

Transport Research Laboratory



Risk Approach to Prioritising Maintenance
Risk Factors for Value Management

by R Abell

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**Client: Highways Agency, Network Services
(Alex Tam)**

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Executive Summary

The Strategic Road Network (motorways and all-purpose trunk roads) in England is maintained by the Highways Agency using renewals, to replace assets when they come to the end of their serviceable life, and routine maintenance, for cyclic maintenance and the removal of safety hazards soon after they appear on the network. This study was concerned with the assessment of proposed Roads Renewals maintenance and was not to address Structures Renewals or routine maintenance.

Value Management and development of the Roads Renewals maintenance programme starts from the identification of potential maintenance lengths and, currently, extends to prioritisation of the proposed maintenance schemes. Risk needs to be better considered throughout all of the process. This report describes how key factors that contribute to the risks associated with the selection and prioritisation of Roads Renewals schemes may be included in the Value Management process.

The aim of this study was to produce a method for the inclusion of risk to better influence the Value Management process. It was recognised that this was not to replace the overall approach in the Value Management process but to supplement the process and better inform the development of the Roads Renewals maintenance programme using the outputs from the established Value Management process. The study identified key Risk Factors for different (roads) asset types that can influence the relative priorities of schemes with similar Value Management scores.

For all risks, a structured approach is needed to aid the consistency of decision making and cost effectiveness in the allocation of resources. For Roads Renewals, a risk assessment that covers all years in which work will be undertaken must be carried out for all proposed projects costing more than £0.25m. The aim of the risk assessment is not only to ensure that the final scheme outturns are as close as possible to the outturn expected when the project was approved but also to help ensure the maintenance option assessment includes the key areas of uncertainty as part of the Value Management process.

For Value Management of the Roads Renewals programme it has been assumed that there are three broad types of risk to be considered; business, project and operational. This study has been aimed at project risks but the approach could be applied to the other areas.

It was recognised that greater consideration of risk is needed for the Value Management process and will form a key part of future changes to the Value Management approach. There are however many areas in which levels of risk affect the assessment of asset performance and the need/priority for maintenance.

Many aspects of risk have been identified but it was agreed this study would consider the effects of risks on the Value Management process, and how the Value Management process may take better account of those risks, only for the following four Risk Factors:

- Costs of the proposed maintenance;
- Selection of the maintenance treatment;
- Duration of maintenance works;
- Future asset performance.

Depending on the levels of acceptable risk, this approach produces a range of pessimistic and most likely outcomes. It can be extended to also include optimistic estimates but these are not required in the current Highways Agency approach to managing risk. Based on the desk study review undertaken at an earlier stage of this work, confidence levels no more reliable than those currently recommended by the Highways Agency are available for development of pessimistic estimates. The method therefore incorporates the 80 percent confidence level for events to determine the pessimistic estimates.

For each of the Risk Factors, the target, or most likely, and pessimistic estimates have been used to provide an initial basis for the assessment of the effects of uncertainty in the Value Management process.

The primary activity in the development of the maintenance programme for Roads Renewals is currently prioritisation of the Value Management scores. Where schemes have similar scores and are close in the prioritisation to the budget limit, secondary factors (e.g. Benefit-Cost Ratio) are used to discriminate between proposed schemes.

Experience with risk based estimates is very limited for maintenance schemes. It is therefore recommended that risk estimates are used initially as a secondary selection measure in the prioritisation process. The provision of pessimistic and most likely values, with proven robustness against the levels of confidence required, would enable the Highways Agency to utilise a wider range of metrics as inputs into the Value Management process.

Whole life cost analysis tools provide Economic Indicators and contributions to the Value Management scores for both the most likely scheme estimate and the pessimistic estimate. These can then be included in the proposed maintenance programme as one of the secondary selection criteria.

For the four Risk Factors considered in the study, it has been shown how they can be incorporated into the Value Management scoring framework. The Factors are common across pavements and non-pavements and metrics have been identified that will enable schemes with similar Value Management scores to be prioritised based on improved secondary selection criteria.

Calculation of the impact of individual Risk Factors, in terms of revised Value Management scores, enables the Value Management process to focus efforts on those schemes where the Value Management score is most sensitive to the assumptions made for the selected maintenance treatment and the effects to be reflected in the scheme prioritisation to determine the maintenance programme. The report includes a simple example of how the effect of each Risk Factor on the Value Management score for the most likely solution, could be assessed.

For development of the Roads Renewals maintenance programme, these extra criteria derived from the risk based estimates would supplement the primary criterion, the Value Management scores, and can be considered with the current secondary prioritisation criteria (e.g. Benefit-Cost Ratio). If the Risk Factors are considered individually, this is likely to over-complicate the prioritisation process and it is therefore recommended that a weighted estimate of the Overall Risk Susceptibility should be generated from the effects of the four individual Risk Factors and used with the existing secondary prioritisation criteria to prioritise the schemes in the Roads Renewals programme. This approach also enables the inclusion of other Risk Factors and optimistic risk levels for the four Factors considered in this study, when the appropriate information becomes available, by altering the weights of the factors included.

There is currently no experience of including levels of risk in the Value Management and Programme Development processes for Roads Renewals. It is therefore recommended that an assessment of the effects of adopting the approach developed in this study is undertaken for the Roads Renewals programme in one year for a Highways Agency Region (i.e. more than one Managing Agent Area).

1 Introduction

The Strategic Road Network (SRN) in England is a nationally significant asset, comprising the motorways and all-purpose trunk roads, which is managed and operated by the Highways Agency (HA). The HA responsibilities include building, maintaining, improving and operation of the network. Maintenance of the road network includes renewals maintenance to replace assets when they come to the end of their serviceable life and routine maintenance that is primarily cyclic maintenance and the removal of safety hazards soon after they appear on the network. Renewals maintenance includes separate programmes for Roads and Structures Renewals.

This study was concerned with the assessment of proposed Roads Renewals maintenance and was not to address the works undertaken as part of Structures Renewals or routine maintenance.

