LoBEG Good Practice Guide

Lifecycle Planning for Highway Structures

Version 2.0
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London Bridges Engineering Group

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Definitions

Discount Rate

The annual percentage rate at which the present value of a future pound, or other unit of account, is assumed to decrease through time [1].

Discounting

A technique used to convert costs or benefits that occur in different time periods to ‘present values’, so that they can be compared on a consistent basis [1].

It is a separate concept from inflation, and is based on the principle that, generally, people prefer to receive goods and services now rather than later.

Inflation

The rise in the general level of prices of goods and services in the economy over a period of time.

Inflation Rate

A measure of inflation; it is the percentage rate of increase in the level of consumer prices or the percentage rate of decrease in the purchasing power of money.

Note: Provided inflation for all costs included in the lifecycle plan of are approximately equal, it is normal practice to exclude inflation effects from an WLC/WLV analysis. However, inflation should be applied when the outputs from the analysis (e.g. the Lifecycle Plan) are used for budgeting purposes.

Lifecycle Plan

A long-term strategy for managing an asset, or a group of similar assets, with the aim of providing the required performance while minimising whole life costs.

Net Present Cost (NPC)

The discounted ‘present cost’ of all future costs, e.g. work, Traffic Management, access and possession costs). It is calculated as:

$$NPC = \sum_{t=0}^{T} \frac{C_t}{(1+r_t)^t}$$

Where

T = the time horizon in years

t = current year, with t = 0 in the base year

C_t = costs incurred in year t, i.e. labour, plant and material,

r_t = the discount rate for year t, expressed as a fraction

Net Present Value (NPV)

The discounted ‘present value’ (normally monetised) of all future costs, benefits and dis-benefits (e.g. traffic delay, environmental impact, carbon footprint etc.). It is calculated as:

$$NPV = \sum_{t=0}^{T} \frac{M_t}{(1+r_t)^t}$$

Where

T = the time horizon in years

t = current year, with t = 0 in the base year

M_t = monetised benefits/dis-benefits in year t

r_t = the discount rate for year t, expressed as a fraction

Time Horizon

The period covered by the lifecycle plan (and used to analyse the Whole Life Costs); typically, this is between 30 and 60 years for long-life assets.

Whole Life Cost

The cost of all items/activities that need to be considered in a whole life costing analysis [2], such as the costs of acquiring (includes design and construction costs), operating and maintaining an asset over its whole life through to its eventual disposal.

Whole Life Costs are used to calculate a Net Present Cost (NPC),

Whole Life Costing

A technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs. Being able to compare the future costs of alternatives allows selection of the most effective overall solution and helps planning and controlling the cost of ownership.

Whole Life Value

A balance of the stakeholders' aspirations, needs, requirements and whole life costs [2], i.e. a balance between risks, performance, cost of interventions and interventions.

Whole Life Value is used to calculate a Net Present Value (NPV),

1 Introduction

1.1 General

This Good Practice Guide describes the lifecycle planning methodology developed by the London Bridges Engineering Group (LoBEG) Asset Management Working Group. The Group consider this methodology to be appropriate for bridges and other highway structures.

1.2 Purpose

The purpose of this guide is to provide a step-by-step guide to lifecycle planning for highway structures, explaining terminology and techniques and how and when lifecycle planning can be used. This guide is intended to ensure a degree of consistency and comparability between lifecycle planning activities.

The proposed lifecycle planning methodology aligns with recognised good practice including the guidance provided in *BSi PAS 55: Asset Management* [3, 4], the *CSS Framework for Highway Asset management* [5] and *Management of Highway Structures: A Code of Practice* [6].

1.3 Lifecycle Planning

Lifecycle Planning is the activity of producing a Lifecycle Plan, where the latter is defined as:

> ***A long-term strategy for managing an asset, or a group of similar assets, with the aim of providing the required performance while minimising whole life costs [6].***

1.4 Benefits of Lifecycle Planning

The benefits of formal lifecycle planning for bridges and other highway structures are considered to include the following:

- *Long-term View of needs* – enables a long-term view (10 years plus) of needs (maintenance and upgrade) to be undertaken in a formalised and systematic manner.
- *Finance Planning* – helps to demonstrate and justify the short, medium and long-term finances required for individual structures, groups of structures and the structure stock.
- *Whole Life Costing* – demonstrates that Whole Life Costs are taken account of when determining maintenance interventions and strategies.
- *Transparent Decision Making* – demonstrates, through analysis of alternative solutions, the impact of alternative maintenance activities.
- *Audit Trail* – systematically compiles assumptions, information sources and engineering judgements associated with the development of lifecycle plans to provide a formal audit trail (that will support future internal usage/challenge and any external review).
- *Knowledge Transfer* – full documentation of lifecycle plans provides an important knowledge capture and transfer mechanism.

There are ever increasing pressures and expectations on bridge managers to demonstrate and justify financial plans. To address these, bridge managers require a robust lifecycle planning approach.

1.5 Layout of the Good Practice Guide

The layout of the Good Practice Guide is summarised in Table 1.

Table 1: Layout of the Good Practice Guide

Section	Description
2. Overview of Lifecycle Planning	Provides a brief description of lifecycle planning and the different factors to be considered during lifecycle planning.
3. Assumptions and Rules	States the assumptions and rules that apply to the lifecycle planning process described in Section 4.
4. The Lifecycle Planning Process	Presents the lifecycle planning process and provides a detailed description of each stage in the process.
5. References	Relevant documents referred to for the purpose of this study.
Appendices	Provides supporting information, including: • Default data for lifecycle planning, e.g. element service lives, deterioration rates, unit rates of maintenance activities, etc. • Description of the method for evaluation of works cost. • Description of the method for evaluation of risk/penalty costs.

2 Overview of Lifecycle Planning

2.1 Asset Management and Lifecycle Planning

Fundamental to asset management is a sound understanding of how an asset is likely to behave/deteriorate throughout its service. The lifecycle of an asset can, in general, be described as shown in Figure 1. However, for long-life assets that have already been brought into service, the most important part of the lifecycle is the deterioration and maintenance cycle, i.e. what activities (e.g. maintenance and/or replacement work) are required to maintain the structure in perpetuity and ensure it provides the required network service. Understanding these issues enables the asset manager to assess the impact of alternative maintenance strategies and to justify current and future expenditure.

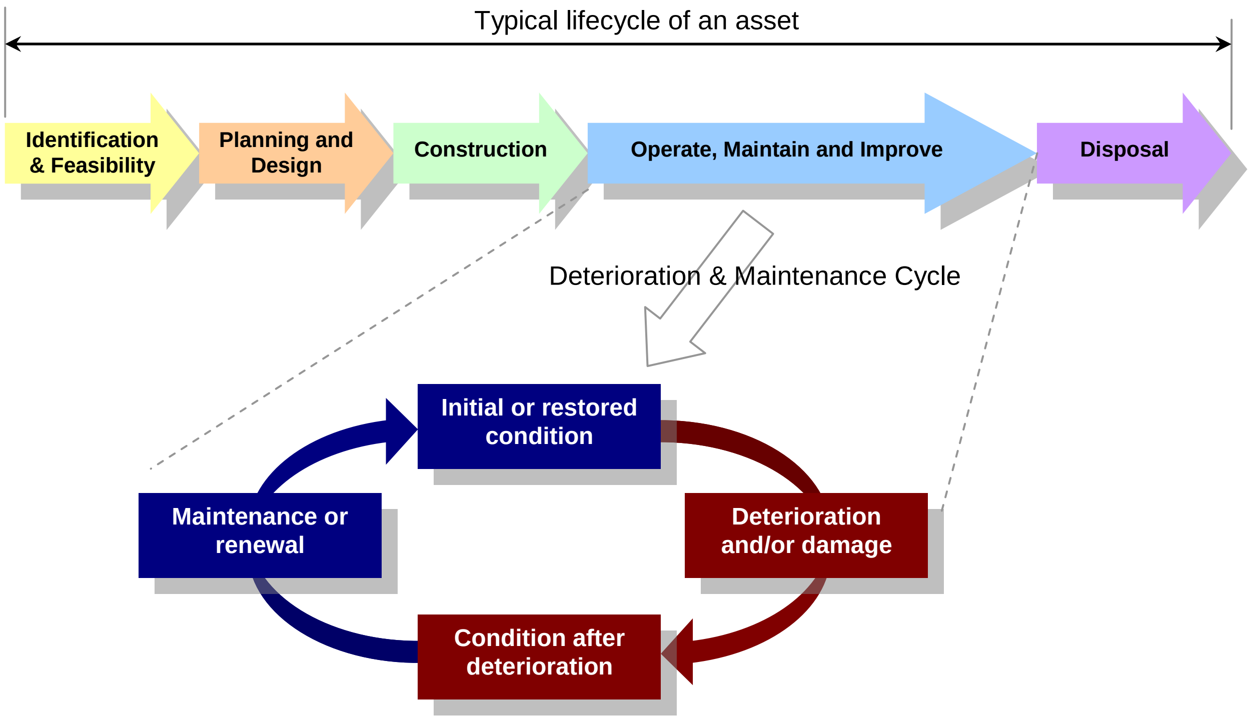

Figure 1: Typical Lifecycle of an Asset

Adopting a systematic approach to address the above mentioned issues associated with the different stages of an asset's life (construction, operation, maintenance , etc. as shown in Figure 1), with a view to minimising the whole life costs is called **lifecycle planning**; the outputs of which are lifecycle plans where these are defined as:

> ***A long-term strategy for managing an asset, or a group of similar assets, with the aim of providing the required performance while minimising whole life costs [6].***

Issues that are typically considered when developing a lifecycle plan include, but are not limited to:

i. the expected deterioration mechanisms and the associated rates of deterioration;

ii. service lives of the asset components;

iii. the required level of asset condition and/or performance;

iv. the type and timing of maintenance and renewal activities and their expected impact on asset condition/performance and deterioration;

v. any statutory requirements which govern iii or iv;

vi. the expected costs of maintenance/renewal activities;

vii. any risks to public safety or those carrying out the work;

viii. any service disruption – due to undertaking the work or not undertaking the work;

ix. any impacts on the wider community (residents, facilities, businesses etc.) – due to undertaking the work or not undertaking the work;

Integrating the above considerations into a lifecycle planning analysis is challenging when dealing with complex assets such as highway bridges and structures, especially if the bridge manager is seeking to develop and compare a number of alternative lifecycle plans for one bridge and/or group of similar structures in order to identify the preferred solution. As such, it is important to have a robust and consistent approach that enables lifecycle plans to be developed in a systematic (step-by-step) manner.

