Harpur Hill, Buxton, SK17 9JN
Telephone: +44 (0)1298 218000
Facsimile: +44 (0)1298 218590

HEALTH & SAFETY LABORATORY

An Asset Management Model for UK Railway Safety – Literature Review and Discussion Document

HSL/2005/34

Project Leader: **Dr S Turner**
Author(s): **G Brownless, BSc(Hons), PhD**
Science Group: **Human Factors**

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FOREWORD

This report concerns a potential asset management model focused on safety on the UK railways, based on a literature review. It gives an outline of what such a model might look like, what might be involved and some implications of adopting such a model. It should not be construed as a definitive description nor as reflecting Railway Inspectorate or HSE policy. Rather, it is to promote interest and debate on the topic and to serve as a basis for any further work in the area.

CONTENTS

EXECUTIVE SUMMARY

Her Majesty's Railway Inspectorate (HMRI) asked the Health and Safety Laboratory (HSL) to assist them in researching an asset management model for UK railway safety. Asset management approaches may allow the UK to allocate spending on rail safety to maximum economic effect.

Asset management here means a holistic, systematic and optimal way of managing assets to achieve desired outcomes in a sustainable way. HSE research and discussions with rail stakeholders suggests that such an asset management model does not exist either for UK nor international rail systems. Investigating suitable asset management models, the work was unable to find a truly strategic model either from other sectors nor a generic model capable of being applied to rail. The research suggests that a strategic gap exists, and that other sectors that are highly dependant on the performance of physical assets may benefit from such a model to enable them to more effectively and efficiently deploy assets for both operational and safety performance.

OBJECTIVES

1. Conduct a literature survey to identify physical-asset management models for safety on the UK national rail network.
2. Discuss identified models, or, if no suitable models are identified, make recommendations for devising a suitable model.

MAIN FINDINGS

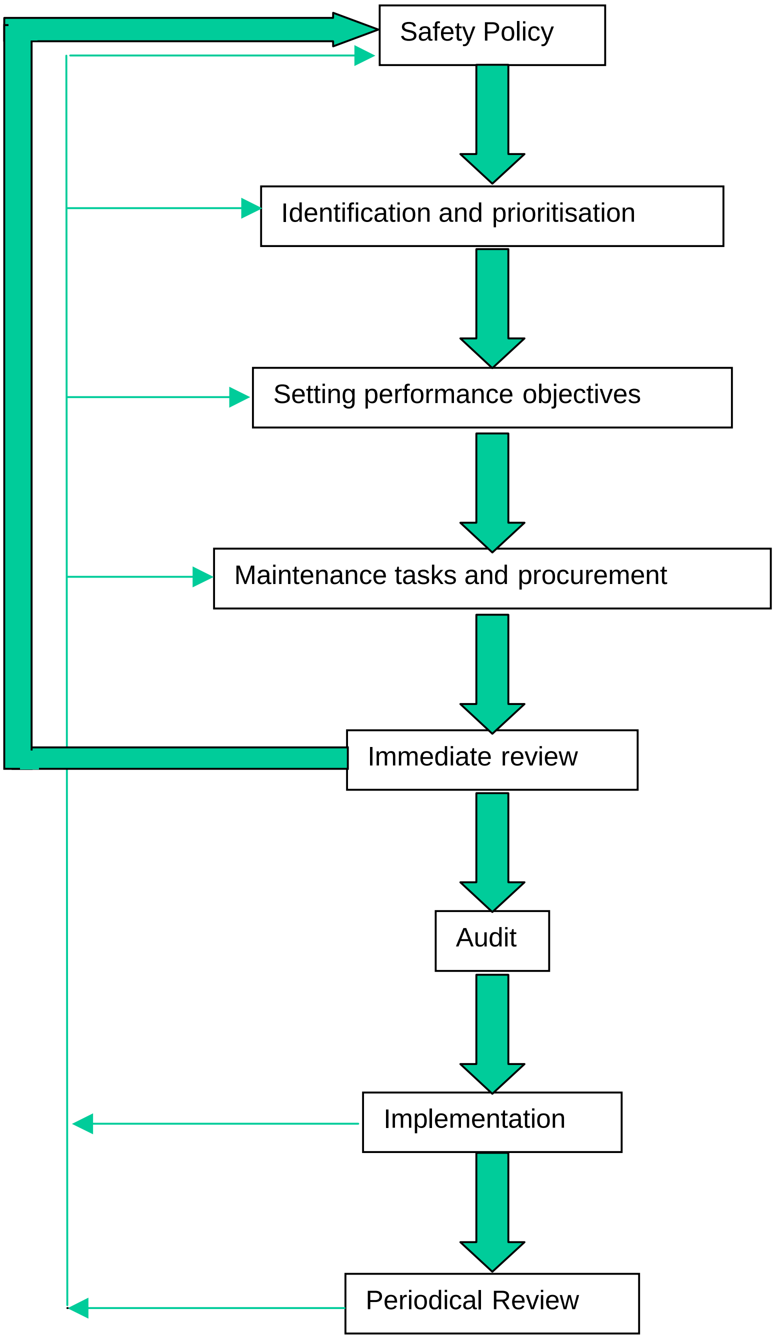
The literature survey identified much work on asset management approaches but most of it was of limited relevance to the task here, generally through being insufficiently detailed, too focused on business instead of safety or in not taking the holistic view sought by HMRI. Although no asset management model for safety was identified in the survey for the rail or other industries, several useful references were found that provided the basis for proposing an outline model, which is summarised in the diagram below.

High level safety targets are set, and accident statistics and the Rail Safety and Standards Board's Risk Profile Bulletin and Safety Risk Model are used to identify and prioritise assets. From these, necessary performance standards are deduced and maintenance schedules and procurement policies constructed. These stages will require good communication between different departments/organisations in the rail industry and will probably require further development of the Safety Risk Model.

The immediate review stage is used to tune the high level targets to ensure that the proposed approach is feasible (e.g. within the available budget).

Full adoption of this approach or similar has policy (and possibly legal) implications for HMRI as it implies moving away from ensuring that risks from each asset are reduced as low as is reasonably practicable and accepting that this has been done for the rail system as a whole. This approach is most suitable for a situation where the challenge is to optimise safety performance within a fixed budget. Through cost benefit analysis or a target setting approach, optimisation of safety performance may be combined with optimising other types of performance.

More limited consideration of this approach would assist HMRI (and other stakeholders) to probe whether the rail industry, in particular Network Rail, have a coherent, holistic approach to controlling the safety performance of their assets in order to meet their high level safety targets.



Outline asset management model

RECOMMENDATIONS

1. HMRI should rapidly disseminate this report to selected key internal and external stakeholders involved in railway safety.
2. HMRI should rapidly disseminate this report to other HSE major hazard divisions/directorates and the Risk Policy Unit.
3. Depending on comments and level of interest following (1) and (2) HMRI should:

    a. disseminate the work more widely (for example, through seminars);

    b. commission work to review RSSB’s Safety Risk Model to confirm that it is feasible to use it in the role described and identify/investigate any issues;

    c. take forward the approach in consultation with key stakeholders;

OR

    d. commission work to develop an inspection checklist based on the ideas set out in this work.

1 INTRODUCTION

Her Majesty's Railway Inspectorate (HMRI) asked the Health and Safety Laboratory (HSL) to assist them in researching an asset management model for UK railway safety. HMRI is interested in how the railway industry, particularly Network Rail, organise themselves to provide a coherent, systematic approach to maintaining their physical assets e.g. track and signals. Whilst accidents and associated precursors show safety performance on the 'front-line' and high-level targets show the aim, HMRI are also interested in the 'middle-ground', that is, how Network Rail manages its safety-critical assets, whose performance on the 'front-line' affect whether the high levels targets are satisfied.

Specifically, HMRI asked HSL to conduct a literature search to identify and review suitable approaches to asset management for railway safety and, if unsuccessful in identifying a suitable model, to consider how a holistic asset management approach might be developed. This report documents the work HSL has carried out.

The remainder of this section describes what is meant in this report by 'asset management' and HMRI's particular interest in it. Section 2 reports relevant results from the literature survey, section 3 proposes an outline asset management approach for the railways and discusses implications of this whilst section 4 briefly considers how asset management for safety (the focus of this work) can be combined with asset management for commercial benefit. Finally, conclusions and recommendations are given in sections 5 and 6 respectively.