Value Management forms a key part of the development of the programme of Renewals maintenance. Different Value Management processes are applied to maintenance proposed as part of Roads Renewals, Structures Renewals and Local Improvements. Roads Renewals maintenance includes works on carriageway pavements and a variety of non-pavement assets including drainage, geotechnical assets, lighting and vehicle restraint systems. The connection of risk analysis to maintenance and network enhancements has been discussed by Booth and Harrod Booth (2010). It was shown that the approaches are not consistent across the different asset types and that the overall consideration of risk is not fully visible to key stakeholders associated with the programmes of works. This does not enable the Agency to assess risk exposure and consequences in a manner that supports the management of performance or enable the HA to respond to risk in an even-handed way.

Value Management and development of the Roads Renewals maintenance programme starts from the identification of potential maintenance lengths and, currently, extends to development of the maintenance programme. Risk needs to be better considered throughout all of the process. This report describes how key factors that contribute to the risks associated with the selection and prioritisation of Roads Renewals schemes may be included in the Value Management process.

Value Management for Roads Renewals assesses technical solutions to meet the maintenance need, including the Do Minimum works if the proposed works are not authorised. Scheme proposals based on the agreed technical solutions are prioritised using scores assigned to the proposed technical solutions as part of Value Management. Where schemes have similar Value Management scores, the prioritisation is currently refined using secondary prioritisation criteria (e.g. Benefit-Cost Ratio).

Although schemes may have similar Value Management scores and can be differentiated by the secondary criteria, there may be different aspects and levels of risk for each of the proposed solutions associated with those scores that can also be used to discriminate between the schemes. Risks may arise from a variety of sources and impact on different aspects of the maintenance work (e.g. initial cost of the maintenance, duration of maintenance works, performance of the applied treatment which is reflected in the future cost of maintenance of the asset). It is not yet possible to quantify all the aspects of risk to help distinguish schemes with similar Value Management scores but it is necessary to try and take account of some of the key risks. Factors to be considered in these assessments may include local (political) constraints, local levels of funding and public/user complaints as well as uncertainty in costs and asset performance.

The aim of this study was to produce a method for the inclusion of risk to better influence the Value Management process. It was recognised that this was not to replace the overall approach in the Value Management process but to supplement the process and better inform the development of the Roads Renewals maintenance programme using the outputs from the established Value Management process. The study identified key Risk Factors for different (roads) asset types that can influence the relative priorities

of schemes with similar Value Management scores. The study has identified four key Risk Factors and shown how they can be incorporated into the Value Management scoring framework defined in the current Value Management Guidance. The Factors are common across pavements and non-pavements and metrics have been identified that will enable schemes with similar Value Management scores to be distinguished. In turn, these factors may feed into a harmonised Value Management process but initially they may be used to discriminate between proposed schemes when the current scoring process results in similar scores. The key Risk Factors considered in this study were limited to those associated with quantifiable aspects of maintenance and the expected performance of the asset.

2 Risk in Value Management assessments

2.1 Value Management Process

Value Management of proposed Roads Renewals maintenance schemes considers many aspects of the work proposed for the next 4 years (the Programme Period) including:

- Identification of the maintenance need and the appropriate treatment;
- Estimated cost and duration of the proposed works;
- Expected future performance of the asset (with and without the proposed maintenance).

The assessments are primarily for maintenance to be undertaken within the next 2 years but the indicative maintenance for years 3 and 4 is also identified. Inevitably there is more uncertainty and risk associated with the predictions for years 3 and 4. The introduction of Risk Factors to the Value Management process considered in this study is primarily for year 1 and year 2 schemes but the approach can be used for later schemes if sufficient data is provided with the maintenance proposals.

Roads Renewals maintenance proposals are assessed during Value Management in accordance with the Value Management Guidance (Highways Agency, 2010b) updated each year. For 2010/11 maintenance options on the trunk road network have been assessed by:

- Value for money;
 - Technical justification is based on objective evidence showing how the scope, extent and timing of the proposed treatment option will address the existing defects. The costs of the works paid by the Highways Agency and the costs of the delays to road users at maintenance sites, provide a measure of value for money from the maintenance budget.
- Reduction of disruption;
 - Assesses whether the proposed scheme will minimise disruption to road users compared to other maintenance options including the Do Minimum option.
- Safety;
 - The extent to which the defects within a scheme pose a risk to the safety of road users and how well the proposed works address this risk.
- Environmental sustainability.
 - The likely impact that the proposed scheme will have on the environment and whether sustainable construction practices have been proposed.

The Value Management process is used to assess schemes proposed for the 4-year maintenance programme and provides the following benefits:

- Detailed analysis of the proposed schemes;
- Identifies the information needed to support schemes proposed for later years;
- Provides Value Management scores and related data (e.g. Benefit-Cost Ratios) that can be used to prioritise the proposed schemes and develop a National Roads Renewals Programme.

Proposed schemes are assessed in a series of workshops:

- The first workshop for the overview of maintenance need reviews the need for maintenance over the programme period. This identifies potential schemes based on:
 - Condition data held within the relevant asset system (e.g. HAPMS, HAGDMS, HADDMS);
 - History of reactive repairs to Category 1 and Category 2 defects as described in the HA Routine and Winter Service Code (Highways Agency, 2006) and recorded in the Routine Maintenance Management System (RMMS) or other asset systems;
 - Local issues raised by others (e.g. complaints from the police or public);
 - Location of other related adjacent works (e.g. network improvements or maintenance of other assets);
 - Agreed scheme Risk Registers;
 - Agreed treatment options for years 1 and 2 schemes;
 - Do Something - the proposed treatment;
 - Do Minimum - The minimum treatment needed if the proposed Do Something maintenance is not carried out;
 - The need and details of any additional information/surveys to support each scheme.

- At the second workshop year 1 and 2 schemes are reviewed with the scheme Risk Registers. Maintenance treatments are confirmed for the Do Something and Do Minimum options. The review includes an assessment of the WLC analyses of the proposed maintenance options that provide an Economic Indicator of the Value for Money compared to the Do Minimum option for each of the Do Something options for a scheme. The Economic Indicator shows the Benefit-Cost ratio of the maintenance option and can be used in the subsequent scheme prioritisation for schemes with similar Value Management scores.