2.2 Balancing Risk, Performance, Cost and Interventions

Highway structures deteriorate over time and thus interventions are required to sustain safety and functionality. The need to intervene and the associated considerations can be considered under the following headings:

- *Interventions* – the maintenance interventions/treatments that are applicable to a structure or element given its location, material, defect type, defect cause, access etc.
- *Performance* – the performance of the structure and/or element, e.g. condition and load-carrying capacity, and how this changes over time and the impact of interventions on this performance.
- *Risk and penalties* – the risks (e.g. to public safety) and penalties (e.g. economic, traffic disruption and load restrictions), i.e. the consequences associated with not undertaking an intervention and/or with undertaking an intervention. An indicative monetary value is usually calculated for representing these consequences and may include but is not limited to:
    - risks of service disruption, e.g. indicative costs related to road user delays, diversions, loss of access to facilities and lost business;
    - risks to safety, e.g. indicative costs related to risks of litigation, adverse public opinion, injury and loss of life;
    - impacts on sustainability, e.g. indicative costs for carbon footprint and other environmental factors, such as noise pollution; etc.
- *Cost of intervention* – the cost of the intervention (including direct costs of maintenance and renewal, i.e. labour, plant and material, access and traffic management costs, etc.) and how cost savings can be achieved through combining/packaging works together.

These are all interrelated and/or interdependent, as illustrated by Figure 2.

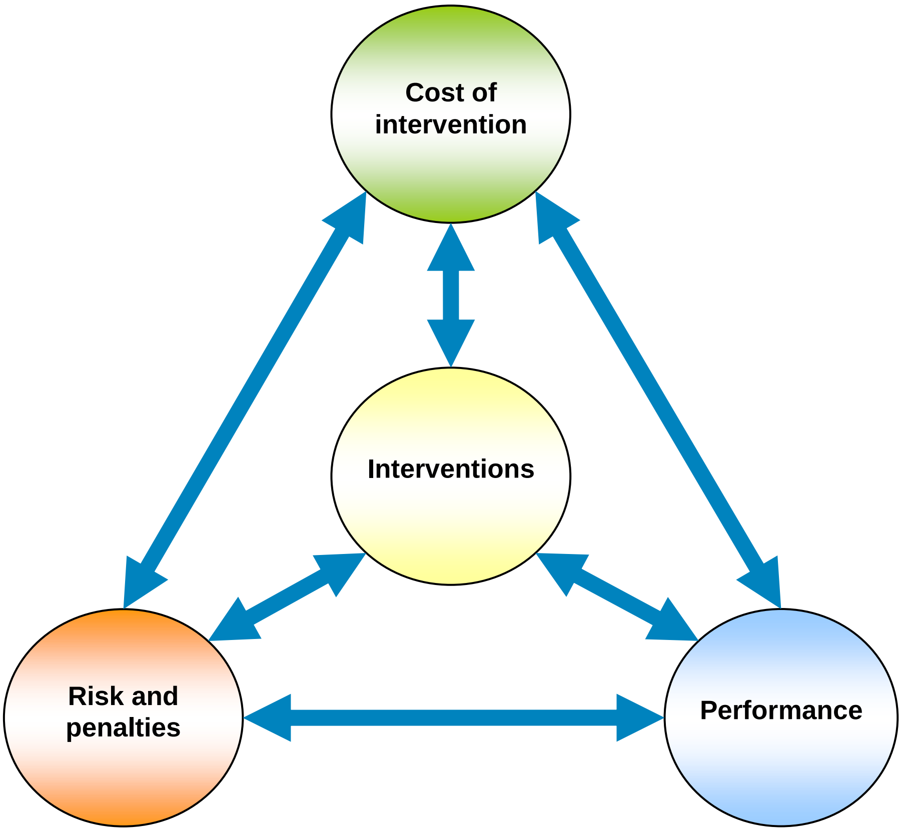

Figure 2: Balancing Risk, Performance, Cost and Interventions

Understanding and defining the relationships between risks, costs, performance and interventions is the key to lifecycle planning. The lifecycle planning process presented in the Good Practice Guide provides a step-by-step approach for working through these key areas of lifecycle planning.

3 Assumptions and Rules

The following Assumptions and Rules apply to the Lifecycle Planning Process described in Section 4.

3.1 Cost Elements

3.1.1 Costs Included/Excluded

Prior to developing lifecycle plans, the rules for inclusion or exclusion of certain cost types (or monetised benefits/dis-benefits) should be defined and documented in order to ensure consistent and comparable values. As a minimum a NPC/WLC approach should be adopted (i.e. include all real costs incurred by the authority), but some authorities may wish to move towards a NPV/WLV analysis that includes monetised benefits/dis-benefits for other criteria such as traffic delay costs and socio-economic impact.

A pragmatic approach should be taken, giving due consideration to the information available (i.e. can realistic 'monetised' values be produced), the experience of the staff involved and the needs and requirements of the authority (e.g. carbon footprint).

3.1.2 Inflation and Current Cost

Provided inflation for all costs included in the lifecycle plans is approximately equal, it is normal practice to exclude inflation effects.

This means the costs used in a lifecycle plan should be in today's prices. However, it is important to bear in mind that if the outputs from the lifecycle plans are used to produce a financial plan, then the figures (for year two of the financial plan onwards) need to be inflated using the appropriate index.

3.1.3 Presentation of Costs

The costs from lifecycle plans can be presented in a number of ways, but the outputs of the analysis should typically include:

- *Lifecycle Costs* – the actual costs that will be incurred by the authority over the period of the plan. This requires future costs to be inflated accordingly.
- *Net Present Cost/Value (NPC or NPV)* – discounting is applied to enable comparison between alternative lifecycle plan options, e.g. 3.5% for the first 30 years and then 3% for the next 30 years.

3.1.4 Routine Maintenance and Inspections

The lifecycle plans should capture routine maintenance and inspection activities/costs, where applicable, especially if alternative maintenance strategies have a considerable impact on the associated routine/inspection requirements. Some bridge managers may wish to use this to assess the relative impact of different strategies on revenue and capital budgets.

3.2 Default Data

3.2.1 General

This Good Practice Guide provides the LoBEG Asset Management Working Group agreed default data, e.g. deterioration rates, service lives, uplift factors, unit rates etc. However, the default data should not be treated as 'set in stone', instead they should be used as guidelines and bridge engineers/mangers are encouraged to challenge and amend the default data to reflect their local knowledge and experience.

3.2.2 Service Lives and Deterioration Rates

The default service lives and deterioration rates provided in Appendix A are based on:

- Extensive literature review (taking account of suppliers' specifications);
- Engineering experience and judgement;
- Current loading requirements; and
- An assumption that a routine maintenance regime is in place (**Important**)

Therefore, the default service lives and deterioration rates given in this Guide are not necessarily the same as the suppliers' specifications but reflect how the LoBEG working party consider these components and materials actually perform based on past experience.

The default service lives and deterioration rates given in this Guide assume that a regime of routine maintenance is in place. The Management of Highway Structures: A Code of Practice [6] defines routine maintenance as:

> *"minor work carried out on a regular or cyclic basis that helps to maintain the condition and functionality of the structure and reduce the need for other, normally more expensive, maintenance works. Examples of routine maintenance common to highway structures include cleaning out expansion joints and drainage systems, greasing of metal bearings, removal of vegetation, removal of blockages in watercourses including removal of silt. Energy costs are also associated with routine maintenance."*

As such, the default service lives and deterioration rates given in this Good Practice Guide should be amended if routine maintenance is not in place.

4 The Lifecycle Planning Process

4.1 Overview

Lifecycle plans should be developed in a consistent manner, capturing and recording key information in a systematic manner. The following summarises each of the stages of the lifecycle planning process as proposed by LoBEG, and Figure 3 presents the process flow:

1. ***Establish the need:*** Establish whether or not there is a need to undertake a Lifecycle Planning analysis and record the rationale for undertaking or not undertaking the analysis.
2. ***Define analysis type, scope and parameters*** – Define the type of analysis (e.g. NPC/WLC or NPV/WLV), the scope of the analysis (i.e. in order to provide clear demarcation of the structures/elements included), the type of scenarios to be analysed (e.g. Do Minimum, proactive, minimise traffic delay etc.), and the analysis parameters, e.g. time horizon and discount rate.
3. ***Compile data*** – Assemble the data and information that will support the lifecycle planning process. This includes:
   - inventory data, including structure and component/element details;
   - inspection data and performance requirements;
   - deterioration rates of the components and materials;
   - intervention options for addressing potential defects; and
   - unit rates for calculating the works and other costs (e.g. access, traffic management, etc.) associated with undertaking intervention(s).
4. ***Forecast deterioration when no action is taken*** – Calculate how the structure(s) (and its components) is expected to behave over the analysis period given no action is taken (this forms a base case that other lifecycle plans build upon).
5. ***Define Type of Lifecycle Plan*** – Define the purpose/aim of the Lifecycle Plan as this will influence intervention times and selections, e.g. Minimise WLC, Do Minimum, reactive or proactive etc. If several plans are to be developed and compared then steps 5 to 8 are repeated for each.
6. ***Select and Apply Interventions*** – Select maintenance, renewal, upgrade, etc. activities and amend the condition/performance accordingly.
7. ***Calculate intervention costs*** – Calculate the costs associated with the selected intervention activities.
8. ***Calculate penalty costs*** - Calculate an indicative monetary value representing the risks and penalties associated with the maintenance strategy (both for undertaking and not undertaking activities).
9. ***Compare alternative lifecycle plans*** – If there are several lifecycle plans for the structure/group of structures, then compare these using NPC, NPV etc. and select the preferred plan.
10. ***Adopt preferred lifecycle plan*** – Use the preferred plan to inform budgets, work plans, etc.

The following sections provide further guidance on each of the above stages.