1.1 BRIEF INTRODUCTION TO ASSET MANAGEMENT

At face value, 'asset management' is exactly what it says: managing assets. However, it is often used in a more restrictive way and for the purposes of this work may be usefully taken as the definition from (BSI, 2004a):

> *'the optimum way of managing assets to achieve a desired and sustainable outcome'*

and as only applying to physical assets such as track, rather than, for example human resources or intangible assets (e.g. reputation).

The key point is that it refers to optimising the management of assets, which implies a holistic, systematic and structured approach. Essentially, the approach comes from recognising that whilst doing too much maintenance is overly expensive, cutting back on maintenance or making too little capital investment can be a false economy because of increased and unexpected failure of equipment or reduced quality of products. Thus the optimum is to be found somewhere in between these two extremes.

The main driver for developing the techniques has been more effective performance for organisations, whether through cheaper unit costs or more consistent (or higher) quality products. However, since failures are likely to cause accidents if they occur in safety critical equipment, an asset management approach can be applied to controlling safety risk. As will be discussed later in the report, safety will often be an aspect of described asset management approaches but is usually not the main focus.

1.2 HMRI'S INTEREST IN ASSET MANAGEMENT[1]

Policies for obtaining and maintaining physical assets on the UK railways have evolved over the last 150 years or so (the approximate age of the national rail network). Currently, Government spending on the railways is around £5 billion a year (DfT, 2005); when other income such as ticket sales are considered, it becomes clear that running the UK railways is expensive and thus the money available needs to be allocated carefully. It appears that the rail industry, and particularly Network Rail as the infrastructure controller, are recognising a strategic gap on asset management. A suitable strategy would ensure that resources are effectively and efficiently deployed in a systematic way to deliver outputs on operational and safety performance across the railways system. Given that the available budget is limited and represents a large amount of money, even a proportionally small gain in performance is attractive.

Since the railways are to be run such that the safety risk is as low as is reasonably practicable (the requirement to be 'ALARP'), in the absence of such a model it is difficult to be sure whether the rail network as a whole is 'ALARP'; that is, whether spending on safety is optimal. This consideration has some implications that will be discussed in section 3.

Hence, efficiency gains are a motive for investigating the application of asset management techniques to railway safety.

However, a more important reason from a strictly safety point of view is that HMRI wish to be able to demonstrate that they have confidence that railway safety is being properly managed. An asset management approach, which would demonstrate what performance was required of assets and why particular safety standards were set, would go some way to satisfying this wish. As will be discussed, there is common ground here with the role of railway safety cases.

Figure 1 gives a crude representation of how safety is ensured on the railways and where asset management could help, from a purely safety point of view. The top of the figure shows the 'Safety Requirements' that the railway must meet and the bottom of the figure shows the safety performance of assets (e.g. how often tracks fail). Thus poor safety performance of assets means the safety requirements are not met. The middle ground concerns how safety is controlled and managed on the railways – 'quantified risk assessment' represents analysis of safety performance, showing where the highest risks are; and 'standards' represents the way required performance of assets is specified. What is not always clear is how safety performance and its analysis is used to set standards, which is a connection that an asset management approach would make (these connections are the blue, dashed lines). Another key question, both for the operator and the regulator, is whether the safety case is being complied with. An asset management approach (which would be recorded) would make it easier to ascertain that an operator was efficiently managing their risks, hence this box is outlined with a blue, dashed line.

An important point to note is that an asset management approach implies tackling these two areas – of optimisation and safety management – in a strategic, global manner rather than in an isolated manner for particular assets (a more tactical approach). That is, the railway infrastructure is treated as a single system taking into account the many interconnections between various assets and associated procedures.

There are (at least) two other key questions that, as will be argued in later sections, an asset management approach can help to answer:

[1] Much of this section is based on discussion with R. Livermore, HMRI (Livermore, 2004).

1. How safe is safe enough?
2. How does spending resources on safety conflict with spending resources on improved performance?

These issues will be discussed later but it is worth noting that, for (1), a factor to be considered is whether there is agreement (do the operator, regulators and other stakeholders have the same views) and, for (2), that there is a large synergy between performance and safety (since a reliable, punctual service implies a safe service).

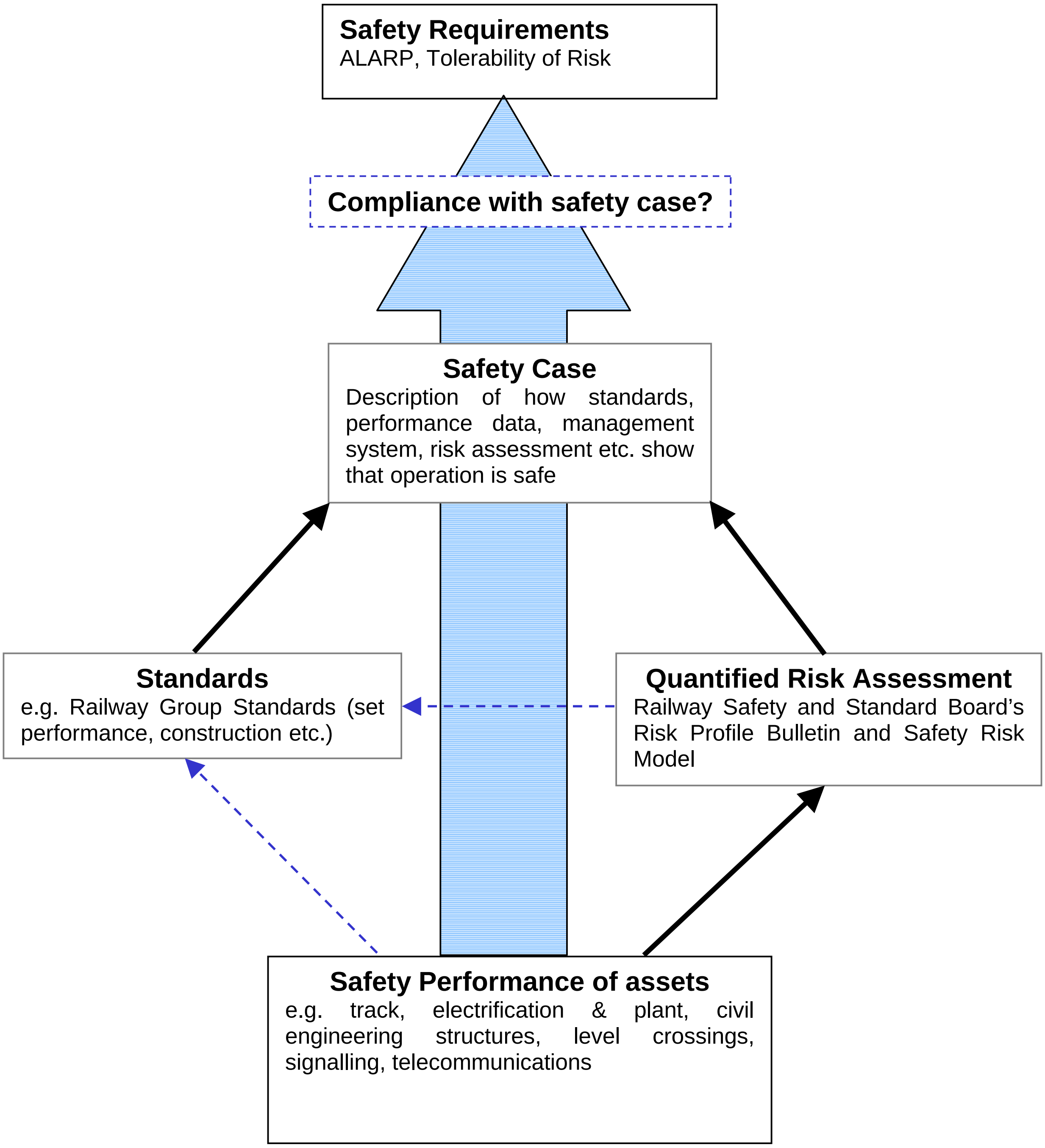


Figure 1 Crude representation of how safety is managed on the railway network. Refer to main text for explanation

2 RAIL ASSET MANAGEMENT LITERATURE REVIEW

Literature databases were searched for documents and articles on asset management in the rail industry and also other industries, such as utilities.