- The third workshop is aimed primarily at scoring each scheme, reviewing the Risk Register and confirming none of the technical details of the schemes have changed.

2.2 Definition of risk

In the review of how risk is considered during development of the maintenance programme, Booth and Harrod Booth (2010) found general agreement in the definition and effects of risk but few examples of how risk is included explicitly in the development of road maintenance programmes.

The PIARC Technical Committee on Risk Management for Roads (PIARC, 2005) defines a hazard as the 'likelihood of occurrence of an event in terms of maximum intensity' and risk as the 'quantitative expression of uncertainties and harmful consequences associated with a hazard'. Risk however also applies to the occurrence of improved outcomes that can lead to the overall achieved performance better than that planned or expected as part of the maintenance programme. In the same way as the risk of reduced levels of performance can play an important role in maintenance option selection so can the risk of significantly enhanced performance. The Management of Risk

(M_o_R) Practitioners Guide (Office of Government Commerce, 2007) describes risk as an uncertain event which will, should it occur, have an effect on the achievement of objectives. Risk consists of a combination of the probability of occurrence of a positive or negative impact on the objectives and the severity of that impact. This can be expressed as:

$$\text{Risk} = \text{Probability (of failure/improvement)} \times \text{Consequence (of failure/improvement)}$$

For Roads Renewals, when considering the impact of risk on the development of a maintenance programme, it is generally assumed (e.g. Brabhaharan, 2003) that the risk to be considered is the risk of failure as a combination of the probability of a reduction in performance of the asset and the size of the reduction in performance (e.g. closure of the road). The consequences of road failure and closure can be expressed in terms of several factors including damage repair cost, traffic safety hazard, potential loss of life and social and economic disruption. However, consideration of risk as part of the maintenance selection process is wider than this. Choice of maintenance option is based on a number of factors which include the chance of premature failure and the associated cost of repair, but also include errors in estimated cost, the proposed duration of the works and changes to how the work is carried out or how much of the treatment is needed.

For all risks, a structured approach is needed to aid the consistency of decision making and cost effectiveness in the allocation of resources. In the Roads Renewals Value Management process, a risk assessment that covers all years in which work will be undertaken, must be carried out for all proposed projects costing more than £0.25m. The aim of the risk assessment is not only to ensure that the final outturn scheme costs are as close as possible to the cost estimate agreed when the project was approved but also to help ensure the maintenance option assessment includes the key areas of uncertainty, and the size of those unknowns, as part of the Value Management process. In the current Guidance for the Roads Renewals Value Management process, inclusion of a risk assessment on the scheme allows the use of a lower Optimism Bias value in the analysis of the proposed cost of the works. The costs that result from application of the lower Optimism Bias Factor should be used for the development of the maintenance programme.

2.3 Risk management framework

Normally, the identification, assessment and response to risks are established within a risk management framework that represents a systematic application of principles, approach and processes to the tasks of identifying and assessing risks, and then planning and implementing risk responses (Office of Government Commerce, 2007). The HA Major Projects Directorate Project Control Framework (Highways Agency, 2007) acts in this way and it is recognised there is a need to introduce a similar process in the assessment and prioritisation of the Roads Renewals maintenance programme.

Within the maintenance programme planning process, risk assessment applies not only at the strategic level but also on a project or scheme by scheme basis. The risk management framework can be both informative and beneficial at all stages of development if used continuously to identify, assess and address significant risks to achievement of the project objectives.

2.4 Types of risks

There are numerous types of risks that can be identified within asset maintenance activities. Using the Hierarchical Holographic Modelling (HHM) methodology, Dicdican *et al* (2004) identified the possible sources of risks to highway infrastructures in the United States. The HHM model for roads and highways was developed through interviews with highways agencies regarding maintenance efforts, highways issues and literature on maintenance. For the purpose of maintenance and using the HHM model, sources of risk can be classified into six categories namely political considerations, costs, equipment, personnel, safety and contingencies (described as incidents and civil contingencies in the UK). A sample of the risks under those six categories is shown in Table 1.

Table 1. Sample of sources of risk for maintaining highway infrastructures*

Political Considerations	Costs	Equipment	Personnel	Safety	Contingencies
Environment groups	Maintenance	Cost	Engineers	Workers	Oil spills
Residencies	Rehabilitation	Signs	Managers	Contractors	Hazmat spills
Stakeholders	Environmental	Vehicles	Contractors	Customers	Terrorist threat
Government	Political	Signals	Safety	Cost	Heavy rain
Internal politics	Legal	Administrative process	Cost	Liability	Strong wind
	Resources	Replacement	Scheduling	Security	Snow and ice
	Deferred maintenance	Depreciation	Training		Unexpected heavy traffic
	Customer expectation	Extended life	Turnover rate		Vehicular crashes
	Unfunded mandates		Succession planning		
	Training		Working conditions		

* Source: Dicdican R., Haines Y. and Lambert J. (2004).

Other approaches (e.g. PIARC, 2005) have placed risks into categories such as financial, technical, operational, environmental safety and political. Although all these risks are associated with road maintenance activities, not all can be considered individually when assessing maintenance proposals (e.g. as part of a Value Management process).

In the context of the Value Management process as part of the Roads Renewals maintenance programme development, the main risks associated with prioritising the proposed works are uncertainty in the estimates for the costs of the works, the level of disruption caused to road users, incorrect assessment of the levels of safety for road users and road workers, unexpected environmental effects resulting from the maintenance works and changes in the assumed performance of a component or element that lead to a change in the expected future cost of maintenance of that part of the network.

In addition to these risks, the HA must also consider the political risk arising from maintenance activities on the network. In disrupting road users, it is not only the cost of the increased delay to the road users but also the political risk of failure to meet agreed business objectives (e.g. the Journey Time Reliability target in the HA Business Plan (Highways Agency, 2010a)). This political risk does not however form part of the risks to be considered as part of the Value Management assessments. For the assessments of Major Projects (improvement) schemes, the risks described in the HA Major Projects

Directorate Project Control Framework (Highways Agency, 2007) are divided into three categories, strategic, programme and project. The Management of Risks framework (Office of Government Commerce, 2007) suggests that risks may be divided into four categories namely strategic, programme, project and operational. For Value Management of the Roads Renewals programme it has been assumed that there are three broad types of risk to be considered; business, project and operational. This study has been aimed at project risks but the approach could be applied to other areas.