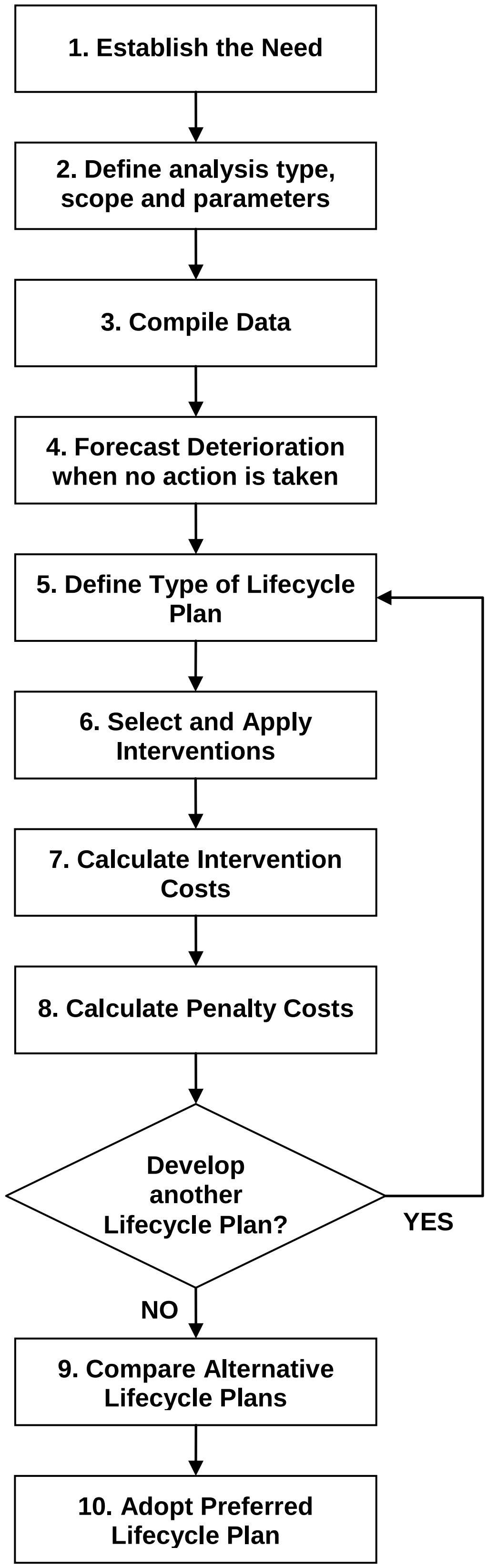

Figure 3: Lifecycle Planning Process

4.2 Stage 1: Establish the need

Time and effort are required to produced robust and meaningful lifecycle plans, therefore it is essential to establish whether or not there is a need to develop them. Section 4.12 provides examples of it may be appropriate to develop lifecycle plans.

Once the need has been established, the rationale for undertaking or not undertaking the analysis should be recorded.

4.3 Stage 2: Define Analysis Type, Scope and Parameters

4.3.1 Type

Clearly define and record the type of analysis that will be undertaken, for example, will it focus solely on direct costs (i.e. NPC/WLC analysis) to the authority or will it also seek to monetise other benefits/dis-benefits, e.g. traffic delay, environmental impact, etc. (i.e. NPV/WLV analysis). If the latter is adopted, then agree upon those criteria to be included and how they will be converted to a monetary, or other, scale.

4.3.2 Scope

Clearly define and record the scope of the analysis with regard to the physical boundaries of the structure/s and/or scheme, e.g. does it include surfacing works, what length of embankments are included, river works, etc.

4.3.3 Parameters

The basic parameters of the analysis should be agreed and recorded, e.g. time horizon and discount rate.

Time Horizon

Within a lifecycle plan (or series of alternative lifecycle plans that are to be compared), the time horizon must be consistent for all structures and elements under consideration.

A time horizon of 60 years is consistent with that used in other economic transport appraisals [10] and may be used when developing lifecycle plans for bridges and other highway structures.

However, a different time horizon can also be used but it is considered that this should not be lower than 30 years in order to produce meaningful outputs.

Discount Rates

In accordance with Government guidance [1], the schedule of discount rates reproduced in Table 2 should be used.

Table 2: The Declining Long-Term Discount Rate

Period of years	0 – 30	31 – 75	76 – 125	126 – 200	201 – 300	301 +
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

4.4 Stage 3: Compile Data

A detailed description of the data and information required to support the lifecycle planning process is presented in the following sections.

4.4.1 Inventory Data

Collate the basic inventory data, such as:

- Structure details, e.g. name, reference, location, dimensions, route supported and obstacle crossed.
- Element details, e.g. type, material and dimensions.

It is suggested that the minimum level of detail (granularity) should be the standard list of CSS Inspection elements [7, 9], reproduced in Table A.1 in Appendix A. This list is considered to provide the appropriate level of detail in the majority of cases.

Important points to consider when defining the inventory information are:

- The structure breakdown should be sufficient to enable all major maintenance and renewal activities to be captured and identified separately. That is, the lifecycle plan is built-up from the activities required on individual elements; as such, the elements need to be identified at an appropriate level of granularity.
- The greater the granularity the more complex lifecycle planning becomes. An overly detailed inventory breakdown may not be required when looking at a 30 to 60 year time horizon.

4.4.2 Inspection data

Ideally inspection data should be held against each of the aforementioned inventory elements/components, this should be the case if the authority uses the CSS BCI procedure [7, 9]. This enables the condition/performance of each component or element type to be assessed separately.

As a minimum, the inspection data from the latest General or Principal Inspection should be collated as this provides the starting point for the lifecycle plan (averaged for a group of structures or the actual data for a specific structure). If historical data is available, it may be beneficial to collate this as well as it could provide insight into service lives and deterioration rates.

4.4.3 Performance Requirements

The level of service required (at structure and component level) both now and in the future should be defined, where possible, in **quantifiable** engineering terms for the analysis period. The following should be considered and, where appropriate, defined as key assumptions that drive the lifecycle plan:

- *Loading* – what loading regime needs to be satisfied?
- *Height* – what vehicle height clearance is required?
- *Width* – what width clearance is required (e.g. a single vehicle or number of lanes provided)?
- *Users* – what facilities are required for users (vehicular and pedestrian)?
- *Safety* – what safety criteria need to be satisfied, e.g. condition to prevent concrete spalling?

- *Condition* – are there any specific condition/aesthetic requirements that need to be satisfied?

If one or more of the above is not currently satisfied then it may be a key influencing factor in the lifecycle plan. It is therefore important to clearly capture the current and required levels of service and any supporting rationale.

If it is known that the service requirements will change over time, then the change in requirements, the reason for the change and the time when the change is expected to occur should be recorded.

4.4.4 Deterioration Rates for Components and Materials

It is recommended that a base set of deterioration rates/service lives are compiled for the analysis, thereby ensuring these will be applied consistently between alternative Lifecycle Plans. The base data should cover all the components and materials in the scope of the plan and seek to reflect the key factors that influence the rate of deterioration or length of service life. It is recognised that this is not an exact science and typically the best source of information is local knowledge, especially as some defects take many years to develop to the point where they require maintenance.

When defining deterioration rates/service lives for the components and materials also consider the factors that may influence these, such as:

- Construction/installation quality (workmanship)
- Vandalism/unforeseen events
- Traffic volume
- Design standards
- Design/construction errors
- Exposure Environment
- Maintenance Effect

The effect of maintenance is dealt with in Section 4.4.6. Of the remaining and/or other factors considered relevant, the bridge engineer/manager should consider how these may influence their structure(s). Where they are considered to have an impact, i.e. increase/decrease service life or rate of deterioration, then a simple classification is suggested, e.g. differentiate between High, Medium and Low impact and produce definitions for each so they are applied consistently.

LoBEG consider Traffic Volume and Exposure Environment to be two significant influences on deterioration rates and service lives in London, Table A.2 and Table A.3 in Appendix A present the classifications produced, i.e.

- *Traffic volume* – three categories are defined based on the annual average daily traffic (AADT) and/or commercial vehicles (CV).
- *Exposure Environment* – descriptions for three exposure environments are provided along with examples of the typical element location.

Once the influencing factors are defined, then the deterioration rates/service lives for each component/material type can be defined. The approach used by LoBEG to define these is shown in Table A.4 and Table A.5 in Appendix A:

- Table A.4 provides a list of typical bridge components and their suggested rates of deterioration.
- Table A.5 provides a list of typical bridge materials and their suggested rates of deterioration.

The default values in Table A.4 and Table A.5 are provided as guidelines and should be amended where appropriate to reflect local knowledge and characteristics.

4.4.5 Intervention Options

A list of potential intervention options should be produced. The list developed by LoBEG is provided in Table A.6 in Appendix A. This is provided as guidance and should be amended where appropriate to reflect local knowledge and characteristics.

4.4.6 Intervention Application and Effects

It is suggested that characteristics of the intervention application (i.e. which components and materials it applies to and at what condition) and the effect of the intervention are recorded as this will ensure they are applied consistently and can be readily reviewed.

Table A.7 in Appendix A presents the application/effects agreed by LoBEG. The table includes (from left to right):

- Material or component type;
- Existing exposure environment;
- Defect cause / maintenance driver;
- Defect type;
- Maintenance Activities;
- Relevant condition range, i.e. what condition range is appropriate for application of the proposed treatment;
- Exposure after [intervention] application – the change in exposure environment due to treatment;
- Condition after [intervention] application;
- Deterioration profile after [intervention] application.

The deterioration profiles of components and materials are primarily based on an assessment of the time to reach condition 4B and 5B, respectively.

The default values in Table A.7 are provided as guidance and should be amended where appropriate to reflect local knowledge and characteristics.

4.4.7 Base Unit Rates

It is suggested that a set of typical unit rates are compiled for the interventions. The set of default unit rates produced by LoBEG are is presented in Table A.8 in Appendix A. Against each maintenance or work activity the following is presented:

- *Unit* – the unit against which base cost is defined, e.g. item, m, m^2;
- *Maintenance Activity Cost Type* – cost types may be set as Constant, Variable or Fixed, where these are defined as:
  - ***Fixed*** – represents a fixed unit rate applied under specified conditions and/or a point in time as outlined in the 'Comments' column. The activity has a fixed cost per item/time period.

  - ***Constant*** – represents the unit rate that remains the same regardless of condition and is normally applied to the full size of the element/component, e.g. element replacement, application of impregnants, etc.
  - ***Variable*** – represents the unit cost rate that is dependant on the condition/severity of the element to which a maintenance activity is applied, e.g. concrete repairs, masonry repairs, metalwork repairs.
  - ***Constant or Variable*** (as appropriate) – represents a maintenance activity where unit rates can be treated as either 'Constant' or 'Variable'. That is when the condition/severity of the element on which a maintenance activity is undertaken is known then the 'Variable' unit rate is used; when the condition/severity of the element is not known then the 'Constant' unit rate is used, e.g. deck strengthening, etc.

- <u>Unit Rates</u> – the rates for the cost types listed above.

The unit rates provided in Table A.8 in Appendix A are based on:

- Typical London rates provided by members of the LoBEG Asset Management Working Group;
- Draft BD36;
- SPON'S Civil Engineering and Highway Works Price Book;
- Unit rates compiled by Atkins through other projects.

The default unit rates are provided as guidelines and should be amended where appropriate to reflect local knowledge and characteristics.

4.5 Stage 4: Forecast deterioration when no action is taken

It is recommended that a 'Do Nothing' lifecycle plan is produced as this will (i) illustrate what happens to the structure/s when no interventions are applied over the analysis period; and (ii) act as the base case/template for the development of the 'Do Something' lifecycle alternatives.

