemented from the OCC in liaison with the possession staff.

A comparator has the ability to put experts on site months in advance of a shutdown; planning, organising, and managing its people and subcontractors from start to finish. The comparator undertakes shutdown planning 9 to 18 months before the anticipated shutdown is to take place. Seven areas: procurement, engineering, maintenance, operations, quality assurance, HSE & security, and administration will have activities that can be executed during this planning period. To ensure these shutdown planning activities are tracked and completed, they are included on a master execution schedule.

Minimising the duration of the outage can have a major impact in reducing the cost of lost production. Providing qualified and experienced personnel to augment the resources available to handle shutdown planning and scheduling, manage the shutdown activities, and assist in the start-up of the facilities to minimise the out-of-service time.

D1.2 Safety Processes

Safety is generally one of the most important requirements for many asset-intensive organisations. Safety Plans are now mandatory and ensure that the supply is fit for use by taking a risk based approach throughout the end-to-end process. Other safety considerations include those relating to workers, particularly in confined or difficult conditions and for work in the highway.

For a comparator, the safety of the public and the workers is its highest priority and its main focus for improvement. It has set up an objective to raise awareness of safety by adding safety procedures, including safety inspections and hazard alerts. The Lost Time Injury Frequency Rate is the key indicator the comparator focuses on, which is a common measure amongst comparators.

Safety is another comparator's first priority, both for customers and for employees. The comparator uses Lost Time Injury Frequency Rate (LTIFR), Medical Treatment Injury Frequency Rate (MTIFR) as well as Recordable Injury Frequency Rate (RIFR) to assess its safety performance. In 2009/10, a safety observation program was implemented, with all employees encouraged to contribute in independent safety observations across operations.

The comparator has a mature and effectively implemented risk management framework which is used to develop safety cases and safety management schemes. These are effectively risk registers consistent with the comparator's risk management framework which prioritise safety risks. These risks are then linked into the relevant plant or process strategy

and used to help define focused intervention activities. In this way interventions are prioritised according to safety and other risks.

Safety is critical to a comparator's business performance. The comparator's operations potentially give rise to risk and some of the assets could have catastrophic consequences to surrounding communities if not properly controlled. Operating major hazard sites means managing process safety risks is always a prime consideration in the way the comparator runs its business. Currently the principal causes of lost time injuries are road traffic collisions, injuries and slips, trips and falls.

D1.3 Resource Planning

The delivery of maintenance activities within a comparator appears to be well understood and controlled. The main asset register and work management system is the EAMS which contains a defined hierarchy of all the comparator's assets and the associated maintenance scheduled tasks as defined by the relevant manufacturer's specification or RCM study. These are translated to Check Sheets and Working Instructions, which are made available to shop floor staff accessible through the on-line documentation system. All disciplines utilise the same system and approach to planning and executing maintenance work (infrastructure, rolling stock and stations).

Resource planning is often undertaken in detail in a Computer Maintenance Management System (CMMS). An example was seen of Total Maintenance Planning (TMP) service schedules that include maintenance action blocks which detail the individual maintenance tasks (actions). The service schedules package the tasks of common frequency and those requiring common competency for the equipment being managed.

Another comparator uses a system where both planned and corrective maintenance work is raised and scheduled within the respective planning support team. Reactive maintenance is raised via the fault management process. Forward plans of between six and eight weeks are generated and issued on a weekly basis to the delivery teams. The comparator does not operate 'hand-held' technology to issue and control work orders, which are managed using a paper system. Planned maintenance is monitored on a monthly basis and it was reported that the management of backlog is not a major concern as plan achievement levels are high.

D1.4 Supply Chain Management

A comparator operates to a set of principles in whether to out-source work or undertake it using in-house resources. Each decision is assessed on a case-by-case basis according to the principles. Due consideration is taken of market conditions, availability of capable contractors in the market, and the in-house work force profile.