2.5 Future Value Management models

Value Management for Roads Renewals maintenance is an evolving process with changes dependent on new and enhanced requirements and capabilities in the Agency and its Service Providers.

Future changes to the Value Management process will depend on a variety of factors including, HA policies and operational environment, the realisation of required capabilities and the overall cost effectiveness of the Value Management process as part of Programme Development. The future shape of Roads Renewals Value Management has not yet been established but it will be strongly influenced by the alignment of the processes for roads, structures and local improvements (LNMS). Changes may include development of the current use of multi-criteria analysis or a move to monetisation of the factors assessed.

It was recognised that greater consideration of risk is needed for the Value Management process and will form a key part of future changes to the Value Management approach. There are however many areas in which levels of risk affect the assessment of asset performance and the need/priority for maintenance.

The risks associated with works at one location impact on work at adjacent maintenance sites. This is difficult to include in a Value Management assessment as the relative priority of each maintenance location is not known at the time of the Value Management of each scheme. Nevertheless it is important to include those risks during the later stages of maintenance programme development.

New factors may need to be introduced into the Value Management process in the future to address new HA aims and objectives (e.g. effects of climate change). There will be elements of risk associated with these factors but at this stage, the Risk Factors considered in this project are those associated with the current Value Management process.

Risk Registers are incorporated in the current Value Management process but there is little formal guidance on the types of risk to include and no indication of how those risks may affect the ranking of proposed maintenance works of apparently similar priority. The Registers do, however, provide a framework for recording the acknowledgement of risks during Value Management assessments. Separate studies have already addressed some areas of risk and how Value Management for Roads Renewals can be improved to reduce those risks but they have not shown how the risks themselves can be taken into account in the assessment of the proposed works.

Value Management is currently aimed at the assessment of proposed works. It is a multi-staged process that stops when the Value Management scores have been allocated to the maintenance options.

Levels of risk change as the information about the proposed maintenance improves. Better (more up to date and/or different measurement types) data reduces the risk of unreliable costs and durations, and improves the reliability of the predicted performance of the road pavement, with or without maintenance.

It is recognised that in the future, Value Management should be extended beyond scoring the proposed maintenance option, to address changes in the schemes up to the

start of implementation that may be introduced as part of the design of the maintenance scheme. The assessment of changes in risk needs to accompany the extension of the Value Management process through the scheme design phase.

3 Risk factors for inclusion in Value Management assessments for Roads Renewals

Risks may be categorised as those related to:

- Success of the current maintenance programme;
 - Cost of the programme;
 - Changes to the programme;
 - Future network performance;
- Reputation of the HA (i.e. political risk);
 - HA objectives;
 - Public perception;
- Future effects, not directly impacting on the current performance of the network.

It is also important to note that some risks may impact in more than one area. The current maintenance programme can be affected by many factors:

- Incorrect identification of the parts of the asset to be maintained;
This may result from inadequate or incorrect data or from lack of skills in the Service Provider or the Agency
- Incorrect estimate of the cost of the maintenance work;
This may be from lack of knowledge of local factors or unknown events when maintenance commences. This is only reflected in the share of the funding used for the scheme, not in the priority of the works.
- Changes to the proposed scheme after the Value Management assessment;
When further information becomes available, the scheme definition and, therefore, its contribution to the maintenance programme may change
- Maintenance priority based on expected future asset performance;
Where whole life costs are used to assess the maintenance priority, there are assumptions and expectations in the analyses that affect the apparent priority of the proposed works. Currently there is no assessment of the reliability of those assumptions and expectations.
- Duration of maintenance works.
This has impacts on the current programme and the reputation of the Agency. Work duration contributes to the delays experienced by road users and the costs of those delays form an important part of the whole life cost analysis of each proposed scheme. Incorrect estimates of work durations may therefore raise/lower the priority of the proposed works.

Delays to completion of a maintenance scheme may also prevent the start of work on other schemes in the programme and therefore impact on the overall success of the approved programme. It is difficult to consider this impact at the time of Value Management as the location of schemes on the network is not known until after prioritisation and allocations for the proposed works.

The reputation of the Agency will be affected by the success/failure of meeting annual objectives. This may be a direct consequence (e.g. meeting the network pavement surface condition Key Performance Indicator) or arise, indirectly, from public/user perception of the road network and the maintenance work (e.g. public complaints about asset condition or the occurrence of maintenance works). Each maintenance scheme

contributes to the levels of risk associated with meeting these objectives but the overall risk comes from the combined risk from all schemes in the programme. The Risk Factors considered in this study are primarily associated with the risks on individual schemes rather than the combined risk to the success of the overall maintenance programme.

The Agency has an aim to manage the trunk road network efficiently and effectively both now and in the future. Implementation of current maintenance contributes to the future performance of the network and allowance for this is one of the main justifications of the use of whole life costs. However, even with the best estimate of future performance in the whole life cost analysis, there is a risk to future network performance from the current maintenance not providing its expected performance. As well as being caused by incorrect selection and design of the maintenance, this may arise from unexpected changes to other factors that impact on asset performance (e.g. traffic and climate). The future impact on the network may come from the acceptability of the achieved condition both to the Agency and the road users. The priority of a proposed scheme (i.e. the Value Management score) includes assumptions on the future performance of the asset. Inaccurate assumptions can raise/lower the scheme priority. The risk of making the incorrect assumptions and the effects of those assumptions is reflected in the risk associated with selecting the right schemes in the maintenance programme.

Local (political) constraints (e.g. high profile need for maintenance had been identified and publicised, or other non-maintenance events on the network interacting with the proposed maintenance) may affect the priority of proposed maintenance schemes. The effect of such constraints may be different for each of the proposed maintenance schemes.

All of these risks may affect the selection of maintenance schemes and, in particular, schemes that have similar levels of priority in the current Value Management process. The aim of this study was to show how the different levels of risk can be used to discriminate between apparently similar schemes.