Many of the references obtained were of limited use in this study because they were insufficiently detailed (magazine articles rather than technical papers) or because they dealt with the implementation of specific solutions, discussing what was done and the results rather than a general, unified approach. A CD-ROM with the overheads from the conference ‘Asset Management for Railway Infrastructure’ (Thistle Marble Arch, London, 19-20th October, 2004) was supplied by HMRI but generally the same comments are applicable to these. The most relevant of these are summarised briefly in this section, together with the British Standards guidance on asset management PAS 55 (BSI, 2004a; BSI, 2004b). The most useful reference (Wilson, 1999) is an extensive document and the parts felt to be most relevant have been extracted and summarised. It is worth noting that the articles retrieved during the literature search were all positive regarding the business benefits of implementing a structured asset management programme.

2.1 THE USE OF RISK ASSESSMENT METHODOLOGIES TO PROTECT RESOURCES AND ASSETS (HUGHES, 2002)

This paper discusses how quantified risk assessment (QRA) may be used to improve maintenance of dams through identifying and prioritising failure modes.

One initiative discussed is a ‘portfolio risk assessment’ for a major UK utility with a purpose ‘to facilitate management of dam safety in the context of the owner’s business.’ As indicated by this statement, what is particularly of interest is the way that a tool (QRA) generally regarded as relevant to safety is seen as being integrated into the utility’s business. Outcomes of the QRA study include identifying areas for improvement in monitoring and surveillance, inspections, community emergency preparedness and business contingency planning as well identification of urgent measures. Identified inputs into the business process include: insurance and loss financing, capital budgeting, business contingency planning, benchmarking, community consultation and public relations. The project team included people with a range of roles including engineers, economists, reservoir safety staff and representatives from all business areas. A drawback of this initiative is that it only covers a ‘snapshot’ of the risk and its integration with planning and target setting is unclear.

Another initiative discussed is pilot application of a software tool called ‘INVESTOR’. The paper says that a pilot in the water industry has been completed and a pilot application in the rail industry was due to commence (at the time the paper was written), however the literature survey and contacts with HMRI have not revealed further details of either of these studies. A key difference compared to the previous initiative described is that it includes whole life cycle costing, i.e. it assists in forward planning, as implied by its name. However, the thrust of the software appears to be towards using reliability data to improve business performance and its connection to safety is not explicitly covered.

The topic of this paper is of relevance to the current project but the initiatives covered are probably not what HMRI are seeking, although this cannot be confirmed from the paper which necessarily gives only a brief summary.

2.2 MULTIVARIATE STATISTICAL MODEL FOR PREDICTING OCCURRENCE AND LOCATION OF BROKEN RAILS (DICK, 2003)

This reference does not describe an asset management model and thus is not directly relevant to this work. However, it is an example of the type of work that may need to be done to fully utilise an asset management approach on the railways and it shows what could be done in terms of targeting maintenance. As will be discussed later in the literature review, an understanding of the failure profile with time of an asset is crucial to developing an optimised approach to managing it. This paper describes the statistical determination of key parameters in the likelihood of a rail breaking. Unsurprisingly, the rate of breakage is found to increase with the age of the rail but other factors, such as track geometry, were found to be important.

2.3 MAINTAINING THE BALANCE (DWYER, 2001)

This reference is included as an example of the less detailed articles retrieved by the literature search but nevertheless gives a good summary of key aspects of asset management in general, covering aspects such as human factors, life-cycle costs and the 'repair or replace?' dilemma. The article is based around the 'Macro' project, led by the consultancy Woodhouse Partnership, which produced a combination of management techniques and software tools. The article argues that the project results go beyond Reliability Centred Maintenance (which will be discussed below) because it includes the cost of failures and thus allows the maintenance plans to be optimised, whereas Reliability Centred Maintenance's 'approach is to eliminate them [i.e. failures]'. It seems clear that an approach allowing (financial) optimisation of a maintenance strategy would be necessary for a 'grand unified theory' but may not be the most appropriate starting point for developing an asset management model for safety concerns. The paper notes that 4 out of 7 zones of Railtrack were using methods from the 'Macro' project with the others due to be trained in the methods at the time the article was published (May, 2001).

2.4 ASSET MANAGEMENT DECISION MAKING (WOODHOUSE, 2004)

This paper covers the same ground as the previous reference but with more detail in a number of areas, for example, more information on the 'Macro' project. Again the emphasis is on optimisation from a business perspective rather than optimal asset management to achieve safety targets. However, it is noted that across-the-board application of fully developed asset management approaches may result in the amount of money spent on asset management itself not being optimal. In this context, the author suggests prioritising the assets in question into different bands, suggesting typically:

- Vital few areas (5-10% of the total) requiring full quantitative treatment;
- Core areas (30-60% of the total) for which templates or structured rules are adequate; and
- Low criticality (remainder) where 'structured common sense' may be applied to modifying or adopting maintenance strategies rather than starting from a zero-base, in contrast to the previous two categories.

This approach maps closely with the approach suggested by the Hazardous Installations Directorate for the level of quantification and detail required for COMAH safety reports. The reference notes the need to distinguish between business efficiency (doing the right thing) and administrative efficiency (doing something well) and suggests that often there is too much emphasis on the latter, rather than asking if something should be done at all. The paper also emphasises the use of life cycle assessment, stakeholder interests and covers commonly found constraints in applying asset management in organisations. These constraints are not directly relevant to this project but are reproduced below because they may be of interest to HMRI / Office of the Rail Regulator should they choose to investigate asset management in the rail sector:

- **'Silo' thinking:** departmental, functional or regional barriers. Suggested causes are poor experience of organisational change, strong local management personalities, badly structured performance / reward schemes;
- **Short-termism:** success measured as 'on-time' and 'on budget' without taking into account subsequent performance and value;
- **Conflicting Performance Measures:** one group can only succeed at the expense of another;
- **Lack of business skills for engineers / facilities managers**.
- **Deficiencies in risk evaluation:** risk evaluation requires rational, consistent quantification and management of commercial, technical, safety, reputational risks;
- **Fire fighting:** allowing too little time to plan ahead or recognising / rewarding crisis management (rather than skills in avoiding the crisis); and
- **Data:** too much, too little or the wrong type.

2.5 PAS 55-1: ASSET MANAGEMENT PART 1: SPECIFICATION FOR THE OPTIMISED MANAGEMENT OF PHYSICAL INFRASTRUCTURE ASSETS (BSI, 2004a)

The British Standards Institute state that this reference document has been created as a Publicly Available Specification in order to meet demand quickly. Part 1 gives the specification for an asset management system at a relatively high level. The identified attributes that an asset management system should have appears thorough but only a high level model is presented thus limiting this reference's usefulness to this project, since it does not set out how to apply the system specifically to safety or the railways. Interestingly however, there is a strong emphasis on prioritising maintenance from a safety risk-type assessment rather than a business risk-type approach.

The document covers physical asset management, as opposed to management of (say) human or intangible assets. Asset management is defined as 'systematic and coordinated activities and practices through which an organisation optimally manages its assets, and their associated performance, risk and expenditures over their lifecycle for the purpose of achieving its organisational strategic plan' and, more succinctly, as 'the optimum way of managing assets to achieve a desired and sustainable outcome.'

The model set out for an asset management system consists of the following key headings:

- Policy and strategy;
- Information, risk assessment and planning;
- Implementation and operation;
- Checking and corrective action; and
- Management Review.

The text then sets out requirements for each of these topic areas. Brief descriptions of selected key points are given below.

Policy and Strategy

The policy should be endorsed by top management in an organisation, be of an appropriate scale and nature and be consistent with other policies and commitments. The strategy should again be consistent with other policies or strategies, identify the assets and state their required performance (whilst taking into account stakeholder requirements), be optimised and take account of the risk assessment, in particular identifying critical assets.

Information, risk assessment and planning

Organisations are required to set up and maintain an asset management information system that is adequate to support their asset management (including policy, strategy, risk identification and assessment, objectives, targets, plans and review). Interestingly it also explicitly states the information should be accessible to relevant third parties (e.g. contractors) where appropriate. A risk assessment should be done and should include physical failure, operational risks (including human factors), external events (e.g. extreme weather, services), design and installation risks and also stakeholder risks (e.g. reputation damage). Organisations are required to take into account their risk assessment in their asset management and related planning, with an emphasis on pro-active rather than reactive actions. Organisations should establish a procedure for identifying and accessing legal, regulatory or asset management requirements applicable to it. Performance or target conditions should be set, communicated to employees and third parties and reviewed periodically. Asset management plans should be made and maintained, setting out responsibilities and time-scales and the means by which objectives are to be met.