The performance of out-sourced contracts is monitored monthly and a 'demerit' points system is used to help focus attention on important issues. However, the contracts perform well and there is a good relationship between the comparator and its contractor.

Another rail comparator performs well in the area of supplier management and is considered to have been one of the organisations that have best learned from the outsourcing and contracting process. The asset management department of the comparator works with certified contractors. The comparator has adopted a performance based contract. These put more risk on the supply chain, but also offer more opportunity for efficiency innovations. There is more freedom for the contractor to organise maintenance operations in an efficient manner, as long as they meet the performance criteria. Practice has indicated that it appears that contractors that have a performance based contract use significantly less time for maintenance than the same contractors do in a maintenance process contract.

The move to implementation of performance-based contracts was based on:

- Stopping prescribing activities, frequencies and required implementation time;
- Checking all the functions in parallel, rather than sequentially;
- Move to proactive maintenance based on FMECA analyses, rather than reactively on the basis of inspections.

There are drawbacks of this approach from the comparator's perspective, including:

- Heavy administrative burden;
- Lack of visibility into actual maintenance costs; and
- Need to change management focus away from being strongly process-led.

One of the keys to this successful implementation was the realisation that the management of RAMS requirements could be extended to help clearly define the contract interfaces.

Different approaches to outsourcing asset management activities have been observed elsewhere. Activities on one network are completely outsourced under a single contract which covers operational and maintenance work, 'steady state' asset replacement work, and minor capital works (known as 'customer capital'). The same types of activities on other networks operated by this comparator are delivered either in-house or using a range of contractors. Generally the rationale for this difference is the size of the networks, although the retention of intellectual property and 'know-how' are also drivers. This rationale is regularly reviewed.

Within another comparator, the majority of the maintenance is conducted in house (approximately 60-70%). The rest is outsourced on the basis of criteria such as low added value, low criticality or non-unique activities (e.g. general facilities maintenance). This means that the comparator is an "informed asset owner" and has more control over its operations.

D1.5 Comparator Good Practice

The following areas of good practice have been identified:

- Long-range planning enables optimisation of shutdown opportunities;
- All comparators operate within a safety critical environment;
- Clear and well defined process are used for resource planning;
- Resource planning usually utilises a computerised management system;
- Supply chain should be managed on a (measured) performance basis; and
- Clear set of criteria should be in place to understand when it is beneficial to out-source.

D2: Evidence from Follow-Up Discussions

D2.1 Shutdowns (Possessions)

All the comparators had planning systems that optimise the clustering of work into packages that maximise the potential shutdown (possession) opportunities. The intent of most comparators is to understand the shape of both renewals and maintenance plan sufficiently far in advance to ensure that the work drives the shutdown plan and not vice versa.

D2.2 Safety Processes

No further evidence was obtained for this area.

D2.3 Resource Planning

No further evidence was obtained for this area.

D2.4 Supply Chain Management

Generally, maintenance is undertaken by a mix of in-house and supply chain resources, but the former deliver most work.

D2.5 Summary of Further Good Practice

The following areas of good practice have been identified:

- Clustering work to maximise shutdown opportunities; and
- Majority of maintenance work is undertaken in-house by these comparators.

APPENDIX E: ORGANISATION AND PEOPLE

E1: Evidence from Comparator Case Studies

E1.1 Learning Culture

Although the behaviours and culture of the employees have been identified as a key enabler for the success of a comparator, it has not been easy to identify the factors that drive achievement of this objective.

One of the comparators demonstrates clear leadership characteristics which are characteristic of high-performing asset management organisations. This manifests itself in its members of staff who, in general, provide a high degree of confidence that the organisation has a common understanding and set of behaviours which are consistently applied.

The top management of another comparator are demonstrably committed to asset management with clear accountabilities and responsibilities defined throughout the organisation to deliver its requirements. All the posts have clearly set out roles and responsibilities with the Asset Management policy carrying the Managing Director's signature. This culture permeates the entire organisation, with the majority of people clear about what asset management means and what they are trying to achieve as an organisation.