Many aspects of risk have been identified in Sections 2 and 3 but it was agreed that in this study the effects of risks on the Value Management process, and how the Value Management process may take better account of those risks, are considered for the following Risk Factors:

- Costs of the proposed maintenance;
- Selection of the maintenance treatment;
- Duration of maintenance works;
- Future asset performance.

4 Value Management and Risk

For the implementation of the Risk Factors given in Section 3 into the Value Management process and the scoring framework, consideration needs to be given to:

- What information, data and supporting documentation is required to form the basis for analysis of that risk?
- How should the input information be analysed for that risk?
- How should the output from the analysis be factored into the Value Management scoring framework?
- Does the Value Management scoring framework need to be modified?

4.1 Approach to Integration of the Four Factors

The four risk factors given in Section 3 can be subdivided into:

1. *Costs and durations of treatments*

The cost of the proposed maintenance and the duration of the maintenance works are potential outputs from scheme planning and estimation activities and the risk assessment which is required in the current Value Management process. The outputs from the initial scheme planning and risk assessment should provide the necessary information into the Value Management scoring framework to support further analysis. The Value Management Guidance requires the use of the approach to handling risk described in the Highways Agency Value for Money Manual and especially Part 4 of the Manual (Highways Agency, 1999a and 1999b). Part 4, Risk Analysis and Management, promotes the use of the Highways Agency risk assessment approach using the HARM Risk Management tool and associated guidance (Highways Agency, 2008a).

2. *Future asset performance*

Selection of the correct maintenance treatment and prediction of the future asset performance may be investigated through a technical review of the scheme submissions and use of the existing whole life cost (WLC) calculation tools. The existing whole life costing analysis tools can test the impact of different treatment options and treatment life performance assumptions. Scenario testing can be done with the existing WLC tools currently available for assessing maintenance options for the principal assets maintained as part of the Roads Renewals programme but their ease of use for these analyses may need further development. The use of SWEEP for pavements (Highways Agency, 2010d), SAS Drainage (Highways Agency, 2010e) and SAS Geotechnics (Highways Agency, 2010f) supports the assessment of the economic impact of changes of treatment type or changes in the assumptions of the expected lifetimes of chosen treatments.

4.2 Costs and Durations of Treatments

The Highways Agency Risk Assessment process, as covered by Part 4 of the Highways Agency Value for Money Manual provides a framework and methodology and supporting software tools to undertake a risk assessment of proposed schemes. It is understood that adherence to this guidance and use of the supporting software tools is limited for Roads Renewals maintenance schemes. When the guidance is followed identified risks are reviewed individually, risk values allocated and risk profiles subjected to systematic accumulation using the Monte Carlo analysis technique.

Monte Carlo simulation is an industry best practice approach, commonly found in risk management and project planning to generate a pattern of potential probabilistic

outcomes. A similar approach is applied for the basis of the PERT programme and project planning approach.

Depending on the levels of acceptable risk, this approach produces a range of pessimistic (i.e. many of the risk events occur) and most likely (i.e. the expected) outcomes. It can be extended to also include optimistic estimates but these are not required in the current Highways Agency approach to managing risk. The approach developed can be used for the scheme costs and with scheme durations which lead to assessment of the contribution to scheme whole life costs made by the costs of delays to road users incurred at roadworks. Booth and Harrod Booth (2010) identified different options for including different confidence levels to use to assess optimistic, most likely and pessimistic outcomes. The Risk Assessment and Management approach adopted by the Highways Agency for Major Projects assigns the most likely outcome, adopting a Normal Distribution, at the 50 percent confidence level and the pessimistic outcome at the 80 percent level, allowing for a 10 percent error margin. The most likely estimate is known as the Risk Estimate. Although the Highways Agency approach (Highways Agency, 1999a) is now some years old and aimed particularly at new roads and major improvements to the road network, from the review by Booth and Harrod Booth (2010), no other confidence levels are available that would be more reliable. Until better estimates are available from the analysis of maintenance schemes, it is recommended that the 50 percent (most likely) and 80 percent (pessimistic) confidence levels currently recommended by the Highways Agency are adopted for use in the improved approach in the Value Management process.

A Risk Allowance, at a 20 percent confidence level, would also provide optimistic estimates but these are not currently required within the Highways Agency Risk Assessment and Management approach. This approach does not link the probabilistic outcomes of the costs associated with risk to the scheme project plan but a similar approach to identify pessimistic (long), the most likely and optimistic (short) scheme delivery durations or pessimistic (high), most likely or optimistic (low) costs could be used for maintenance scheme assessments.

As optimistic assessments are not currently required in the Highways Agency guidance and to reduce the additional work required for maintenance scheme proposals it is recommended, in line with the Highways Agency Value for Money Manual Part 4 (Highways Agency, 1999a), the optimistic estimates do not form part of the initial implementation for the Value Management of Roads Renewals schemes. Nevertheless it should be recognised when the risk allowances are embedded in the process, inclusion of optimistic estimates will help show the potential benefits to the Highways Agency from alternative maintenance schemes.

To provide an initial basis for the assessment of the effects of uncertainty in the cost and duration estimates in the Value Management process the following information could be provided:

- Target cost and target duration for a scheme (as currently provided);
- A pessimistic estimate of the cost of works;
- A pessimistic estimate of the duration of works.

The effects of these are illustrated in Figure 1 in which the most likely (cost and duration ratios are both equal to 1), pessimistic (higher cost, higher duration) and optimistic (lower cost, lower duration) expected outcomes are shown for example schemes A and B (the most likely estimates for schemes A and B are at the same point on the graph). The risk allowances between the most likely and the pessimistic estimates are shown for both schemes. The risk allowances associated with scheme duration are similar for both schemes A and B but the consequences of the risks to cost are much bigger for scheme A than for scheme B. As scheme B has the lower level of risk associated with it, that scheme would be chosen if risk formed part of the scheme selection process.

The provision of pessimistic and most likely values, with proven robustness against the levels of confidence required, would enable the Highways Agency to utilise a wider range of metrics as inputs into the Value Management process. Appendix A describes how a weighted score was used in the Value Management process for 2009/10 (Highways Agency, 2008b).