Implementation and operation

Organisations are required to set up an organisational structure of roles, responsibilities and authorities, suitable for achieving its asset management policy, strategy and plans. A number of requirements relate to the need to consider and communicate with all relevant parts of the organisation, moreover staff and contractors should be made aware of, and qualified for their role in relation to assets (including the design stage). Organisations are also to ensure that their asset management programme is viable. The programme should be documented in a secure way and necessary activities identified and controlled. PAS 55-1 also calls for emergency situations to be considered and prepared for.

Checking and corrective action

Organisations are required to monitor and measure performance and keep associated records of this as well as of incidents and near misses, and associated investigations. Measures are to be put in place to ensure that these functions are implemented. Organisations are also required to audit their asset management programme based on an organisation’s risk assessment.

Management review and continual improvement

An organisation’s top management is required to review the asset management programme periodically and keep abreast of developments in asset management, changing or adapting their own asset management programme as appropriate.

2.6 PAS 55-2: ASSET MANAGEMENT PART 2: GUIDELINES FOR THE APPLICATION OF PAS 55-1 (BSI, 2004b)

This part of the Publicly Available Specification sets out to provide guidlines for the interpretation and application of the requirements specified in PAS 55-1. As such, much of the material is similar to that described in the previous section. However, some new, relevant information is included and is summarised here.

The following key dimensions of asset management are given:

- Holistic – taking a larger view and avoiding a 'silo' approach;
- Systematic – a methodological, consistent, justifiable and auditable approach;
- Systemic – optimising the system as a whole rather than individual assets;
- Risk based – identifying risks and associated costs/benefits and prioritising accordingly;
- Optimal – establishing the optimum balance between performance, cost and risk; and
- Sustainable – taking a long term and life cycle approach.

These dimensions are consistent with other literature read in the preparation of this review and are thus proposed as a good summary of the general approach required for effective asset management.

PAS 55-2 also suggests that performance requirements and risks should be costed to facilitate comparison. The guidance suggests that in cases where this is difficult, costs could be estimated by asking 'what would we be prepared to pay to avoid harm to our reputation?'

A process diagram for asset management based on PAS 55-1 is presented in PAS 55-2; a summarised version is presented in Figure 2.

An example is given of application to a railway system (presumably a metro system), which is presented here to show how asset management could be applied to railways. Firstly, the asset management objective is stated:

'Timetables that deliver a train every five minutes in central areas and every ten minutes elsewhere – all day, every day.'

From this relatively high level objective, required features may be deduced such as the number of trains needed and the level of availability of track, signals etc. As the system is complex, simulation modelling is used to determine the optimum level of availability, since too little availability implies failure to achieve the objective but too much would be wasted effort (on a cost – benefit basis). For example, the simulation modelling might lead to the following performance target being proposed:

'To achieve an average of 97% system availability on the route.'

Realising this performance implies certain reliability characteristics for components, often expressed in terms of Mean Time Between Failure or Mean Time To Failure and Mean Time To Repair. This approach allows the viability of the primary objective to be established (the timetabling objective here), assists in creating plans for achievement of the objective (design, maintenance and capital investment requirements) and provides a baseline for measuring performance.

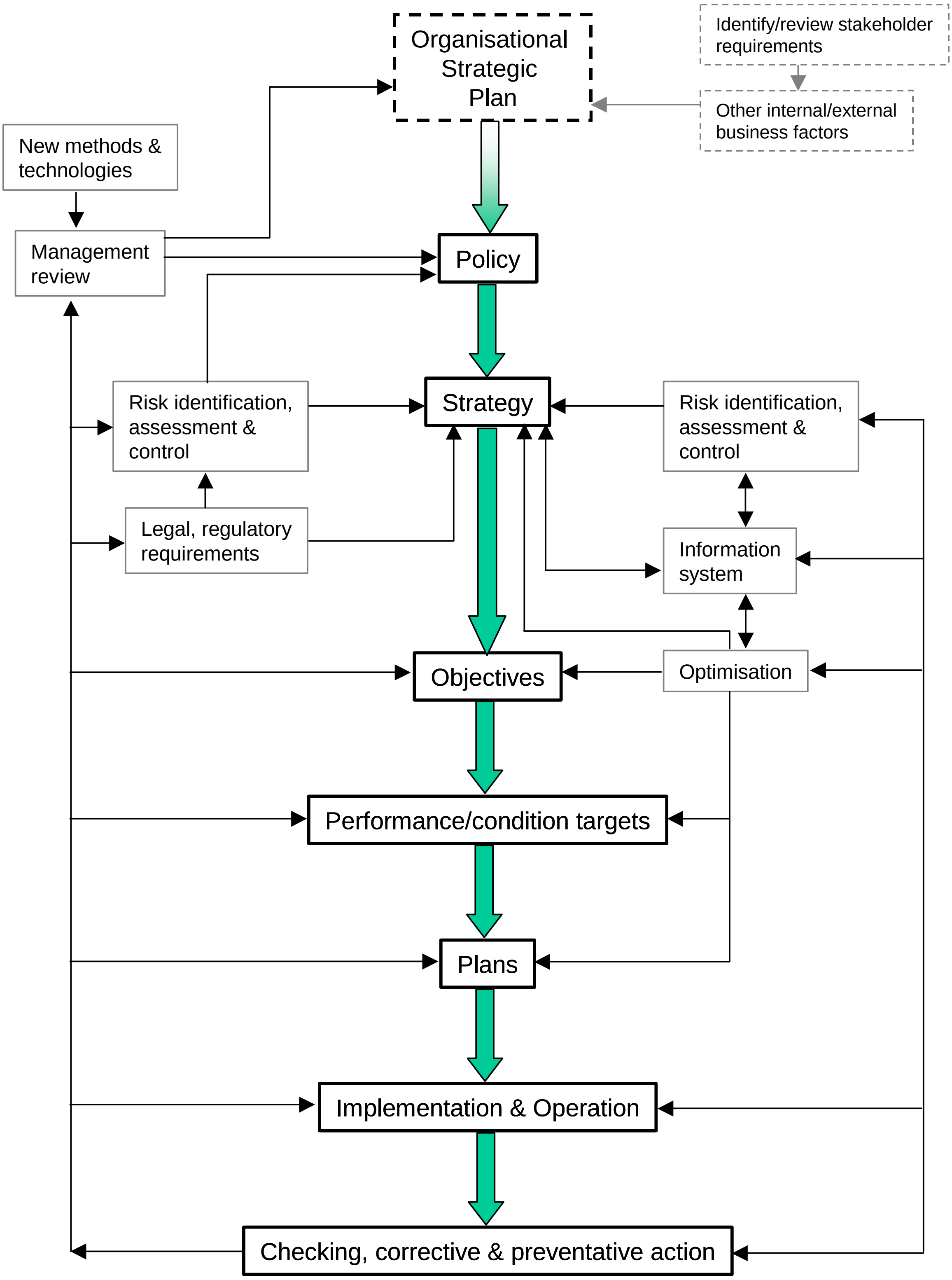


Figure 2 Process diagram for asset management, adapted from PAS 55-2, including interaction with the organisational strategic plan.

2.7 ASSET MAINTENANCE MANAGEMENT A GUIDE TO DEVELOPING STRATEGY AND IMPROVING PERFORMANCE (WILSON, 1999)

This publication gives an extensive examination of the topic, from how it may further a business, through policy and models to techniques to be employed. It also gives much attention to human resource issues, such as in-house versus external maintenance, training and motivation of staff. The document is over 800 pages long with a focus on maintenance of fixed plant (e.g. a chemical process site or oil refinery) and therefore the summary given here represents an effort to identify and report the most relevant ideas.

The reference points out that maintenance, and maintenance staff, should not be seen merely as ‘overheads’ but as serving functions that add value in the same way that, say, a train and train driver do. There is much discussion of multi-skilling and of the benefits of a high level of interaction between production and maintenance staff. Given the different organisations involved in the UK railways, this could usefully be interpreted as good communication between the Train Operating Companies and the maintenance providers and where feasible, tackling more than one maintenance task at a time (e.g. sharing possessions) to minimise on downtime.