Another operates with an approach based on central policies with local implementation. These are well integrated which allows a better degree of freedom and flexibility at a localised level. There is a clear line of sight within the organisation from the top to the bottom and vice versa and this has been achieved through PAS 55 awareness. Both individuals at the top of the organisation and ground workers get input in the reporting mechanism and feedback and review process, which again implies a good relationship and communication throughout the organisation from a hierarchical perspective.

An example has been identified in one of the comparators where the CEO made a specific appointment of somebody to drive the maintenance improvement programme. This provided focus and leadership. This individual and their team took ownership of the Asset Management process and sought to deliver improvements from the ground up.

One of the other comparators has developed an organisational structure that is similar to Network Rail's devolved organisation, with leadership provided from the centre, but delivered locally. They have a matrix organisation that splits responsibility for delivering its work into two streams:

- National systems, planning, operations and information - provide national optimisation and coordination; and
- Local level regional organisations providing local knowledge and authority.

E1.2 Change Management and Incentives

One of the drivers of change that has been seen in many utility-based comparators has been the influence of regulators. They have driven a programme of standardisation via metrics and processes over successive periodic reviews; both to improve the process and to enable 'regulation by comparison' between organisations. Peer pressure is applied through regular publication of comparison tables by the regulator.

Another comparator has based its continuous improvement approach on effective embracement of quality management principles, inspired by Deming. Again, though, this drive for improvement is supported by its regulatory regime, the need to satisfy customer requirements and the commercial perspective of seeking to identify the optimum balance of investment with performance and safety risk.

A good example of change management can be found in the manufacturing industry. A plant suffered from a culture which included militancy, resistance to change and poor workmanship. The comparator faced a massive reorganisation and the task of changing management in an existing plant with older workers and strong unions. However, the factory had a high potential capacity along with a good transport infrastructure.

The unions were involved early and an agreement was signed that all the products would be sourced from this factory on the condition that they adopted standard operating methods, processes, as well as achieving the quality and productivity levels seen elsewhere.

The biggest challenge was changing the people's thinking that worked at the plant. Each employee was provided with the company's vision, code of conduct and operating principles written in it and they were asked to sign a new contract detailing the new philosophy and way of working. Some 20% of the workers refused to go along with this and left the company. This made the job of transforming the organisation a lot easier. Investment in new equipment combined with empowerment of the staff to continuously improve and spread best practice were key enablers in turning the factory around.

E1.3 Skill and Competence Levels

Good practice within the comparators is recognised as having the organisational capability and corporate objectives for developing the skills, knowledge and engagement of their people.

A comparator has clearly defined and managed staff competence. It has set-up a working group with responsibility for overseeing the mechanisms for the definition, monitoring and continuous improvement of staff competence. They oversee the competence management system, provide a range of asset management related training courses (delivered in-house) and undertake periodic cultural and staff satisfaction surveys, amongst other things.

Another rail organisation has recognised that the move to a commercial and asset management focus requires a different set of skills.

Broader asset management competences have been seen to have been managed through the application of the annual performance review process. The objectives set within these performance reviews appear to be clearly cascaded through the company and are recorded on a central software system. However, maintenance requirements analysis skills and competences are developed as required, i.e. as specific needs or approaches are defined rather than through a vision of future needs.

As with many organisations, one of the comparators have a large proportion of their engineers in their late 50's, which means that they are coming up to an age of retirement. New recruits will be trained up in time to replace these existing staff. Workers are encouraged to be multi-skilled and work across different areas. However, some engineers are still made to be specialist and focus on niche areas. Again, with this comparator, there is recognition that there is an on-going change of skill sets required within maintenance. This needs to be managed and decisions made on how these resources are going to be acquired and combined together in a team.