A pessimistic viewpoints of scheme outcomes (e.g. as shown in Figure 1) may not represent a viable scheme delivery option (i.e. the pessimistic cost and/or duration would not occur as the scheme would not be delivered in a way that the risk could materialise). Therefore it is always necessary to consider only the outcomes that can be associated with realistic maintenance options.

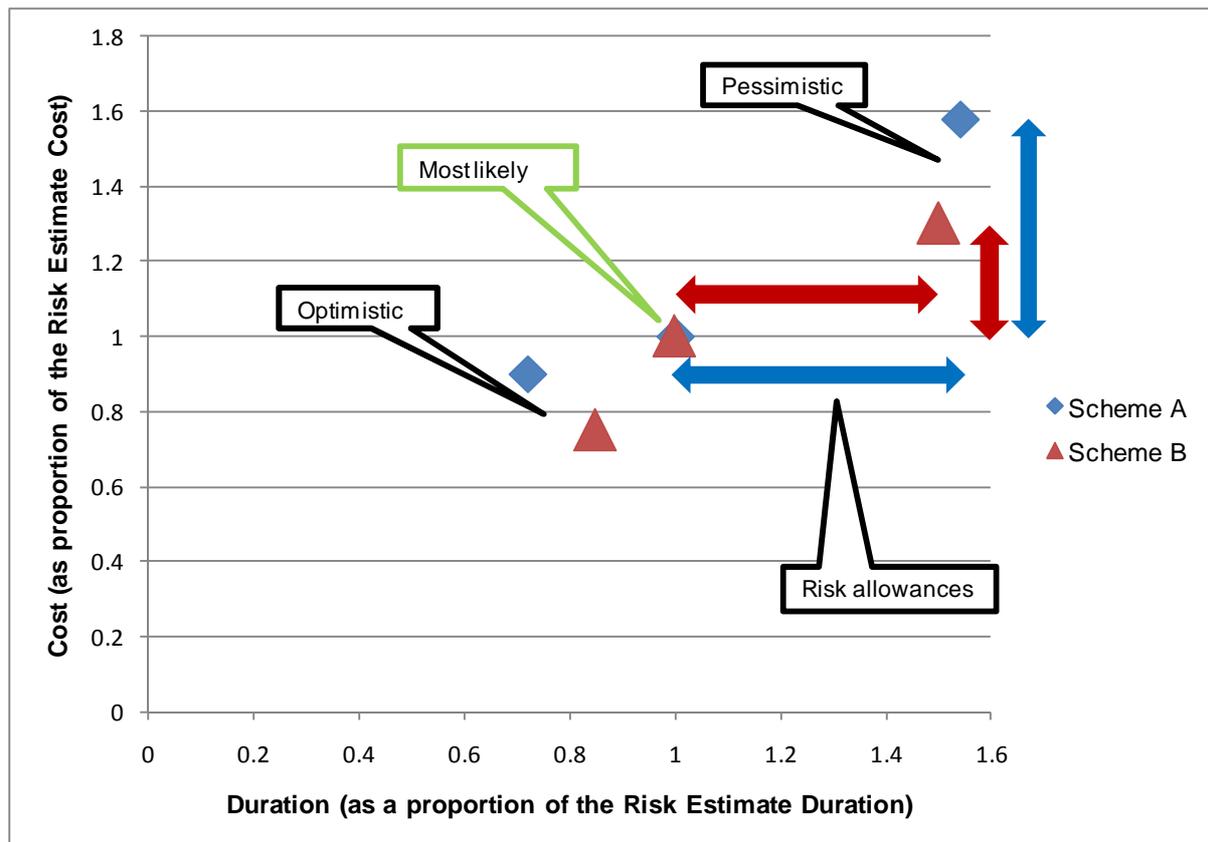


Figure 1 Example of risk allowances and risk estimate

4.2.1 Use of Uncertainty in the Cost of Maintenance in Value Management

The primary factor in the development of the maintenance programme for Roads Renewals as described in the Programme Development and management Manual (Highways Agency, 2010c) is currently prioritisation of the Value Management scores. Where schemes have similar scores and are close in the prioritisation to the budget limit, secondary factors (e.g. Benefit-Cost Ratio) are used to discriminate between proposed schemes.

Experience with Service Provider generated risk based cost estimates is very limited for maintenance schemes. It is therefore proposed that the cost estimates are used initially as another secondary selection measure in the prioritisation process. The current whole life cost analysis tools (SWEEP and the SAS tools) should be used to provide Economic Indicators and hence contributions to the Value Management scores for both the most likely scheme cost and the pessimistic cost estimate. These could then be included in the

proposed programme listing as one of the secondary selection criteria as shown in the example in Table 2.

The secondary criteria enable the differentiation of schemes with similar Value Management scores. Such differentiation, utilising the same levels of pessimism (levels of confidence in the risk occurring), would be able to highlight those schemes which are least likely to expose the Highways Agency to large fluctuations in scheme delivery costs. In the example in Table 2, Scheme 31 indicates a 9 percent reduction in the Value Management score for the defined change in level of confidence (i.e. difference between most likely and pessimistic estimates). This change is accompanied by a 60 percent increase in the proposed scheme cost. Scheme 32 shows a 5 percent reduction in Value Management score and a 10 percent increase in the proposed scheme cost for the same change in level of risk (i.e. the difference between the most likely and pessimistic estimates). Adopting a risk averse approach to the secondary criteria for selection of schemes with similar Value Management scores would give a higher priority to the lower risk scheme because the consequence of the risk occurring is higher (all risks are equally likely). In the example in Table 2, this is Scheme 32.

Currently, inclusion of known risk elements allows for a reduction in the Optimism Bias factors applied to the scheme costs. It is the reduced factors that would be applied in the pessimistic cost estimates used in the risk analyses.

Table 2 Proposed presentation of Most Likely and Pessimistic scheme Value Management scores and scheme costs*

Scheme No.	Value Management score (most likely)	Proposed scheme cost (most likely)	Value Management score (pessimistic)	Proposed scheme cost (pessimistic)
31	72	£754,273	65	£1,204,563
32	72	£1,492,302	68	£1,639,242

* All values are shown for illustration only

4.2.2 Use of Uncertainty in Maintenance Duration in Value Management

For the duration of maintenance works a similar approach to that for the costs of proposed maintenance may be adopted. The current Value for Money Manual guidance does not require calculation of different expected durations for various levels of confidence but it is reasonable for this to form part of the analysis in a scheme risk assessment and the associated contingency planning.