Proactive maintenance

The importance of carrying out the right tasks at the right time with speed and skill is noted; the risk is that without a suitable maintenance programme the situation will deteriorate to one of ‘fire-fighting’, making it difficult to adapt or plan ahead e.g. training staff in new working methods. It is noted that proactive maintenance is generally more efficient than reactive maintenance since required staff and material resources will be at hand. Thus a proactive approach is advocated. Maintenance is put into two broad categories: preventative and corrective. When combined with condition monitoring, corrective maintenance is identified as a potentially effective strategy i.e. proactively monitor a component’s condition and schedule corrective maintenance when the component deteriorates.

Purchasing for optimal performance

The reference notes that despite high expenditure on maintenance, relatively little attention is paid to procurement. That is, an operator should consider the life-cycle cost of the system. Figure 3 below, taken from the reference, shows the ‘procurement paradox’; note also the shape of the curve. For low capital cost, maintenance costs may be high giving a high total life cost; for high capital cost, the high initial outlay causes a high total life cost thus the optimum is somewhere in between.

Coupled with consideration of life-cycle costs, the reference states that up to 50% of maintenance defects and safety problems may be built in at the design and equipment manufacture stage.

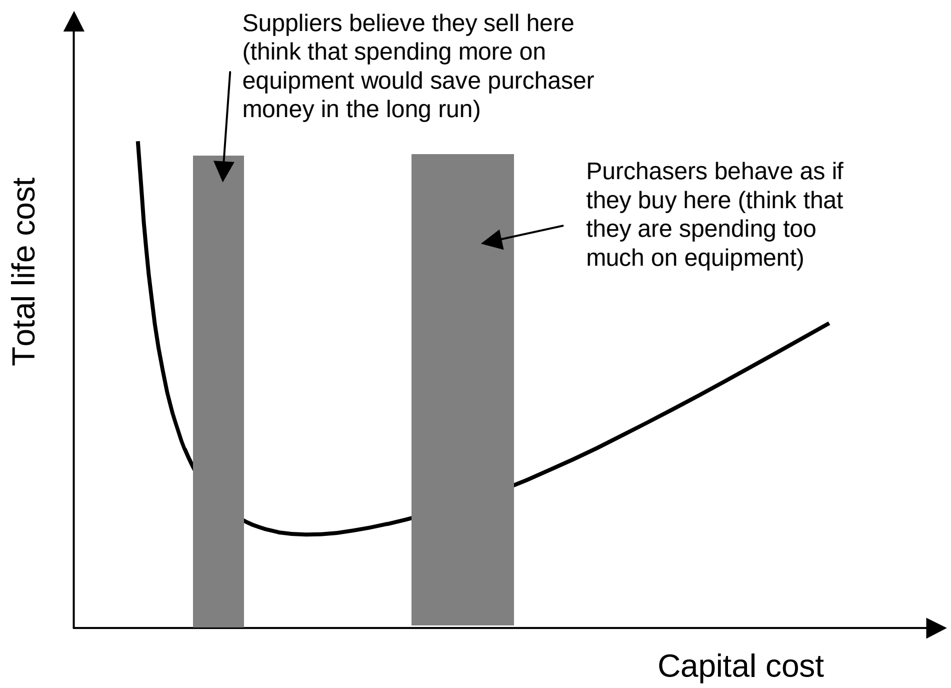


Figure 3 The procurement paradox, reproduced from (Wilson, 1999)

Reliability Centred Maintenance

This method seeks to analyse potential failure modes of equipment and the effects of failure on an organisation's production, that is, a Failure Modes and Effect Analysis. The Failure Modes and Effect Analysis team should include people who operate and maintain the equipment and be supported by operating experience. Based on this, failures can be prioritised and the most appropriate maintenance strategy chosen e.g. designing out the fault or condition monitoring. The information gathered could also be used for training operators in potential problems, as a checklist for maintenance staff (including as a checklist of actions operators may try before calling maintenance staff), help to ensure that equipment is used as intended and help organise an efficient spares/supply strategy. The reference identifies the following classifications for consequences:

- **Hidden failure consequences:** no direct effect but expose the plant to other, often serious, consequences and are frequently associated with protective devices that do not fail-to-safe;
- **Safety consequences:** a failure with [direct] safety or environmental consequences;
- **Operational consequences:** a failure affecting production (for railways, smooth running of trains); and
- **Non-operational consequences:** none of the above and so involves only the repair costs.

The reference suggests the following as the order in which maintenance tasks would ideally be selected:

1. Design-out problems / design in provision for reliability and maintenance (e.g. easy access to components, built in sensors);
2. Basic servicing task (e.g. lubrication);

3. On-condition based maintenance;
4. Scheduled (fixed time) maintenance; and
5. Operate to failure.

For some assets, such as rails, on condition based maintenance appears an attractive choice. However this approach requires an understanding of the failure behaviour of an asset. Equipment is often assumed to have a 'bath-tub' failure profile i.e. high initial failure probability due to, for example, a sub-standard or incorrectly installed component, then a gradually rising failure probability with age and finally a zone of rapidly increasing failure probability that is the 'wear-out' zone of the component. The reference points out that the 'bath-tub' model is often not appropriate and gives examples of six failure profiles. These profiles are shown in Figure 4 together; 'A' shows the 'bath tub' profile. The percentages shown are taken from the reference and based on a study of components on civil aircraft; they show the percentage of items studied which conformed to a particular failure pattern. Whilst acknowledging that the distribution may be different for other industries, the authors suggest that as assets become more complex, patterns E and F become more common.

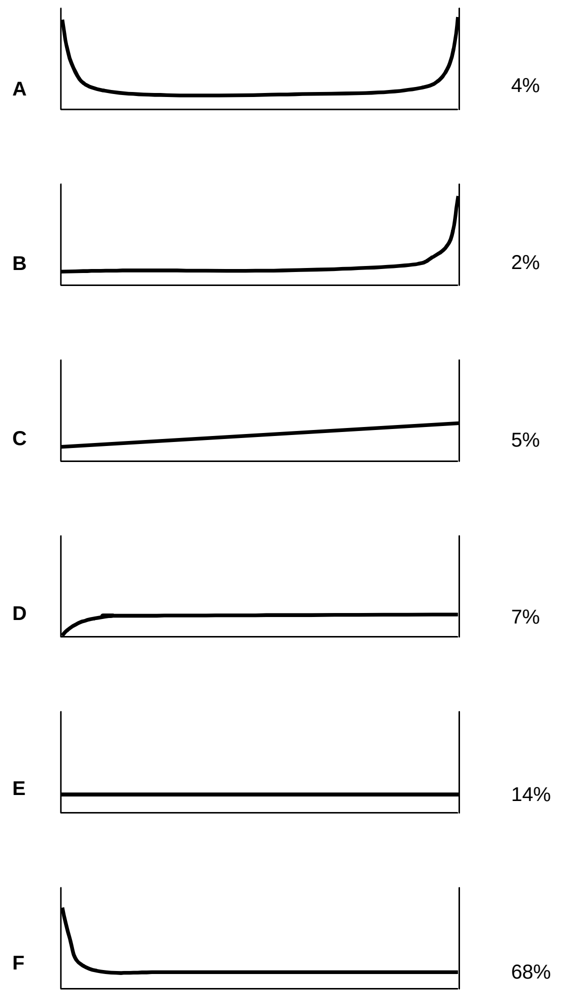


Figure 4 Probability of failure with time (time from installation as horizontal axis, probability of failure as vertical axis). Taken from (Wilson, 1999)

Reliability centred maintenance is likely to be resource intensive to introduce if done from scratch for every component. Therefore different approaches are suggested, depending on the similarity between components and their criticality. Thus for components that are similar a standard template may be used or a ‘task force’ may be created to implement the approach in particular areas. It should also be remembered that in some cases, where components are cheap, readily available, easy to replace and not critical, the optimum strategy may in fact be ‘operate to failure’ (e.g. light bulbs).

Reliability centred maintenance teams need to have detailed knowledge of the component from different perspectives (operations, maintenance etc.) and may typically consist of:

- Operations supervisor;
- Engineering supervisor;
- Operator;
- Craftsman (mechanical and/or electrical etc.);
- External specialist (technical or process), if needed; and
- Facilitator.

It is also noted that the outcomes need to be reviewed (e.g. annually) and audited, preferably soon after the teams have finished their work. The main aims of reliability centred maintenance are summarised as:

- Identifying the correct asset strategy;
- Prioritising the effort;
- Increasing plant reliability; and
- Reducing effort where not justified.