The condition data provides the starting position and the collated deterioration rates and service lives are used to demonstrate how this will change in the future (given no intervention). This can be highly effective when used to demonstrate when 'critical' conditions (e.g. 4B or worse on the CSS BCI scale) will be reached.

4.6 Stage 5: Define Type of Lifecycle Plan

Where possible, it is recommended that alternative lifecycle strategies are considered, although it is recognised that in some instances there may only be one appropriate strategy, where this is the case effort should not be expended on impractical alternatives. Alternative lifecycle strategies that may be considered include:

- **"Do Minimum" Strategy** – the minimum required to sustain safety across the analysis period, e.g. infrequent/irregular but major interventions to satisfy/meet the minimum safety and performance targets.
- **Preventative Strategy** – regular and frequent minor interventions to maintain the condition of the structure by slowing down the rate of deterioration.
- **Targeted Strategies** – with interventions aimed towards:
  - Minimising Whole Life Costs while satisfying safety/performance targets;
  - Minimising network disruption; satisfying the disruption targets;

- Delivering a required condition score;
- etc.

Figure 4 provides an illustration of how the application of different maintenance strategies can have a pronounced effect on the timing of interventions.

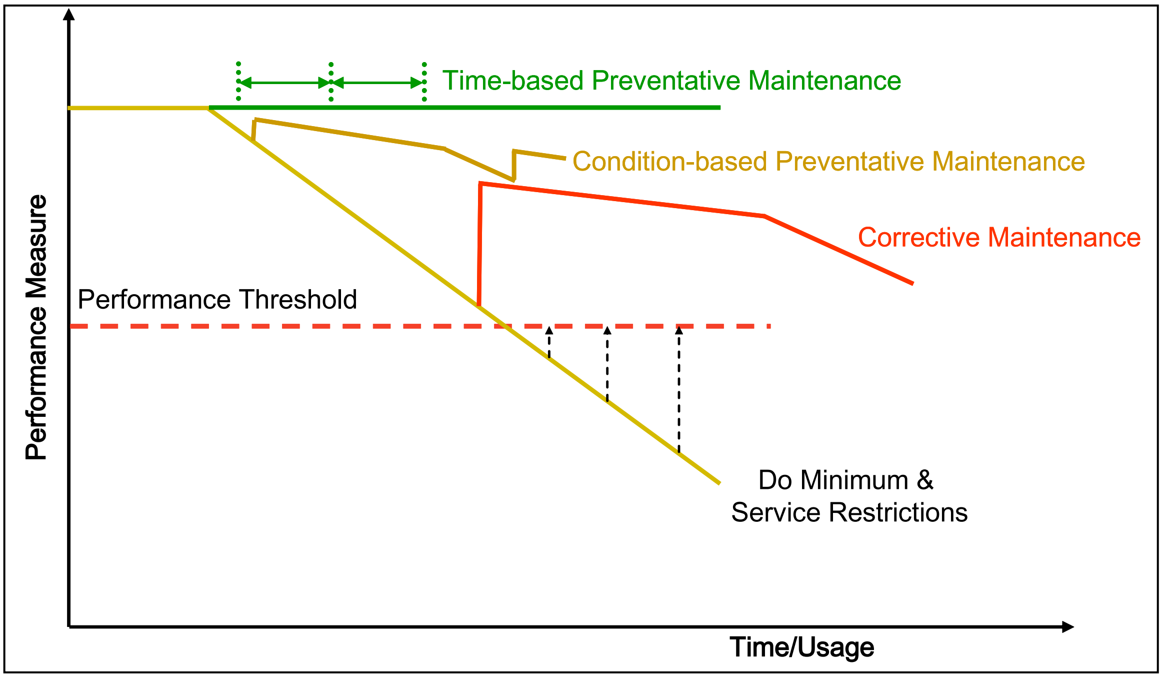

Figure 4: Alternative Maintenance Strategies

For each lifecycle alternative it is suggested that Stages 6 to 8 include a sensitivity analysis of key parameters and assumptions.

4.7 Stage 6: Select and Apply Interventions

It is likely that there will be a number of feasible maintenance or renewal options for the structure(s), components and elements included in the lifecycle plans. It may be feasible to use combinations of options, e.g. preventative maintenance combined with essential treatments to meet the requirements.

Based on the knowledge of the structure/s and on the information at hand (such as that described in previous sections), the type (i.e. work activity) and timing of interventions should be determined.

A list of potential intervention options is provided in Table A.6 in Appendix A. This is provided as guidance and should be amended where appropriate to reflect local knowledge and characteristics.

The rationale/justification behind the selection of appropriate options should be documented. This will enable the full documentation of the rationale and will facilitate in understanding the plan, when revisited at a later stage.

4.8 Stage 7: Calculate Intervention Costs

A logical process, that reflects the detail of the lifecycle plans, should be developed for deriving costs. The process developed by LoBEG is shown in Figure 5 and includes:

- *Activity Cost* – the process for calculating the cost of an individual work activity on a specific element (see Section 4.8.1); and
- *Scheme Cost* – the process for combining a series of Activity Costs for conversion into a scheme cost (see Section 4.8.2).

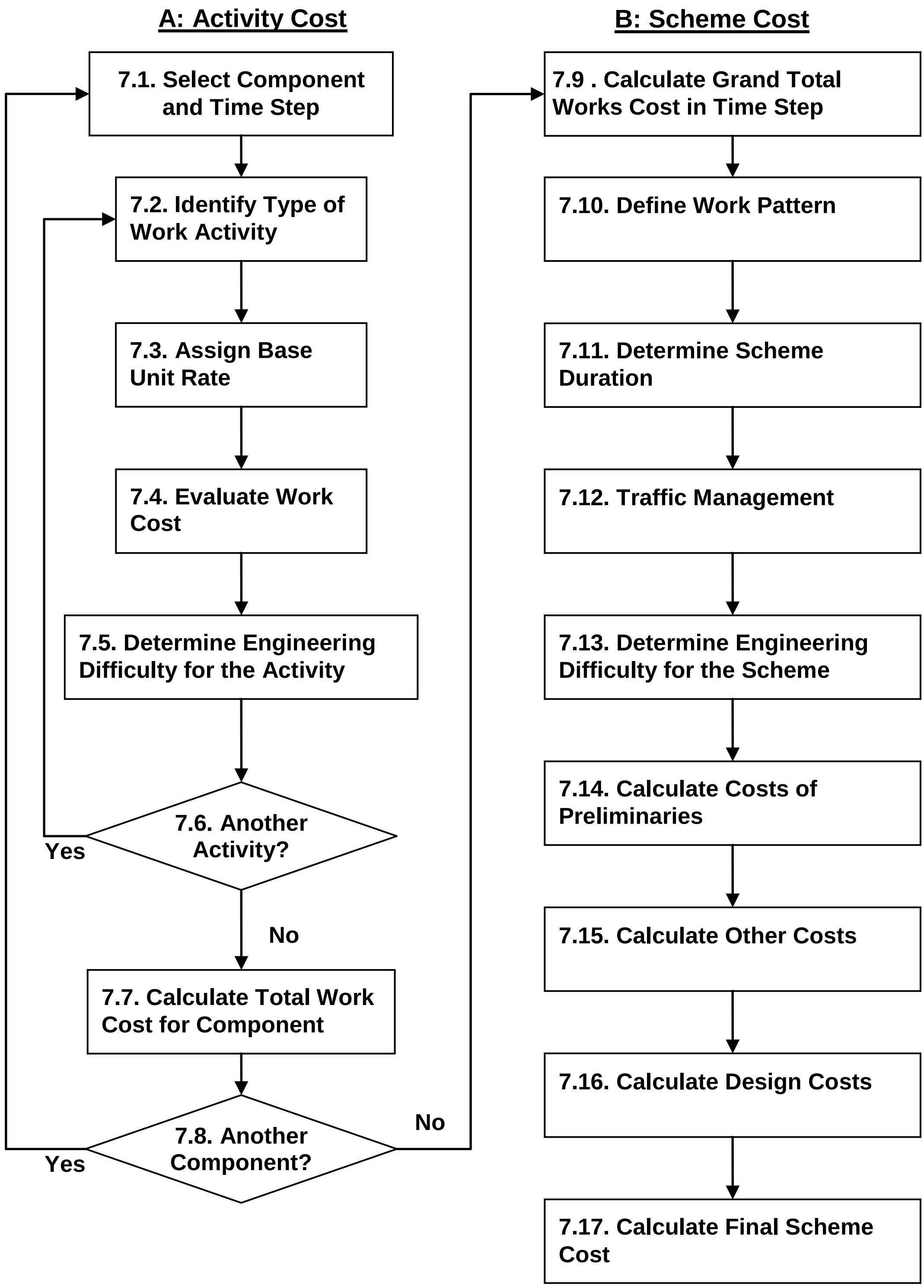

Figure 5: Costing Process

4.8.1 Activity Cost

The following sets out each of the steps in the Activity Costing process.

- ***Step 7.1: Select Component and Time Step*** – This is a component and/or element or a group of components and/or elements that have associated intervention(s), i.e. work activity/activities at specific year(s) in the analysis period selected as described in Section 4.7.
- ***Step 7.2: Identify Type of Work Activity*** – This is the maintenance or work activity or the combination of activities selected as described in Section 4.7 for the identified component(s) and/or element(s) at specific year(s) or time steps in the time horizon. A list of potential intervention options is provided in Table A.6 in Appendix A while the permissible intervention options depending on the component/material type are given in Table A.7 in Appendix A. These are provided as guidance and should be amended where appropriate to reflect local knowledge and characteristics.
- ***Step 7.3: Assign Base Unit Rate*** – Each identified work activity can be assigned a default base unit rate (i.e. rates for works only) using the definitions provided in Section 4.4.7. A set of default base unit rates is presented in Table A.8 in Appendix A.
- ***Step 7.4: Evaluate Work Cost*** – Evaluating the works cost should be based on:
  - *Work quantities* – The quantity of work required should be determined based on the component(s)/element(s) dimensions and the severity/extent of the defect.
  - *Maintenance cost type and unit rates* – described in Section 4.4.7. Also, see Table A.8 in Appendix A.
- ***Step 7.5: Determine the Engineering Difficulty of the Activity*** – The engineering difficulty of the works can influence cost in a number of ways, for example painting undertaken in a confined space above ground level is considered to be relatively more difficult and therefore more expensive as compared to painting undertaken in an open space and at ground level. Table A.9 in Appendix A lists a set of 'Engineering Difficulty' examples relevant at activity. The engineering difficulty costs for the activity can be calculated either by applying a suitable uplift factor to the work cost calculated in Step 7.4 above or based on local knowledge and experience.
- ***Step 7.6: Calculate the Cost of Another Activity*** – One component and/or element, at any given time step, may require more than one maintenance activity. If this is the case, then steps 7.2 to 7.5 should be repeated for each activity.
- ***Step 7.7: Calculate the Total Work Cost for the Selected Component*** – The total work cost is the summation of the individual work costs (see Step 7.4) and engineering difficulty costs (see Step 7.5) for an individual component and/or element at a specific time step.
- ***Step 7.8: Calculate the Total Work Cost for Another Component*** – Often more than one components and/or elements on a structure and/or group pf structures may require maintenance activities at a given time step. If this is the case, then steps 7.1 to 7.7 should be repeated for each component and/or element. It is noted that the timing of work activities may require to be adjusted in order to combine the timing of interventions of two separate but associated elements so that it coincides rather than having to undertake works at two

separate time steps, e.g. to undertake concrete repairs to the deck soffit and abutments.