E1.4 Comparator Good Practice

The following areas of good practice have been identified:

- Clear strong leadership is required;
- Roles and responsibilities should be defined;
- Regulatory pressure is seen as one of the drivers for improving performance;
- Cultural change requires a clear decision on whether staff are "in" or "out"; and

- Need to understand the competencies needed to achieve the desired culture.

E2: Evidence from Follow-Up Discussions

E2.1 Learning Culture

Strong leadership is a critical success factor for the introduction of a revised approach to maintenance. Leadership needs to be provided by a recognised senior manager, who is prepared to push through the necessary changes.

One of the comparators also commented on the core team used to implement the revised approach. They noted that they need to be able to communicate using the terminology of the particular maintenance environment as well as understanding the revised maintenance processes.

E2.2 Change Management and Incentives

The drivers for change were generally reported as being the need to:

- Improve network performance;
- Reduce unit costs; and
- Justify their cost-base to external stakeholders.

The comparators were specifically asked whether the penalties and rewards associated with asset availability were a driver to change the maintenance approach. They were not seen as a driver for the change, but were incorporated into the assessment once the change had started.

E2.3 Skill and Competence Levels

No further evidence was obtained for this area.

E2.4 Summary of Further Good Practice

The following areas of good practice have been identified:

- Strong level leadership and drive is required to drive the changes into the organisation;
- Drivers for change are improving performance and reducing costs; and
- Whether present or not, the need to reduce non-availability penalties is not seen as a key driver.

APPENDIX F: REVIEW AND IMPROVEMENT

F1: Evidence from Comparator Case Studies

F1.1 Feedback Loop

One of the utility comparators has a 'Use & Maintain' phase of their Asset Management Model. This is the area where the opportunity to carry out corrective and preventative maintenance ('programmed maintenance') is undertaken. There are opportunities to improve these processes through the 'reliability engineering' aspects of their work.

Their MRA is refreshed on a regular basis as a consequence of this approach and they have gone around the 'loop' at least once. This has resulted in updates to the proposed frequencies from data improvements and improved history.

In the rail sector, a comparator has a second-line group within the maintenance delivery organisation that has responsibility to enhance system reliability, availability, maintainability and safety for more effective service. This requirement varies across the disciplines, with signalling and rolling stock approaching the task in a more formal manner than stations, as it is these disciplines which have the highest impact on line performance.

The crucial step of recording failure details and following this information up methodically is not neglected. The fault management system requires detailed analysis of faults and incidents, and this information gathering starts during the incident response process. It is then completed and utilised by the second line parts of the organisation.

F1.2 Continuous Improvement

One method observed to ensure a strong asset management culture is embedded in an organisation, enabling effective integration and continuous improvement, is through an asset management governance structure.

Overall governance is provided by the Asset Management & Performance Steering Committee which provides regular review and continuous improvement. Typically, this group is chaired by the "Chief Operational Engineer" who owns the overall asset management system. This particular rail comparator budgets reliability targets across each line and the assets on those lines.

The main driver for continuous improvement of maintenance is the management of reliability, availability and maintainability of the railway system. Quality of service is also influenced by other attributes concerning functionality and performance such as the frequency of service, life cycle costs and fare structures.

Providing clear responsibility for the compliance, governance, strategy and direction of the asset management, including continual improvement is seen as good practice. This good practice is demonstrated in one of the utility comparators, who also publish a meeting timetable as part of their processes.

Key to continued world-class performance is the development of best practices that reduce costs and increase efficiency for every asset in a company's portfolio. Best practices are also safe practices. The global scope of one of the comparators focuses on leading their industry in this area. It shares its best practices for safety and environmental excellence, leading to opportunities for continuous improvement. Another factor in this comparator's successful track record of continuous improvement is a commitment to developing new technology. They were granted more than 4,000 patents in the United States and Europe during a typical four-year period.

The manufacturing comparators have all generally been using lean principles in their day to day manufacturing and production lines for more than a decade. This transfer of best practice and standardisation of maintenance activities is now second nature to their

employees, who have been empowered to make continuous improvement and hold regular kaizen events in order to achieve this.