In the same way as pessimistic estimates of cost lead to revised Value Management scores, the pessimistic estimates of works duration (and hence delays to road users) also causes changes in the Value Management scores and the Benefit-Cost Ratio used as a secondary prioritisation factor for development of the maintenance programme. The increase in works duration is associated with increased traffic management costs but it would be assumed no other change in works costs arise with the change in work duration.

Experience has shown Service Providers continue to be over optimistic in the delivery times for maintenance works and it is therefore appropriate to include the likely effects of that optimism on the priority of each scheme. Optimism Bias factors are not applied to the works durations in the current Value Management process so, at present, no account is taken of the sensitivities to time over-runs on the maintenance schemes.

It is proposed that the most likely and pessimistic scheme durations should be analysed, using the available whole life costing tools, to provide two sets of Value Management scores and outturn Economic Indicators.

By using pessimistic estimates of rates of working to generate the pessimistic view of the works durations and, hence, the costs of delays to road users that feed into the Value Management score, the potential effect on each scheme and the risk to the Highways Agency from a large change in work duration could be shown. The costs to road users incurred by delays at roadworks are not directly attributable to the Highways Agency but as work duration does not feed into the Value Management scoring directly, they do provide a measure of the effect of incorrect estimates of work duration on the Value Management score by contributing to the change in WLC.

In the same way as described for the effects of works costs in Section 4.2.1, the percentage change in the Value Management score can be used to represent the level of risk to the Highways Agency and that level of risk then used as one of the secondary criteria in the scheme prioritisation process.

4.3 Future Asset Performance

The existing whole life cost analysis tools can also be used for additional analyses to test different scenarios that illustrate the impact of the choice of alternate treatments and changes to the assumed future performance of the network on the Value Management scores.

Calculation of the impact of individual Risk Factors will enable the Value Management process to focus efforts on those schemes where the Value Management score is most sensitive to the selected maintenance treatment and assumed future performance of the road asset. It is not proposed to combine the testing of these individual factors into a single assessment. If the levels of confidence of the risks being realised are maintained at the same level in all cases such combination could be considered in the future.

In the current Value Management process the review identifies the best year in the 4 year programme period for the proposed maintenance treatment. As part of the review of the proposed works, the technical review and the WLC analyses consider alternative treatments and different years in which to apply the proposed treatment.

Having selected the proposed treatment and the year of implementation, re-analysis of the proposed treatment can show the level of risk with the assumed treatment choice.

For the best alternative treatment (e.g. the next lowest WLC option or the most practical alternative treatment) the WLC analyses and technical review information could be used to provide the equivalent Value Management score for the next best alternative treatment option.

The difference between the Value Management score for the proposed treatment and the score for the best alternative treatment shows the level of risk associated with the choice of the proposed treatment (i.e. by using the proportional change in the Value Management score). This level of risk can then also act as one of the secondary selection criteria in the scheme prioritisation process.

The WLC estimates also take into account the estimated future performance of the asset (i.e. future maintenance requirements during the analysis period). For the proposed maintenance option, the same analyses, but with the assumed future performance reduced (e.g. by reducing the predicted treatment lives during the analysis period, but not altering the types of maintenance treatments) would lead to revised values of WLC and the associated Economic Indicator that would modify the overall Value Management score by changing the scores based on Value for Money and Reduction of Disruption components. The scores for Safety and Environment based on the Value Management technical review would not change.

The revised Value Management score for the proposed maintenance then enables the risk susceptibility due to assumed future performance of the asset to be calculated in the same way as for the other Risk Factors.

4.4 Implementation of Risk Factors

No changes to the Value Management scoring framework are needed to support the recommended approach for incorporating the four Risk Factors considered in this study in the current Value Management process. However, the analysis of the effects of risk on the schemes would be made easier if changes are made to the whole life costing analysis tools. These changes would enable easier re-analysis of each scheme option with revised parameter values and assumptions, rather than needing the complete creation of a new WLC analysis each time. Use of the upgraded tools would need to be fully described in the Value Management Guidance but would enable improvements to be made to the prioritisation of maintenance works for the Roads Renewals programme.

For each proposed scheme it is recommended that Service Providers are required to provide pessimistic estimates of the Value Management scores resulting from pessimistic and most likely estimates for scheme costs, scheme duration, selected maintenance treatment and future asset performance. These should be in accordance with the principles laid out in the Value for Money Manual (i.e. indicating an 80 per cent level of confidence for the pessimistic estimates).

Information on alternative treatments or changes in the expected performance of the chosen treatment would come directly from the current Value Management reviews (e.g. changes in assumed performance of maintenance treatments) and could be used directly in the WLC tools to provide data for assigning revised Value Management scores.

It is inevitable that inclusion of these, or other, Risk Factors will lead to a longer Value Management review process. However, with modified WLC tools the change would be small. The Service Providers would provide supplementary information on the effects of risk susceptibility with the existing information for each scheme for use in the Value Management process.

It is proposed the levels of risk determined with the approaches developed in this study do not affect the current assessment of the Value Management score for the proposed maintenance option. The levels of risk susceptibility could, however, contribute to the prioritisation process by providing better secondary information to discriminate between proposed schemes with similar Value Management scores.

The four Risk Factors considered in this study would lead to four levels of risk susceptibility. To include all these in the prioritisation, the factors could be considered in a nominated priority order. For example:

- Duration of maintenance works;
- Costs of the maintenance;
- Selection of the maintenance treatment;
- Future asset performance;

These extra criteria would need to be considered with the current secondary prioritisation criteria (e.g. Benefit-Cost Ratio). This however may over-complicate the prioritisation process and it is therefore recommended that a weighted estimate of the Overall Risk Susceptibility would be provided for use in the prioritisation process. This may, for example, be based on:

$$\begin{aligned} \text{Overall Risk} \\ \text{Susceptibility} = & 0.5 * \text{Risk susceptibility due to duration of maintenance work} \\ & + 0.3 * \text{Risk susceptibility due to cost of maintenance work} \end{aligned}$$

- + 0.1 * Risk susceptibility due to selection of maintenance treatment
- + 0.1 * Risk susceptibility due to future asset performance

The Overall Risk Susceptibility would then be used with the existing secondary prioritisation criteria to prioritise the schemes in the Roads Renewals programme. This approach also enables the inclusion of other Risk Factors and optimistic risk levels for the current factors, when the appropriate information becomes available, by altering the weights of the factors included.