4.8.2 Scheme Cost

The following sets out each of the proposed steps in the Scheme Costing process.

- ***Step 7.9: Calculate Grand Total Works Cost in Time Step*** – A scheme is a combination of all the activities undertaken on some or all components and/or elements at a specific time step. Thus the total scheme cost will be a summation of all the works cost undertaken within the time step. At this stage, the scheme requirements should also be defined, which include the items described in Steps 7.10 – 7.16 below.
- ***Step 7.10: Define Work Pattern*** – An appropriate work pattern (e.g. daytime, night-time, 24 hour working, etc.) should be determined for the proposed scheme as this may influence the costs and overall duration of the scheme. Lifecycle plans with alternative arrangements may be developed to enable comparisons to be undertaken on costs and implications. Identifying when work can be undertaken in parallel or series will have a significant impact on the duration of any associated traffic management arrangement. A sample set of work patterns is provided in Table A.10 in Appendix A, along with what is considered to be effective working time. It is noted that more than one work patterns may be applicable to the scheme depending on the maintenance activities and works location. The work pattern cost can be calculated either by applying a suitable uplift factor to the grand total works cost calculated in Step 7.9 above or based on local knowledge and experience.
- ***Step 7.11: Determine Scheme Duration*** – The scheme duration is an estimate of number of days, based on the bridge engineer's judgement, within which the scheme works can be undertaken, taking into account the:
  - Activities to be undertaken;
  - Location; and
  - Permissible work patterns.
- ***Step 7.12: Determine Traffic Management Cost*** – The appropriate Traffic Management (TM) arrangements should be selected based on the type of maintenance activities (location), work pattern, scheme duration, etc. Works that, given the structure arrangement (e.g. obstacle and route supported), can utilise the same TM and access arrangements should be identified. Table A.11 in Appendix A provides a list of traffic management arrangements, along with suggested rates per hour, which are applicable at scheme level. Lifecycle plans with alternative TM arrangements can be developed to enable the comparison of cost and implications. It is noted that more than one TM arrangement can be applicable to a scheme, depending on the works type and location.
- ***Step 7.13: Determine Engineering Difficulty of the scheme*** – The engineering difficulty at scheme level can influence the scheme cost in a number of ways. For example, consideration should be given to the remoteness of the site and whether this poses any significant access difficulties, etc. Table A.12 in Appendix A provides a set of example 'Engineering Difficulty' scenarios which are applicable at the scheme level. The engineering difficulty costs for the scheme can be calculated either by applying a suitable uplift factor to the costs calculated in Steps 7.9, 7.10 and 7.12 above or based on local knowledge and experience.

- ***Step 7.14: Calculate Costs of Preliminaries*** – Preliminaries do not include site clearance or work associated with contaminated land, both of which are covered under Other Costs instead. The costs of preliminaries can be calculated as a percentage of the scheme cost (i.e. the sum of costs calculated under Steps 7.9 – 7.13). Preliminaries typically cover the items listed below.
  - Site set up;
  - Site facilities (stores, offices, servicing etc.);
  - Temporary works;
  - Contractor's overheads (site overheads and percentage of head office, staff training, back office staff salaries);
  - Contractor margin;
  - Contractor's site vehicles;
  - Travel expenses;
  - Bonus payments;
  - Site information boards;
  - Progress photos;
  - Scheme registration (considerate contractors);
  - Landfill costs / skip licences;
  - Licences.
- ***Step 7.15: Calculate Other Costs*** – Other Costs act as a 'catch all' for costs that cannot be assigned elsewhere, such as those associated with site supervision, keeping the Health and Safety file up-to-date, site clearance, etc.
- ***Step 7.16: Calculate Design Costs*** – Design costs can be calculated as a default percentage of the total scheme cost (i.e. the sum of costs calculated under Steps 7.9 – 7.13). Design costs typically include the costs for the following:
  - Feasibility study;
  - Outline design;
  - Site investigation/testing (5% of contract value);
  - Detailed design;
  - Contract documentation and procurement.
- ***Step 7.17: Calculate Final Scheme Cost*** – All the costs calculated in steps 7.10 to 7.16 summed together give the final scheme cost, i.e.

4.9 Stage 8: Calculate Penalty costs

An indicative monetary value representing the risks and penalties associated with not undertaking and/or significantly delaying intervention(s) should be calculated, e.g.

- **Loss of Service:**
  - *Impact on availability:* In extreme circumstances, it may become necessary to close lanes and/or entire structure(s) for safety reasons. When appropriate, penalty costs associated with the structure(s) and/or lane closures could be quantified by vehicle delay costs.

- *Impact on other routes:* Not undertaking and/or significantly delaying an intervention may impact the route supported and/or crossed by the structure, i.e. pose a risk to:
  - railways, e.g. service disruption
  - waterways, e.g. pollution
  - traffic flow on local authority roads (over/under the structure)
  - farm access, etc.
- *Impact on Utilities:* Disruption of utility services, e.g. gas, water, telecommunication, etc.

- **Safety Risk:**
  - *Risk to structural Integrity:* In extreme circumstances structural failure may occur, e.g. a load bearing element reached condition 5 (failed). When appropriate, associated penalty costs, e.g. vehicle delay costs, reconstruction costs, etc., should be calculated and taken into consideration while developing lifecycle plans.
  - *Risk to public safety:* If some elements are permitted to deteriorate to an unacceptable level (e.g. expansion joints, bearings) they may cause vehicle accidents due to their impact on the running surface. When appropriate, associated penalty costs, e.g. accident/casualty costs, should be calculated and taken into consideration while developing lifecycle plans.
- **Environmental Impacts** may include pollution (air/noise) due to traffic delays, or carbon footprint cost (associated with re-construction), etc. Where, appropriate such costs should be quantified and taken into consideration while developing lifecycle plans.

Penalty costs could be calculated based on the following and /or other suitable factors:

- *Element Importance* – This takes account of the importance of an element to the overall structure in terms of load carrying capacity, durability and public safety.
- *Element Serviceable Condition Threshold* – The condition of an element beyond which it is considered to be unserviceable or close to it and/or in a dangerous condition thus posing the aforementioned risks (to service, safety and environment) and incurring penalties.
- *Average Replacement Cost for an Element* – Used to calculate the indicative monetised value of the associated risks/penalties.

The calculated penalty cost could be added to the Final Scheme Cost calculated in Stage 7 to evaluate the total cost for a specific timestep. This will enable a comparison between different strategies both in terms of scheme costs as well as the penalties that may be incurred. The whole life value of the structure will be a summation of the final scheme costs and penalty costs incurred within all the timesteps over the selected time horizon.

4.10 Stage 9: Compare Alternative Lifecycle Plans

The alternative lifecycle plans developed under Stage 5 of the Lifecycle Planning Process (see Section 4.6) should be compared to identify the preferred solution based on the lifecycle costs and/or the net present cost/value. For example, Figure 6 shows how net present values may build up over time for three alternative maintenance strategies.

The strategy with the lowest **Net Present Cost/Value** that provides an acceptable balance between interventions, risks, cost and performance (see Figure 2) is likely to represent the preferred option (i.e. engineering optimum solution).

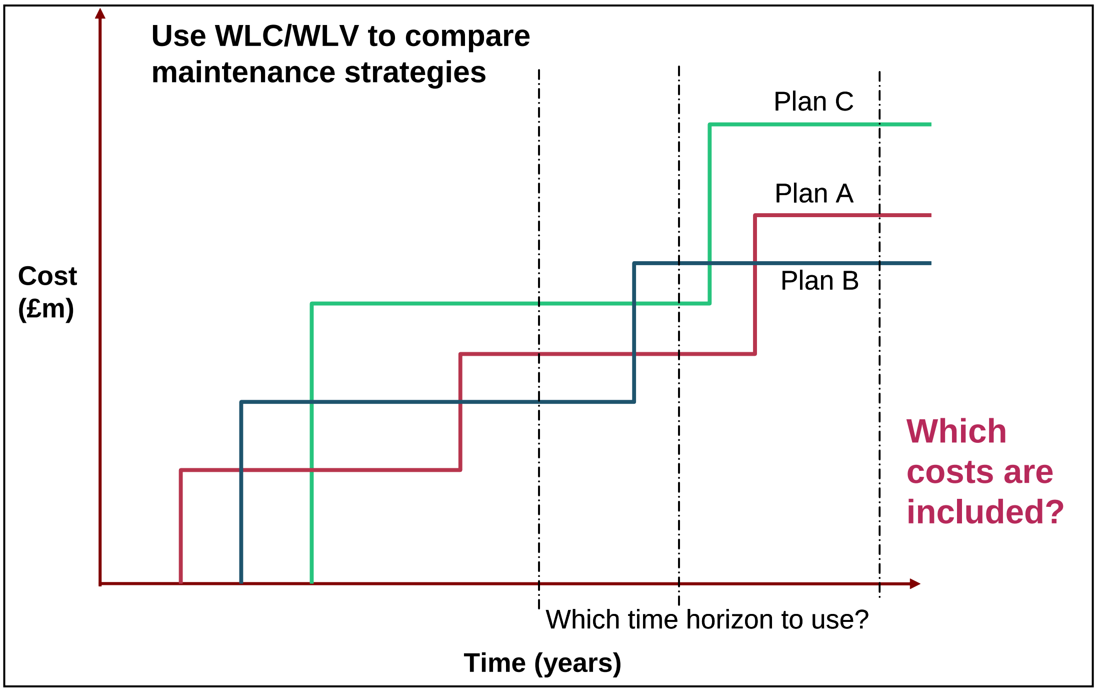

Figure 6: Cost Profiles for Three Alternative Maintenance Strategies

4.11 Stage 10: Assemble and Implement Preferred Lifecycle Plan

Lifecycle plans for each structure and/or group of similar structures are constructed by aggregating the selected maintenance activities or interventions for all the components and/or elements in each year throughout the time horizon. This may include the results of separate evaluations, and actions omitted from the evaluation because they were common to all options or had insignificant effect upon the outcome. The timing and frequency of applying the maintenance activities or interventions should be adjusted to minimise the whole life costs by combining works together if appropriate.