Asset strategy

The outcome of an asset strategy is a reasoned case for why a particular approach is being taken for equipment (e.g. predictive, preventive or corrective maintenance) or whether a combination of approaches is appropriate. The reference suggests that the strategy could be built up starting with the most critical equipment. It suggests that time is best spent on asset strategy when there is knowledge of corporate objectives, whether there is planned expansion or contraction, an understanding of replacement programmes, knowledge of latest statutory requirements (e.g. safety regulations), an appreciation of the state-of-the-art in maintenance (to give an idea of what is achievable) and when an idea can be formed of the skills and techniques which are most appropriate for maintaining the equipment (implying employing/training suitable personnel).

Figure 5 shows proposed steps in developing an asset strategy. The emphasis is on ensuring that a cost effective approach is used and on endeavouring to apply an optimum maintenance frequency.

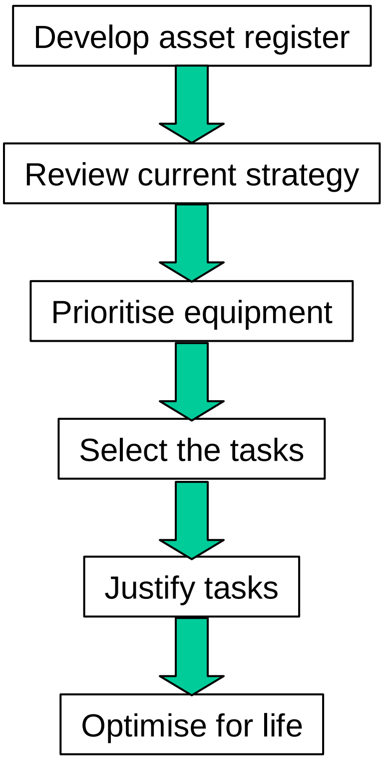


Figure 5 Steps in developing an asset strategy, reproduced from (Wilson, 1999)

2.8 OVERVIEW OF LITERATURE REVIEW

The articles examined suggest that the tools and approaches described as 'asset management' present a process of optimisation allowing a company to save money and improve performance. An alternative way of looking at this, of more interest in the current work, is that the approach should also suggest the best way of deploying scant resources to achieve the desired outcomes.

The approaches described generally consist of the following:

- Setting high level targets ('top-down');
- Identifying how to achieve the targets ('bottom-up' or 'organic'); and
- Prioritisation – identifying what needs to be done and not doing too much *or* too little of it.

There are two key differences between most of the asset management literature reviewed and the topic of interest in the current work:

- Most of the literature is aimed at fixed plant or point features whereas railways are linear networks (albeit with point features associated with them); and
- The general thrust is at improving business performance. Although safety is generally given a high priority, it is only one factor in business performance.

Since different segments of railway track will have different features, either because of designed versus actual usage, or because of the immediate environment (e.g. risk of landslip, in a tunnel), an optimised asset management strategy will have to distinguish between different stretches of track. The second point is not necessarily an important difference given a fixed budget and/or defined safety targets since asset management approaches are designed to optimise performance, whether for commercial or safety reasons. The problem comes if a ‘grand unified theory’ is desired, which requires an asset management model to balance resources between commercial and safety goals. This may not be too great a problem since poor safety will be associated with poor performance; therefore, there should be great synergy between commercial and safety aims. Since a key part of asset management is removing unnecessary maintenance, another key tension (between doing maintenance and shutting a line) may not in fact be a major issue.

Finally, it is worth noting that (Wilson, 1999; p118) suggests that an asset management approach typically gives a reduction of 20-30% on maintenance spend in the process industries. Whilst a scoping study might possibly show that gains would be smaller in the rail industry, the figure cited does suggest that a systematic approach to asset management is worth serious discussion.

3 ASSET MANAGEMENT FOR RAILWAY SAFETY

This section discusses the application of asset management to rail safety. It is beyond the scope of this report to recommend a definitive model for asset management to rail safety; nevertheless, this section gives an outline of what such a model might look like and gives some prerequisites for such an approach.

The UK rail system is large and complex meaning that application of asset management would be a large exercise, therefore attention is given to making use of existing information. Implicit in the smooth and effective application of asset management to railway safety is the ability of the various departments and organisations that form the UK rail industry to work closely together. Therefore, whilst the initial brief for this work was to focus on Network Rail, the following discussion is framed in terms of the rail industry i.e. including train operating companies and train leasing companies. Note also that successful application of asset management to the railway network is consistent with what should be described in a railway safety case, since it is a structured system for ensuring an organisation does what it (reasonably) can to improve safety. That is, the safety case should contain an organisation's asset management arrangements. That said, effective application of asset management for rail safety raises important policy (and possibly legal) questions for HMRI concerning ALARP[2]; these will be discussed where appropriate below.

An effective asset management system should lead to an integrated approach to risk management on the railways i.e. treating the railway industry as a single system, allowing the wider effects of an asset procurement or maintenance decision to be appreciated.

3.1 PROPOSED OUTLINE MODEL

An outline of the proposed asset management model for railway safety is shown in Figure 5. The proposed model is by no means definitive but more a basis for further work and discussion. As noted earlier, much of this is in common with what might be expected from a railway safety case so that a more immediate use may be as a checklist for evaluating safety cases. The following sections describe each step in more detail, with an overview at the end.

Safety policy

As noted, a key part of asset management is knowing what an organisation wants to achieve. Therefore, a vital first step is the establishment of high level safety targets for the UK rail industry which will necessarily require top management commitment.

This target setting approach is very much in vogue and, to a certain extent, already in place but may present tensions with ALARP. ALARP is based on individual practices and assets, which each must be ALARP, rather than on the global approach implied by asset management. That is, asset management is about optimising spending on the whole system whereas broadly speaking ALARP is currently interpreted as ensuring that each asset is as safe as is reasonably practicable. Thus ALARP is a 'safety first' approach, whereas an asset management approach is more suitable for a situation where the problem is one of allocating a fixed budget in an optimal way. Since it is suggested that an asset management approach is applied in a prioritised way, this tension may not be a large problem in practice. Indeed, as noted above, there are analogies

[2] Strictly speaking, 'the requirement to reduce risks as low as is reasonably practicable', referred to here onwards as 'ALARP' for brevity.

with the Hazardous Installation Directorate's approach for COMAH installations. However, it is highlighted as a potential policy difficulty.