Two lessons have been identified from the recent performance of one of the manufacturing comparators:

- In the rush to grow the company, many new employees and suppliers were not adequately trained in the methods;
- “Kaizen” is simply a slogan, unless employees have been thoroughly trained to use the many tools and techniques that this philosophy of management employs.

F1.3 Standardisation

Little evidence has been found from the selected comparators on the benefits of standardisation during this initial review.

One of the comparators has minimised its operating costs by standardising the type of asset used. This provides a standardised approach to maintenance, which means that costs are kept low and productivity together with availability is high.

In another rail comparator, service schedules are treated as being equivalent to design decisions. As such, all changes to maintenance requirements need to be approved by a person having suitable engineering authority.

F1.4 Benchmarking and Benefit Realisation Tracking

UK utilities operate in a regulated environment where the Regulator regularly compiles and publishes comparator tables of key metrics such as maintenance efficiency and operational expenditure by asset type.

Performance indicators are the core of steering and control within one of the rail-based comparators. Each indicator has an agreed yearly target. They are reported quarterly and are embedded in the main business units.

The indicators are grouped based on a system engineering technique; with specification trees constructed for rail safety and sustainability. Specifications and inspections were organized by subsystem, greatly clarifying the view both overall and in depth

Another rail comparator has been liaising with benchmarking organisations to prepare a set of comparisons against industry averages. These include customer, efficiency and financial comparisons.

Benchmarking is used elsewhere as an important element of asset management to identify best practice, promote innovation, monitor trends and understand the drivers of cost and performance. However, the complexity of normalisation and the different structural factors often have to be considered.

The primary focus of benchmarking is maintenance unit costs, asset reliability and capital programmes. A focus on maintenance unit rate reductions is important to drive efficiency, but it is essential to understand how maintenance activities contribute to the optimisation of asset costs over their whole life. The long term aim is to achieve an appropriate level of reliability at a sustainable minimum cost.

Benchmarking

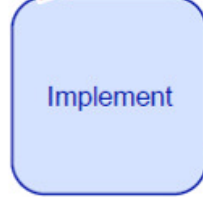
- Unit rate reporting – monitor improvement overtime
- Comparison to other metros / organisations
- Identify gaps for further investigation



- Understand differences
- Drill-down studies
- Share good practice
- Technical visits
- Make recommendations



- Define and plan improvement initiatives
- Manage improvement programme(s)
- Trial changes
- Extrapolate future costs and performance



Business Improvement

- Deliver improvements
- Change processes
- Invest in people and technology

Comparative regulation has been shown to have significant benefits. The Office of the Gas and Electricity Markets (Ofgem) estimated that this provides incremental efficiency improvements of 1.13% per year over 15 years. The National Audit Office (NAO) found that this was likely to underestimate the benefits.

F1.5 Comparator Good Practice

The following areas of good practice have been identified:

- Assign responsibility for reliability improvement;
- Impose strong governance and a defined process for continuous improvement;
- Impose strong governance to control variation in order to obtain benefits of standardisation; and
- Impose strong governance and a defined process for benchmarking.

F2: Evidence from Follow-Up Discussions

F2.1 Feedback Loop

Good practice was seen in most of the comparators as being a Plan-Do-Check-Act (PDCA) feedback loop based on assessment of failure and reliability data.

F2.2 Continuous Improvement

The above noted good practice facilitates continuous improvement in performance by enabling the reliability and failure experience to be fed back into the maintenance process.

F2.3 Standardisation

No further evidence was obtained for this area.

F2.4 Benchmarking

No further evidence was obtained for this area.

F2.5 Summary of Further Good Practice

The following areas of good practice have been identified:

- An embedded PDCA-based feedback is seen as good practice; and
- Regular review of reliability and failure data facilitates continuous improvement.

Balfour Beatty

Rail