4.12 Implementation and Review

4.12.1 Implementation

Lifecycle planning for highway structures has the potential to become a complex and involved activity; as such, it should only be applied in appropriate situations and to the level of detail.

The approach described in this Good Practice Guide supports all forms of lifecycle planning, from generic lifecycle planning for groups of structures to detailed lifecycle planning for individual structures. When applying the approach, the user must determine, at each stage, the level of detail required to support their particular analysis, i.e. generic or structure specific.

The following are considered to be appropriate times for using lifecycle planning:

- Individual Structures:
  - New construction, reconstruction and major maintenance;
  - During Principal Inspections to determine the forward maintenance strategy for complex and/or high lifecycle cost structures;
  - To support Asset Management Plans and Financial Plans.
- Groups of structures:
  - To assess the benefits/dis-benefits of alternative maintenance strategies;
  - To support Asset Management Plans and Financial Plans.

4.12.2 Review

Many of the criteria that are used to develop lifecycle plans (e.g. deterioration rates, maintenance effects and costs) are uncertain, therefore a lifecycle plan (be it generic or structure specific) must be seen as a 'living' plan that needs to be regularly reviewed and updated. It is recommended that:

- Structure specific plans are updated, at maximum, at each Principal Inspection;
- Generic lifecycle plans are updated, at a maximum, of every six years; and
- Relevant plans are updated at the earliest possible convenience when new information becomes unavailable which outdates the current plan.

The information/rationale that supports any alterations/changes made during a review should be fully documented.

5 References

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2. Achieving Whole Life Value in Infrastructure and Buildings, Bourke Kathryn, Ramdas Vijay, Singh Shilpa, Green Andy, Crudgington Andrew, Mootanah Das, BRE, 2005.
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6. Management of Highway Structures: A Code of Practice, TSO, 2005.
7. Inspection Manual for Highway Structures, Volume 1: Reference Manual, TSO, 2007
8. Bridge Condition Indictors Volume 2: Guidance Note on Bridge Inspection Reporting, County Surveyors' Society, 2002.
9. Addendum to CSS Guidance Note on Bridge Condition Indictors Volume 2, County Surveyors' Society, 2004.
10. Economic Concepts in QUADRO, DMRB 14.1.1, Department for Transport, 2006.

Appendix A: Default Data

Table A.1: CSS Element List

ID	Element Type
1	Primary deck element
2	Secondary deck element/s - beams
3	Secondary deck element/s - other
4	Half joints
5	Tie beam/rod
6	Parapet beam or cantilever
7	Deck bracing
8	Foundations
9	Abutments (incl. arch springing)
10	Spandrel wall/head wall
11	Pier/column
12	Cross-head/capping beam
13	Bearings
14	Bearing plinth/shelf
15	Superstructure drainage
16	Substructure drainage
17	Waterproofing
18	Movement/expansion joints
19	Painting: deck elements
20	Painting: substructure elements
21	Painting: parapets/safety fences
22	Access/walkways/gantries
23	Handrail/parapets/safety fences
24	Carriageway surfacing
25	Footway/verge/footbridge surfacing
26	Invert/river bed
27	Aprons
28	Fenders/cutwaters/collision protection
29	River training works
30	Revetment/batter paving
31	Wing walls
32	Retaining walls
33	Embankments
34	Machinery
35	Approach rails/barriers/walls
36	Signs
37	Lighting
38	Services

Table A.2: Structure Traffic Exposure

Category	Annual Average Daily Traffic	Commercial Vehicles
High	>25,000 vehicles per lane	>2,500 vehicles per lane
Moderate	10,000-25,000 vehicles per lane	1,000-2,500 vehicles per lane
Low	<10,000 vehicles per lane	<1,000 vehicles per lane

Table A.3: Structure Environment Exposure

Exposure Environ.	Exposure Description	Typical Element Location
Mild	Structure and/or elements of a structure: • Generally exposed to mild weather conditions, i.e. may be sheltered or in an environment that results in little or no exposure to severe weather conditions; and/or • Not exposed to any aggressive agents, e.g. no exposure to road de-icing salts or greater than 8m away from traffic spray[*], not exposed to or buried in aggressive soil agents, no exposure to contaminated water, etc.; and/or • With no ventilation or condensation problems or where poor ventilation or the level of condensation are unlikely to increase the rate of deterioration.	• Elements protected from salt spray with cladding or by a protective enclosure. • Deck soffit and piers of integral bridges where the obstacle crossed is not a road, i.e. elements are not subjected to spray from salted road. • Tenanted arch bridges. • Half-joints or hinge joints overlaid with functional expansion joints.
Moderate	Structure and/or elements of a structure exposed to: • Moderate (normal) weather conditions, e.g. direct rain, moderate humidity or condensation, some freeze-thaw action etc.; and/or • Moderate de-icing salt spray and airborne chlorides; e.g. within 3 to 8m of traffic spray on routes with de-icing salts; and/or • Low to moderate river flow. But elements are not exposed to or buried in aggressive soils.	• Top of roadside bridge pier or abutment subject to light vehicle spray from salted road. • Bridge deck soffit subject to light vehicle spray from salted road.
Severe	Structure and/or elements of a structure exposed to: • Continuous or regular severe/extreme weather conditions, e.g. hot and cold extremes, high freeze-thaw action, severe humidity or condensation, etc.; and/or • Severe de-icing salt spray, e.g. within 3m of traffic spray on routes with de-icing salts; and/or • Run-off and/or ponding on routes with de-icing salts; and/or • Aggressive soils, i.e. completely or partially buried in aggressive soils that are contaminated with acidic water or water containing sulphates; and/or • Marine environment and/or abrasive action of seawater or completely immersed in sea water; and/or • Corrosive fumes in industrial areas; and/or • Medium to rapid river flow and flooding.	• Roadside bridge abutment, parapet upstand or deck edge beam subject to heavy vehicle spray from salted road. • Section of bridge deck near a leaking expansion joint or gutter e.g. deck end or crosshead. • Half-joints or hinge joints overlaid with non-functional expansion joints.

[*] The 8m limit is based on DMRB BA 33/90.

Table A.4: Default Deterioration Profiles for Components

Group	Component Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
18. EXPANSION JOINTS	Buried Joint	Annual Average Daily Traffic	High	0	7	10	12	13
			Moderate	0	10	15	17	18
			Low	0	17	25	28	30
	Asphaltic Plug Joint	Annual Average Daily Traffic	High	0	2	3	4	5
			Moderate	0	4	6	7	8
			Low	0	8	12	14	15
	Nosing Joint	Annual Average Daily Traffic	High	0	5	8	10	11
			Moderate	0	8	12	14	15
			Low	0	14	20	23	25
	Elastomeric/Reinforced Elastomeric Joint	Annual Average Daily Traffic	High	0	7	10	12	13
			Moderate	0	11	15	17	18
			Low	0	20	30	35	37
	Single Element Elastomeric in Metal Runners	Annual Average Daily Traffic	High	0	11	15	17	18
			Moderate	0	17	25	28	30
			Low	0	20	30	35	37
	Multi Element Elastomeric in Metal Runners	Annual Average Daily Traffic	High	0	14	20	23	25
			Moderate	0	17	25	28	30
			Low	0	20	30	35	37
	Cantilever Comb and Tooth Joint	Annual Average Daily Traffic	High	0	14	20	23	25
			Moderate	0	17	25	28	30
			Low	0	20	30	35	37
	Roller Shutter	Annual Average Daily Traffic	High	0	14	20	23	25
			Moderate	0	17	25	28	30
			Low	0	20	30	35	37
	Sliding Plate	Annual Average Daily Traffic	High	0	14	20	23	25
			Moderate	0	17	25	28	30
			Low	0	20	30	35	37
	Other Expansion Joint	Annual Average Daily Traffic	High	0	10	14	16	18
			Moderate	0	13	19	22	23
			Low	0	18	26	31	32
13. BEARINGS	Elastomeric/Rubber	Environment	Severe	0	20	30	35	37
			Moderate	0	25	40	45	47
			Mild	0	40	60	70	75
	Plane Sliding	Environment	Severe	0	17	25	28	30
			Moderate	0	25	37	43	45
			Mild	0	30	50	57	60
	Roller	Environment	Severe	0	20	30	35	37
			Moderate	0	25	40	45	47
			Mild	0	30	50	57	60
	Pot	Environment	Severe	0	14	20	23	24
			Moderate	0	25	35	38	40
			Mild	0	30	50	57	60
	Rocker	Environment	Severe	0	17	25	28	30
			Moderate	0	25	40	45	47
			Mild	0	30	50	57	60
	Spherical	Environment	Severe	0	17	25	28	30
			Moderate	0	25	40	45	47
			Mild	0	30	50	57	60
	Other Bearing	Environment	Severe	0	18	26	30	31
			Moderate	0	25	39	44	46
			Mild	0	32	52	59	63

Group	Component Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
23. PARAPETS	Concrete	Environment	Severe	0	14	20	23	24
			Moderate	0	20	30	35	37
			Mild	0	25	40	45	47
	Steel (No Painting After Installation)	Environment	Severe	0	14	20	23	24
			Moderate	0	20	30	35	37
			Mild	0	25	40	45	47
	Aluminium	Environment	Severe	0	25	40	45	47
			Moderate	0	30	50	57	60
			Mild	0	40	60	70	75
	Masonry	Environment	Severe	0	25	35	38	40
			Moderate	0	40	70	85	90
			Mild	0	80	140	160	170
	Timber (Hardwood not Treated)	Environment	Severe	0	10	15	17	18
			Moderate	0	14	20	23	24
			Mild	0	17	25	28	30
	Other Handrail/Parapet/Safety Fence	Environment	Severe	0	18	26	29	31
			Moderate	0	25	40	47	50
			Mild	0	37	61	70	74
17. WATER-PROOFING	Mastic Asphalt	N/A	N/A	0	40	60	70	75
	Boarded Systems	N/A	N/A	0	20	30	35	37
	Sheet Systems	N/A	N/A	0	20	30	35	37
	Spray Systems	N/A	N/A	0	25	35	38	40
	Other Waterproofing	N/A	N/A	0	25	35	38	40