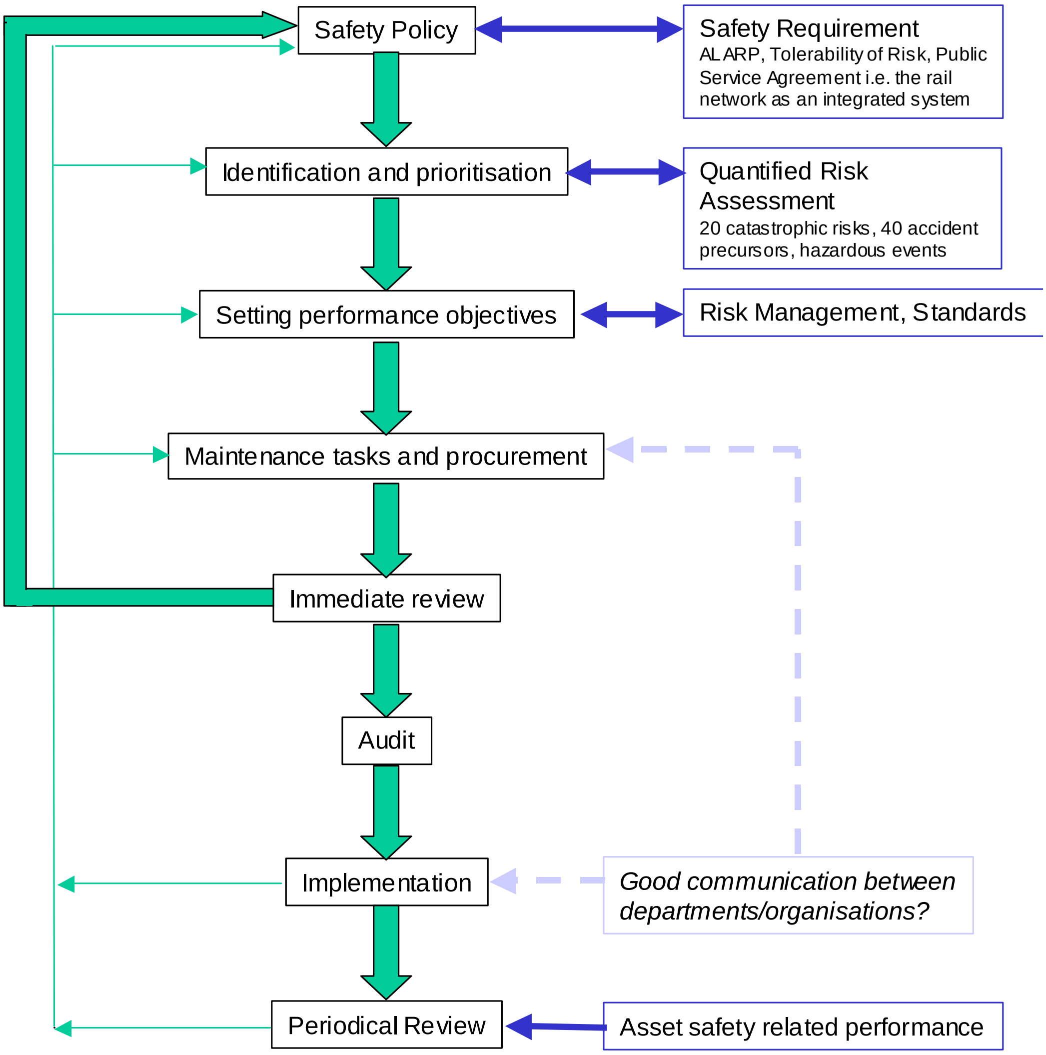


Figure 5 Schematic of the proposed asset management approach, including linkages to items in Figure 1

If one were to accept a globally optimised system (within a fixed budget) as representing ALARP there lies a problem in setting targets. Targets are the driving force for the asset management approach and thus should be set first. When an asset management model is applied, certain targets will imply a certain level of spending which may or may not correspond to the budget available. Thus the immediate review stage, described below, will be important in fine-tuning the targets to the budget available.

The targets need to cover those areas of safety of interest to the railway industry which are broadly incidents giving rise to particularly high levels of societal concern and those that are more classically risk based or equity based. Despite the complications described above, here are three examples of safety targets the rail industry could use:

- A maximum of one incident causing 5 or more fatalities every 3 years. This is largely to address societal concern. (The average over the last 15 years is around 1 incident every 2.8 years, or around 1 incident every 2.5 years for the last 30 years (HSE, 2004).)
- A maximum of 35 fatalities per year across the UK rail system (excluding trespassers and suicides). This could then be broken down into workers and passengers. For workers, this might be expressed in terms of, or derived from, acceptable individual risks for workers (e.g. track-side workers) according to the 'Tolerability of Risk' framework.
- No increase in the number of fatalities due to trespassers and suicides.

The point of these examples is to illustrate the high-level 'starting-point' of an asset management approach; subsequent stages would indicate target levels of precursors etc. It also highlights the potential difficulty with a high level target setting approach – an annual individual risk of 1 in 10 000 may be a worthy objective for certain high risk occupations but require no effort to be made with respect to other workers.

Identification and prioritisation

Based on the high level safety targets, a set of performance objectives needs to be set. To give efficiency gains, and particularly given the size of the UK rail system, prioritisation will be needed. This will depend on identifying assets that are critical to achieve the high level safety targets. For example, it may be that a certain type of level crossing and (say) broken rails on curves on high speed track are the key contributors to multiple fatality incidents. Since the rail network is extensive, for useful application of asset management, it will need to be broken down to a more detailed level than generic asset categories (such as 'level crossings', 'track'), as implied in the examples given in the previous sentence. Accident statistics, the Rail Safety and Standards Board's Risk Profile Bulletin and their Safety Risk Model will help identify and prioritise assets. It is envisaged that the level of detail with which assets are examined will depend on their importance, for example, in the manner suggested in (Woodhouse, 2004) described above.

Setting performance objectives

This step involves taking the output from the previous section and deducing the performance required of an asset in order to meet the high level safety targets. Thus this step requires a detailed understanding of how the different assets making up the rail system behave and interact with respect to safety. This is a somewhat daunting task but already exists in the form of the Railway Safety and Standards Boards' quantified Safety Risk Model. However, since this has been developed at the national level more work would probably be needed to provide sufficient detail for particular types of sections of track, types of level crossings etc. to be identified and targetted. An example of the type of work that might be useful in this area is (Dick, 2003), described in the literature review. In this stage, performance objectives for particular assets, such as level of availability, will be specified.

Maintenance tasks and procurement

Having identified and prioritised assets and specified their required performance, the next stage is to identify how to meet the performance objectives. This is the stage where different approaches to maintenance and procurement i.e. life-cycle assessment should be considered. Although interaction between safety and commercial aims will be discussed in a later section, it is worth noting that this step in particular is likely to require a large interaction, since a large part of the constraint on maintenance will not just be the cost of maintenance itself but the cost of reduced equipment availability (e.g. requiring a section of line to be closed and replacement bus services to be used). This stage is also where good interaction between different maintenance functions and train operators and leasers is required: what is the cost and availability of maintenance time for train operators? if equipment is unavailable for one maintenance function can another maintenance function be carried out at the same time (thus avoiding the need to make the equipment unavailable twice)? what are the best trains to purchase (e.g. cost, required maintenance, demands placed on other assets)?

This area is likely to be the most complicated area of asset management for rail safety because it requires optimisation. For example, if condition based maintenance were used for track and signalling, what would happen if track required replacing but signalling equipment did not – would it be more cost effective to replace signalling equipment at the same time or not to spend resources on currently functional equipment but risk having to re-close the stretch of line for a second period soon after? Good understanding of the failure properties of critical components and accurate costs will allow this to be evaluated provided that a representative cost for the expense and inconvenience of line closures, delays etc. can be assessed (this implies including intangible costs such as reputation and, for example, reduction of quality of life for commuters). As noted, good communication is required here. Initiative and adaptability on the part of maintenance teams 'on-the-ground' will also be required; although this appears to fall outside the scope of this work, it has implications for competencies and training of those organising maintenance 'on-the-ground'.

The output from this stage will be a good understanding of the maintenance and procurement needs and strategies for assets which may then be taken forwards through maintenance plans and procurement strategy.

Immediate review

This stage is to provide a 'feedback loop' to previous stages in the asset management model. It allows a 'reality check' on what is being proposed and as discussed, allows fine tuning of high level targets. For example, the proposed maintenance schedule may be more than the UK believes it can afford to spend on the railways, in which case the high level safety targets would need to be reviewed. This step allows a high level ALARP assessment to be made, with policy (and perhaps legal) implications for HMRI: as noted, ALARP currently is assessed at the level of individual practices or asset groups rather than at a global level. That is, for effective asset management both the regulator and industry would need to take a global view. Under some circumstances, this global approach might not be consistent with the absolute criteria applied for ALARP (i.e. Value Per Fatality, gross disproportion factor) but would allow the best safety related asset performance in the face of a fixed budget. Thus potentially ALARP could be demonstrated by:

1. Demonstrating that the asset management approach used optimised safety spending for the UK rail system; and
2. Arguing that the UK could not (or would not) spend more on rail safety.

This apparently simple picture would be complicated by the fact that performance and safety are inter-related thus money spent on safety would in many cases contribute to improved performance and vice versa. Despite the potential policy difficulties highlighted, this approach to ALARP is not necessarily problematical, since it could be viewed as a structured, prioritised work programme for becoming ALARP.

Audit

An auditing function is suggested to give confidence that the model has been implemented consistently and correctly across the rail system.

Implementation

One of the key features of applying an asset management approach to railway safety is that such an approach may imply doing less maintenance on particular assets, which implies that safety levels may be reduced, albeit by a small amount, for certain assets. As discussed, this has policy implications for HMRI. Such cases might be cases of 'reverse ALARP' e.g. demonstrating that knowledge of failure behaviour or technology have improved such that less maintenance is required or they may require HMRI to admit a policy of spending less in one area in order to spend more in another. Currently this argument is not recognised but this may be less of an objection in the face of a clear asset management strategy which demonstrates exactly how less spending in one area is spent in another area to greater effect[3]. Presuming that there continues to be a large amount of public money spent on the railways, the outcome of applying asset management may suggest altering the way this is distributed e.g. the programme might identify that it was better to spend more money on new trains than on new track. However, it is expected that this last point will not be a major issue in practice.