To support this approach to the inclusion of the proposed Risk Factors, information is needed to support the assessment of the levels of confidence adopted (i.e. pessimistic, optimistic). It is assumed the parameters used in the current Value Management assessments are the most likely values. A review of past maintenance schemes and maintenance records would identify the shift from the most likely values for the parameters to the pessimistic values. Over time these estimates may be refined to be specific to a Managing Agent Area but in the first instance, it is proposed an analysis of the national Roads Renewals programme over 2 or 3 years will identify pessimistic estimates for works costs and works durations. Analysis of maintenance records in HAPMS will identify pessimistic estimates of treatment lives to be used in the analyses. The pessimistic option for the alternative maintenance treatment should already be available as part of the Value Management process.

5 Recommendation

This study has identified 4 key Risk Factors for the development of the Roads Renewals maintenance programme and shown how the effect of pessimistic estimates of those Factors could be incorporated into the Value Management and programme development processes. The approach uses the existing Value Management scoring framework and the whole life costing tools already in use but modifications to the whole life costing tools would ease the estimation of the effects of the Risk Factors.

There is currently no experience of including levels of risk in the Value Management and Programme Development processes for Roads Renewals. It is therefore also recommended that an assessment of the effects of adopting the approach developed in this study is undertaken for the Roads Renewals programme in one year for a Highways Agency Region (i.e. more than one Managing Agent Area). This will allow development of the weighting factors for calculating the Overall Risk Susceptibility resulting from the pessimistic estimates for the four Risk Factors considered in this study. The effects of optimistic risk estimates for the risk factors considered in this study and the effects of pessimistic risk estimates for other risk factors can be included in the future when the information is available.

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Glossary

Abbreviation	Description
AADT	Annual Average Daily Traffic
BCR	Benefit Cost Ratio
HA	Highways Agency
HADDMS	Highways Agency Drainage Data Management System
HAGDMS	Highways Agency Geotechnics Data Management System
HAPMS	Highways Agency Pavement Management System
HHM	Hierarchical Holographic Modelling
JTR	Journey Time Reliability
MAC	Managing Agent Contractor
M_o_R	Management of Risk
PAF	Project Approval Form
RMMS	Routine Maintenance Management System
RWSC	Routine and Winter Service Code
SAS	Scheme Analysis System
SWEEP	Software for the Whole-life Economic Evaluation of Pavements
VM	Value Management
WLC	Whole Life Cost

Appendix A Overview of Roads Renewals Value Management Scoring for 2009/10

Value Management includes the technical review of proposed maintenance activities and allows the relative assessment of these works proposed by Service Providers in order to develop and prioritise the work.

The Highways Agency requires that all Roads Renewals schemes over £250k value require full Value Management. A Small Works programme, survey work and design for future programmes are defined against block allocations, to the Areas. The block allocation does not exceed more than 25 percent of the total allocation.

The assessment and prioritisation of schemes are based on the Value Management scores which the Highways Agency uses to assess schemes in developing a proposed prioritised list of schemes towards a programme of works. This is done at and Area level, before each Area Team submits its proposed schemes to the relevant HA Region. Separate Value Management processes and scoring framework exist for Roads (including pavements and non-pavements such as geotechnics, drainage, lighting and vehicle restraint systems), Structures Renewals works and LNMS.

For roads, the detailed guidance regarding the information on the Value Management scoring is described in "Maintenance and Making Better Use – Value Management of the Regional Roads Programme" (Highways Agency 2008b). Roads schemes are categorised as either Pavement or Non-Pavement schemes which include geotechnics, drainage, lighting and vehicle restraint systems. The same Value Management scoring framework is used by pavement and non-pavements and the scores are based on four criteria:

- Safety;
- Value for Money;
- Reduction of Disruption;
- Environment.

Each scheme is scored against the four criteria that are weighed according to their relative importance. The score for each criterion is out of 100 and is multiplied by the weighting factor to obtain a total weighed score. The total weighted score (also out of 100) is used as the overall Value Management score for use in the scheme prioritisation for the national Roads Renewals programme. The weighting for each criterion is shown in Table A1.

Table A1 Weighting of the four Value Management criteria for Roads Renewals

Criterion	Weighting
Safety	0.2
Value for Money	0.4
Reduction of Disruption	0.3
Environment	0.1

For both pavement and non-pavements, the Value for Money criterion is concerned with ensuring that a project offers good value for money and the Reduction of Disruption criterion emphasises the goal of reducing network disruption and providing Journey Time Reliability. The scoring for Value for Money and Reduction of Disruption is derived from the WLC analyses of the proposed schemes:

- Software for the Whole-life Economic Evaluation of Pavements (SWEEP) in HAPMS for pavements;
- SAS Geotechnics for geotechnics;
- SAS Drainage for drainage.

The Environment score reflects how the project is likely to improve the environment and examples included the use of quieter surfaces and recycling and drainage systems. The Environment score is assessed in the same way for pavement and non-pavement schemes.

Although the Safety weighting is the same for pavement and non-pavement schemes, the definition of safety among pavement and non-pavements schemes are different. For pavement schemes, the scores under the Safety criterion are based on the class of surface deficiencies (SCRIM and texture) and the accident rating of the site. For non-pavement schemes, safety is based on risk assessments of the safety related deterioration. In the case of geotechnics, the risk assessment is done according to HD 41/03 (Maintenance of Highway Geotechnical Assets) and HD 22/08 (Managing Geotechnical Risks).

In addition to the four criteria described above, quality of submission and Journey Time Reliability are also considered for each scheme but they do not contribute to the overall Value Management score.