Table A.5: Default Deterioration Profiles for Materials

Material/ Element Group	CSS Elements	Material Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
CONCRETE	Relevant element types include: 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 14, 22, 28, 29, 31, 35	Insitu Mass Concrete or Precast Plain Concrete	Environment	Mild	0	60	120	180	240
				Moderate	0	40	80	110	120
				Severe	0	30	45	55	60
		Insitu Prestressed Concrete (Post-Tensioned)	Environment	Mild	0	50	75	90	100
				Moderate	0	30	45	55	60
				Severe	0	15	23	28	30
		Insitu Reinforced Concrete	Environment	Mild	0	60	120	180	240
				Moderate	0	35	60	75	80
				Severe	0	15	25	35	40
		Precast Prestressed Concrete (Pre-Tensioned)	Environment	Mild	0	60	120	180	240
				Moderate	0	50	90	110	120
				Severe	0	20	35	45	50
		Precast Reinforced Concrete	Environment	Mild	0	60	120	180	240
				Moderate	0	70	110	130	140
				Severe	0	20	35	45	50
	Element 1	Encased Steel	Environment	Mild	0	60	120	180	240
				Moderate	0	35	60	75	80
				Severe	0	15	25	35	40
METAL	Relevant element types include: 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 14, 22, 28, 29, 31, 35	Cast Iron or Wrought Iron	Environment	Mild	0	50	90	110	120
				Moderate	0	30	55	75	80
				Severe	0	15	25	35	40
		Corrugated Rolled Steel	Environment	Mild	0	50	90	110	120
				Moderate	0	25	45	55	60
				Severe	0	13	23	28	30
		Weathering Steel	Environment	Mild	0	50	90	110	120
				Moderate	0	25	45	55	60
				Severe	0	13	23	28	30
	All of the above and element 7	Fabricated Steel, Rolled Steel, Steel, or Steel Plate	Environment	Mild	0	50	90	110	120
				Moderate	0	30	60	75	80
				Severe	0	15	30	38	40
MASONRY	Relevant element types include: 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 14, 22, 28, 29, 31, 35	Blockwork, i.e. Masonry or Stone	Environment	Mild	0	50	150	250	300
				Moderate	0	40	70	90	100
				Severe	0	20	35	45	50
		Brickwork	Environment	Mild	0	50	125	200	250
				Moderate	0	40	70	90	100
				Severe	0	20	35	45	50
OTHER	Relevant element types include: 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 22, 28, 29, 31, 35	Other Material	Environment	Mild	0	40	65	80	90
				Moderate	0	20	35	45	50
				Severe	0	12	25	35	40
INVERT	Element 26	Natural Invert	Environment	Mild	0	50	100	150	200
				Moderate	0	25	50	75	100
				Severe	0	10	20	30	40
		Other Invert Material	Environment	Mild	0	50	100	150	200
				Moderate	0	25	50	75	100
				Severe	0	10	20	30	40
APRON	Element 27	Natural Apron	Environment	Mild	0	25	50	75	100
				Moderate	0	13	25	38	50
				Severe	0	5	10	15	20
		Concrete Apron	Environment	Mild	0	40	80	110	120
				Moderate	0	35	60	75	80

Material/ Element Group	CSS Elements	Material Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
				Severe	0	30	45	55	60
		Stone Apron	Environment	Mild	0	30	45	55	60
				Moderate	0	20	30	38	40
				Severe	0	8	14	18	20
		Other Apron Material	Environment	Mild	0	40	80	110	120
				Moderate	0	35	60	75	80
				Severe	0	30	45	55	60
FOUNDATIONS	Element 8	Shallow Foundation: Pad [Isolated Footings]	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
		Shallow Foundation: Strip	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
		Shallow Foundation: Raft	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
		Deep Foundation: Piles	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
		Deep Foundation: Piers	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
		Deep Foundation: Caissons	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
		Other Foundation	Environment	Mild	0	38	75	113	150
				Moderate	0	30	60	90	120
				Severe	0	25	50	75	100
SUPERSTRUCTURE AND SUB - STRUCTURE DRAINAGE	Elements 15, 16	Plastic (External)	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
		Metal (External)	Environment	Mild	0	30	60	90	120
				Moderate	0	15	30	45	60
				Severe	0	8	15	23	30
		Other (External)	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
		Internal Drainage System	Environment	Mild	0	30	60	90	120
				Moderate	0	15	30	45	60
				Severe	0	8	15	23	30
		Clay Pipe	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
		Concrete Pipe	Environment	Mild	0	60	120	180	240
				Moderate	0	40	80	110	120
				Severe	0	30	45	55	60
		Other Drainage System	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
DECK ELEMENTS AND SUBSTRUCTURE	Elements 19, 20, 21	MIO Phenolic Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20

Material/ Element Group	CSS Elements	Material Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
		Silicone Alkyd Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		MIO High Build Quick Drying Epoxy Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Water Based Epoxy Sheen Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Extended Cure Epoxy MIO Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Vinyl/Vinyl Copolymer MIO Zinc Phosphate Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Vinyl/Vinyl Copolymer Sheen Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Thixotropic Bitumen	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Pitch Epoxy (two-pack) Polyamide Cured Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		High Build Epoxy Hydrocarbon Resin Modified Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Moisture Cured Polyurethane Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Moisture Cured Polyurethane Semi-Gloss Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Polyurethane Gloss Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Organic Modified Polysiloxane (two-pack) Gloss Finish	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Grease Paint	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Anti-graffiti paint	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
		Other Paint System	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	5	10	15	20
CARRIAGEWAY SURFACING	Element 24	Asphalt	Annual Average Daily Traffic	Low	0	15	30	45	60
				Moderate	0	10	20	30	40
				High	0	8	15	23	30
		Concrete Surfacing	Annual	Low	0	15	30	45	60

Material/ Element Group	CSS Elements	Material Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
			Average Daily Traffic	Moderate	0	10	20	30	40
				High	0	8	15	23	30
		Other Surfacing	Annual Average Daily Traffic	Low	0	15	30	45	60
				Moderate	0	10	20	30	40
				High	0	8	15	23	30
FOOTWAY SURFACING	Element 25	Asphalt	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
		Concrete Surfacing	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
		Other Surfacing	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
REVETMENTS	Element 30	Stone Rip-Rap	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Hand-Placed Stone	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Grouted Stone or Masonry	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Gabion Mesh Mattresses	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Precast Concrete Blocks - Open Jointed or Interlocking	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Cable-Tied Block Mattresses	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Concrete Insitu Slabs	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Grassed Geotextile Mats	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Grout-Filled Synthetic Mattresses	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Stone Asphalt	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Steel Piles	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
		Other Revetment	Environment	Mild	0	30	45	55	60
				Moderate	0	30	45	55	60
				Severe	0	30	45	55	60
RETAINING WALLS	Element 32	Gravity	Environment	Mild	0	40	80	110	120

Material/ Element Group	CSS Elements	Material Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
				Moderate	0	35	60	75	80
				Severe	0	30	45	55	60
		Cantilever on Foundation	Environment	Mild	0	40	80	110	120
				Moderate	0	35	60	75	80
				Severe	0	30	45	55	60
		Embedded	Environment	Mild	0	40	80	110	120
				Moderate	0	35	60	75	80
				Severe	0	30	45	55	60
		Other Retaining Wall	Environment	Mild	0	40	80	110	120
				Moderate	0	35	60	75	80
				Severe	0	30	45	55	60
EMBANKMENTS	Element 33	Reinforced Soil	Environment	Mild	0	35	60	75	80
				Moderate	0	30	45	55	60
				Severe	0	15	25	35	40
		Natural	Environment	Mild	0	35	60	75	80
				Moderate	0	30	45	55	60
				Severe	0	15	25	35	40
		Gabions	Environment	Mild	0	35	60	75	80
				Moderate	0	30	45	55	60
				Severe	0	15	25	35	40
		Other Embankment Material	Environment	Mild	0	35	60	75	80
				Moderate	0	30	45	55	60
				Severe	0	15	25	35	40
SIGNS	Element 36	Regulatory Signs	Environment	Mild	0	5	10	15	20
				Moderate	0	5	10	15	20
				Severe	0	5	10	15	20
		Warning Signs	Environment	Mild	0	5	10	15	20
				Moderate	0	5	10	15	20
				Severe	0	5	10	15	20
		Direction Signs	Environment	Mild	0	5	10	15	20
				Moderate	0	5	10	15	20
				Severe	0	5	10	15	20
		Information Signs	Environment	Mild	0	5	10	15	20
				Moderate	0	5	10	15	20
				Severe	0	5	10	15	20
		Other Sign	Environment	Mild	0	5	10	15	20
				Moderate	0	5	10	15	20
				Severe	0	5	10	15	20
LIGHTING	Element 37	Street or Highway Lighting	Environment	Mild	0	10	20	30	40
				Moderate	0	10	20	30	40
				Severe	0	10	20	30	40
		Traffic Control Lights	Environment	Mild	0	10	20	30	40
				Moderate	0	10	20	30	40
				Severe	0	10	20	30	40
		Illuminated Traffic Signs	Environment	Mild	0	10	20	30	40
				Moderate	0	10	20	30	40
				Severe	0	10	20	30	40
		Illuminated Traffic Bollards	Environment	Mild	0	10	20	30	40
				Moderate	0	10	20	30	40
				Severe	0	10	20	30	40
		Other Lighting	Environment	Mild	0	10	20	30	40

Material/ Element Group	CSS Elements	Material Type	Influencing Criterion	Influencing Category	Time_1A (yrs)	Time_2B (yrs)	Time_3B (yrs)	Time_4B (yrs)	Time_5B (yrs)
				Moderate	0	10	20	30	40
				Severe	0	10	20	30	40
SERVICES	Element 38	Plastic Services	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30
		Concrete Services	Environment	Mild	0	30	60	90	120
				Moderate	0	15	30	45	60
				Severe	0	8	15	23	30
		Other Services	Environment	Mild	0	15	30	45	60
				Moderate	0	10	20	30	40
				Severe	0	8	15	23	30