If HMRI does not have policy objections to implementation, the rail industry would probably need to re-visit its standards to either (i) define them so that they are applicable in a prioritised way or (ii) only apply to specific parts of the system. In the latter case, this could be done by applying priority 'bands' within an asset category (e.g. heavily used, high speed track might be 'red' whereas a lightly used branch line might be 'blue'). For example, to ensure that high specification material is used only on high speed track on curves a standard could:

(i) State that it only applies to curved track with certain line speeds; and

(ii) State that it only applies to category 'red' track.

Periodical Review

This step involves reviewing the asset management study at suitable intervals to ensure that it is still relevant, for example, every three to five years, or when there are major changes to the rail system e.g. introduction of new regulations, drastic changes in budget or priority, new infrastructure.

3.2 OVERVIEW AND DISCUSSION

The advantages of the model described (or similar) is that it allows an optimal approach to managing assets to be developed, with great potential for either saving resources or deploying them more effectively, that it makes use of information that is readily available and could be adapted to give a 'grand unifying theory' for spending on the railways. A further advantage is that it should be relatively easy to inspect an asset management approach since the approach requires much documentary evidence such as asset registers, records of meetings and decisions and should give a clear audit trail between such decisions and maintenance and procurement. Moreover, since effective application would require good communication between different parts of the industry, inspectors may be able to test whether there is a supportive organisational structure by ascertaining the level of communication and familiarity between different

[3] Conversely, if HMRI admits this argument, an asset management model could be used to show that the rail industry, globally, were not 'ALARP' because overall they could be doing more within their budget.

departments and/or organisations. However, it should be noted that adopting this approach requires an accurate model of assets and safety, and confidence in it. In practice this implies a good, suitably detailed asset register and confidence in the Safety Risk Model.

The challenges are that it may require a bold evolution of policy from the regulator and the rail industry and an open minded view of how asset management and maintenance is currently structured (although of course it may show that it is already optimal) and that it will require the various organisations and their departments to co-operate closely with each other.

The disadvantages are that to apply it to the UK railway network will require much work; three identified areas in particular that may be resource intensive are:

(i) An understanding of key features affecting assets' safety performance, perhaps requiring further development of the Safety Risk Model and/or more research;

(ii) An asset register sufficiently detailed to resolve critical assets (e.g. particular characteristics of track such as geometry, age, usage), which is spatially enabled;

(iii) Consistent and accurate costs for procurement, maintenance and downtime (e.g. line or station closed);

and also:

(iv) Currently, the interface between safety and commercial aims is not covered.

The first three points will to some extent be addressed by the prioritisation process; that is, detailed information will only be required for the most critical assets. To address the last point is very difficult because to compare aims directly requires a common currency. The currency chosen is generally monetary but this presents difficulties because many of the 'costs' of interest do not lend themselves to being assigned monetary values. Nevertheless, this area is briefly discussed in the next section.

4 INTEGRATION OF SAFETY AND COMMERCIAL ASSET MANAGEMENT

Integration of commercial and safety concerns is often seen as problematical because the two types of concerns may conflict with each other and it is difficult to express them in a common currency, which would greatly facilitate optimising them e.g. by cost-benefit analysis. The usual approach is to try and attach monetary value to non-financial concerns (which in fact includes some commercial concerns, such as reputation, as well as safety concerns). In this approach the key problems are assigning monetary value to inconvenience, harm and the concern and criticism associated with certain types of incidents which, in classical risk terms, are out of proportion to their importance.

Using this approach for asset management would require a monetary value to be assigned for certain types of incident. The Value Per Fatality currently in use is around £1.3 million (HMRI, 2005a) but this would need to be adjusted for high concern incidents. For high consequence incidents, HSE suggest that in testing whether a course of action is reasonable, a factor of up to ten should be applied (HMRI, 2005b), implying that for a credible high consequence incident the threshold is equivalent to £13 million; this compares well with a cost of £10.5 million derived by Professor Evans, as cited in (RSSB, 2005). These figures could be used as a basis, with the benefit that they are transparent. However, it is not clear that these figures are widely accepted and a cost would still need to be ascertained for inconvenience to travellers, as well as financial costs, in order to have a 'grand unified theory'. There may also be political difficulties with this approach.

An alternative approach is given by taking a target setting approach – deriving a realistic set of targets which include safety as well as performance targets and design an asset management approach which optimises spending in order to reach these targets. Given an initial set of targets, some tuning would no doubt be needed to ensure that the targets were on budget. The advantage of this approach is that it allows people to discuss and compare directly the commercial and safety aspects of the railways, it avoids the direct assignment of monetary value to things which people are uncomfortable or unable to assign monetary value to and does not require spending to be allocated to purely safety or purely performance. The disadvantage is that tuning the targets may be cumbersome, controversial and the cost of each target would not be transparent.

For example, a target setting approach might consist of the following:

- *Safety*: no more than 35 fatalities per year (excluding suicide and trespass), annual individual risk to workers not to exceed 1 in 10 000.
- *Performance*: 90% of trains to arrive at stops and destinations within 5 minutes of timetabled time, 95% of timetabled trains to run over the next ten years (including unavailability due to maintenance and incidents). Network capacity to increase by 5% per year for the next ten years.

The point is that given these targets, there is no longer much distinction between business risk and safety risk, since they are all targets for the railway industry.

5 CONCLUSIONS

Applied to the rail network as a whole, asset management offers a way to ensure that the railway industry is carrying out the right tasks for a safe and effective railway and carrying them out in the most efficient, economic way. An effective asset model would establish a firm basis for safety standards on the rail network. The literature survey carried out in this work did not identify a suitable, strategic asset management model for use on the UK railways system. However, based on the literature survey, an outline approach has been proposed. The suggested approach requires an asset register with sufficient detail to allow the most critical parts of the network infrastructure to be identified and targeted. The approach also would require use, and probably development, of the Safety Risk Model. Full application of asset management would also require HMRI to ensure that it was content with the policy (and possibly legal) implications surrounding 'ALARP'. These points imply that full scale adoption of asset management would be a major undertaking (albeit with potentially large benefits), yet an understanding of the approach may be beneficial in a more modest way. Therefore, the following two sections set out possible alternative approaches.

It is worth noting that such an asset management model would give a generic approach that could be applied to other major hazard sectors in the UK and beyond.

5.1 OPTION 1: STRATEGIC ASSET MANAGEMENT

HMRI could use the principles of asset management to probe whether Network Rail had a structured approach to improving safety on the railways in parallel with ensuring that risks are ALARP on a more localised basis. Models of asset management could be used to inform HMRI on what structures Network Rail should have in place in order to have an optimised strategic approach to asset management. That is, it could be used to probe the planning, organisation and management of Network Rail. For example, how far is the Safety Risk Model used to target or prioritise particular assets for maintenance? This option is suitable for the current climate where HMRI wants to ensure that risks are adequately controlled in every part of the rail industry but may also wish assure itself that Network Rail is operating in a coherent, effective manner as a single organisation.

5.2 OPTION 2: FULL IMPLEMENTATION

This option is in fact two options: full implementation with respect to safety or full implementation for the rail industry. This approach implies a large amount of work and so scoping studies and consultation would be needed to ensure that it was worthwhile. It would also require HMRI to be confident that the asset management structure had correctly identified the most efficient way to improve railway safety for a given level of spending; in essence HMRI would have to accept a global 'ALARP' case. It would also require selection of suitable, balanced and realistic targets. However, it offers the promise of combining commercial and safety interests and ensuring that public money is wisely spent. Thus although more ambitious, the full implementation for the rail industry holds the largest potential gains. This option is suitable for a situation where there is pressure to balance commercial performance and safety performance, where there is increased pressure for openness and transparency (since high level targets should be easily understood by all) and where the problem is ensuring that the highest level of safety is 'bought' from a fairly inflexible budget. Although not explicitly discussed in this work, there may be scope to apply a 'full' approach to parts of the network, since this is implicit in applying asset management in a prioritised way.

6 RECOMMENDATIONS

Based on the above, the following recommendations are made:

1. HMRI should rapidly disseminate this report to selected key internal and external stakeholders involved in railway safety.

2. HMRI should rapidly disseminate this report to other HSE major hazard divisions/directorates and the Risk Policy Unit.

3. Depending on comments and level of interest following (1) and (2) HMRI should:

    a. disseminate the work more widely (for example, through seminars);

    b. commission work to review RSSB's Safety Risk Model to confirm that it is feasible to use it in the role described and identify/investigate any issues;

    c. take forward the approach in consultation with key stakeholders;

OR

    d. commission work to develop an inspection checklist based on the ideas set out in this work.

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