Table A.6: Intervention Options

Maintenance Activities	Assumptions/Comments
Anchorage/stabilisation	Retaining walls, embankments, earth structures, gabions etc.
Anti-carbonation coatings	To concrete elements, e.g. every 20 years and up to 2 applications
Application of impregnants	No limit on number of re-applications (silane)
Bearings: Painting	Only applicable for metal bearings
Bearings: Replacement	Includes removal disposal and installation of a bearing and jacking
Cathodic protection (installation and operation)	Once installed requires annual monitoring; should be captured as annual routine maintenance cost
Cladding	Cladding in tunnels and retaining walls etc.
Concrete repairs (major)	Includes major concrete repairs, major concrete repairs combined with rebar removal and reinstatement, minor concrete repairs and preflexing and crack injection
Concrete repairs (moderate)	Moderate repairs, no metalwork
Concrete repairs (minor)	Minor patch repairs over small area, no metalwork
Deck strengthening	E.g. carbon fibre plate bonding, steel plate bonding, external tendons; can only be applied to elements that were identified as sub-standard due to design
Desalination (chloride removal)	The life and effectiveness of this type of treatment are still being assessed, and are likely to be structure specific in terms of concrete quality, cover, reinforcement details, chloride content and exposure
Element replacement	Assume like-for-like replacement for materials, e.g. replace concrete with concrete; can be applied to elements that were identified as sub-standard either due to design or due to deterioration; includes temporary fencing, earthworks, reinstatement of kerbs, footways and paved areas, and fabrication and erection of bridge elements, and replacement/repair of drainage on substructure or superstructure, e.g. hangers, components etc
Expansion joint: Replacement	Includes removal disposal and installation of an expansion joint
Expansion joint: Replacement of moving components	Applies only to Multi Element Elastomeric In Metal Runners, service life of moving parts is 5 years; assume that the moving parts of Multi Element Elastomeric In Metal Runners joints will be replaced every 5 years throughout the service life of this type of joint at which time the entire joint should be replaced
Expansion joint: Re-sealing	Considered to be undertaken as part of routine maintenance
Foundation repair	
Improvement works	Traffic management, H&S etc.
Invert repair	Import and deposition of filling material
Lighting	Maintenance of lights in structures/subways
Masonry repairs (minor)	Re-pointing small areas, replacement of a few bricks
Masonry repairs (moderate)	Increasing area and severity
Masonry repairs (major)	Increasing area and severity
Masonry strengthening measures	Can only be applied to elements that were identified as sub-standard due to design
Masonry surface treatment	The suitability and effectiveness of this type of treatment are still being assessed (anti-graffiti coating)
Maintenance of Mechanical and Electrical Equipment	In tunnels/subways etc., such as fans, pumps, signals, cameras, fire safety
Metalwork repair	Includes metalwork crack repair (i.e. metalwork stitching and plate welding), weld repair and repair of corroded steelwork sections, bolt/rivet replacement
Paint: Application of paint system	Only suitable where there is no existing paint system in place, i.e. first time of paint system application
Paint: Re-application on top of existing paint system	Suitable for all metals except Aluminium and Stainless Steel, every 15 years, up to 2 applications then apply 'Paint: Wet/dry surface preparation and re-application of paint system' in 10 years
Paint: Wet/dry surface preparation and re-application of paint system	Suitable for all metals except Aluminium and Stainless Steel, e.g. every 25 years
Parapet: Fixings	Maintenance of fixings/holding down bolts
Parapet: Protection system installation/ replacement	
Parapet: Replacement	Includes removal and disposal of existing parapet, installation of new parapet
Pier strengthening	E.g. column wrapping, leaf piers, deck support, plinths; can only be applied to elements that were identified as sub-standard due to design/impact requirements
Scour protection	Mattress, aprons, rip-rap, gabions etc.
Void grouting	Can be applied to post-tensioned and masonry structures
Waterproofing: Replacement	Includes removal of existing waterproofing system, deck preparation (including up to 5% concrete repairs to the deck) and application of new waterproofing system; also includes surfacing removal and reinstatement, and reinstatement of kerbs/footways/paved areas and traffic signs and markings
Edge Protection	In addition to the strengthening and/or other maintenance activities options that can be applied for structures and/or elements of structures that are considered to be sub-standard either due to design or deterioration, interim measures options can also be included. The preferred option should always be strengthening and/or other suitable maintenance activities, however where there is a budget constraint, interim measures can be employed. Therefore, an interim measure should not be permitted to become a permanent feature and should have a maximum allowable life of three years, at which time maintenance/strengthening becomes compulsory.
Monitoring	
Propping	

Table A.7: Intervention Application and Effects

Material or Component type	Existing Exposure	Defect Cause/Maintenance Driver	Defect Type	Maintenance Activity	Relevant condition range?			Exposure after application	Condition after application	1A	2B	3B	4B	5B
Insitu Reinforced Concrete, Precast Reinforced Concrete, Insitu Prestressed Concrete (Post-Tensioned), Precast Prestressed Concrete (Pre-Tensioned) Excludes works specific to pre-stressing	Mild	Carbonation		Anti-carbonation coatings	2B	–	2E	Mild	2B	0	50	100	150	200
				Concrete repairs (minor)	2B	–	3D	Mild	2B	0	50	100	150	200
		Carbonation and/or other defect causes		Concrete repairs (minor)	2B	–	2E	Mild	2B	0	45	90	135	180
				Concrete repairs (moderate)	2D	–	3B	Mild	2B	0	45	90	135	180
				Concrete repairs (major)	3C	–	4E	Mild	2B	0	50	100	150	200
				Element replacement 1	3B	–	4E	Mild	1A	0	60	120	180	240
	Moderate	Abrasion/erosion; chemical damage; environmental factors; freeze thaw action; frost damage; marine organism attack		Concrete repairs (minor)	2B	–	2E	Moderate	2B	0	25	45	55	60
				Concrete repairs (moderate)	3B	–	3E	Moderate	2B	0	25	45	55	60
				Concrete repairs (major)	3C	–	4E	Moderate	2B	0	40	60	70	75
				Element replacement 1	3D	–	4E	Mild	1A	0	50	90	110	120
		ASR		Element replacement 1	3D	–	4E	Mild	1A	0	50	90	110	120
		Chloride ingress (due to traffic spray / sea)	Lamination	Concrete repairs (minor)	2B	–	2E	Moderate	2B	0	20	40	50	55
				Concrete repairs (moderate)	3B	–	3E	Moderate	2B	0	20	40	50	55
				Concrete repairs (major)	3D	–	4E	Moderate	2B	0	40	60	70	75
				Element replacement 2	3C	–	4E	Mild	1A	0	30	60	90	120
	Severe	Sulphate attack; thaumasite	Concrete softening	Concrete repairs (major)	3D	–	4E	Mild	2B	0	35	60	75	80
				Element replacement 1	3D	–	4E	Mild	1A	0	30	60	90	120
		Chloride ingress (due to failed joints)	Lamination	Concrete repairs (minor)	2B	–	2E	Mild	2B	0	35	60	75	80
				Concrete repairs (moderate)	3B	–	3E	Mild	2B	0	35	60	75	80
				Concrete repairs (major)	3D	–	4E	Mild	2B	0	30	60	90	120
				Element replacement 1	3D	–	4E	Mild	1A	0	30	60	90	120
	N/A	Pier/column sub-standard due to design		Pier strengthening	1A	–	4E	N/A	1A	0	50	90	110	120
	N/A	Beam/deck slab sub-standard due to design/deterioration		Deck strengthening	3B	–	4E	N/A	1A	0	50	90	110	120
		Element sub-standard due to design/deterioration		Element replacement 1	1A	–	4E	N/A	1A	0	50	90	110	120
Insitu Mass Concrete & Precast Plain Concrete	Mild	N/A	Cracked; friable or degraded concrete or mortar	Concrete repairs (minor)	2B	–	2E	Mild	2B	0	20	40	60	80
		N/A	Cracked; friable or degraded concrete or mortar	Concrete repairs (major)	3B	–	4E	Mild	2B	0	30	60	90	120
		N/A	Cracked; friable or degraded concrete or mortar	Element replacement 1	3E	–	5E	Mild	1A	0	60	120	180	240
	Moderate	Abrasion/erosion; chemical damage; environmental factors;	Lamination	Concrete repairs (minor)	2B	–	2E	Moderate	2B	0	7	15	23	30
				Concrete repairs (major)	3B	–	4E	Moderate	2B	0	10	20	30	40

Material or Component type	Existing Exposure	Defect Cause/Maintenance Driver	Defect Type	Maintenance Activity	Relevant condition range?	Exposure after application	Condition after application	1A	2B	3B	4B	5B
		freeze thaw action; frost damage; marine organism attack		Element replacement 1	3C – 5E	Moderate	1A	0	15	30	45	60
		ASR		Element replacement 2	3C – 5E	Mild	1A	0	50	90	110	120
	Severe	Sulphate attack; thaumasite	Concrete softening	Concrete repairs (major)	3B – 4E	Mild	2B	0	35	60	75	80
				Element replacement 1	3C – 4E	Mild	1A	0	30	60	90	120
Paint Systems	N/A	N/A	Blistering; chalking; cracking; peeling; fading; flaking; scored or scratched	Paint: Re-application on top of existing paint system	2B – 3B	N/A	1A	0	7	15	23	30
			Blistering; chalking; cracking; peeling; fading; fire damage; flaking; scored or scratched	Paint: Wet/dry surface preparation and re-application of paint system	3C – 4E	N/A	1A	0	10	20	30	40
Fabricated Steel, Rolled Steel, Steel, Steel Plate	Mild	Carbonation and/or other defect causes	Rusty/corroded; corrosion: section loss	Paint: Wet/dry surface preparation and re-application of paint system	2B – 2E	N/A	1A	0	10	20	30	40
				Metalwork repair	3B – 4E	N/A	1A	0	10	20	30	40
				Element replacement 1	3C – 5E	N/A	1A	0	10	20	30	40
	Moderate	Chemical damage; environmental factors; chloride ingress (due to traffic spray)	Rusty/corroded; corrosion: section loss	Metalwork repair	3B – 4E	N/A	1A	0	10	20	30	40
				Element replacement 1	3C – 5E	N/A	1A	0	10	20	30	40
	Severe	Chloride ingress (due to failed joints)	Rusty/corroded; corrosion: section loss	Metalwork repair	3B – 4E	N/A	1A	0	10	20	30	40
				Element replacement 1	3C – 5E	N/A	1A	0	10	20	30	40
	N/A	Beam/deck slab sub-standard due to design/deterioration		Deck strengthening	1A – 4E	N/A	1A	0	50	90	110	120
		Element sub-standard due to design/deterioration		Element replacement 1	1A – 4E	N/A	1A	0	50	90	110	120
Corrugated Rolled Steel	Mild	Carbonation and/or other defect causes		Corrugated culvert: Preventative maintenance	2B – 3B	Mild	1A	0	50	90	110	120
				Corrugated culvert: Relining (strengthening)	3C – 4E	Mild	1A	0	50	90	110	120
	Moderate	Abrasion/erosion; environmental factors chemical damage		Corrugated culvert: Preventative maintenance	2B – 3B	Moderate	1A	0	25	45	55	60
				Corrugated culvert: Relining (strengthening)	3C – 4E	Moderate	1A	0	25	45	55	60
	Severe	No driver		Corrugated culvert: Preventative maintenance	2B – 3B	Severe	1A	0	12	22	27	30
				Corrugated culvert: Relining (strengthening)	3C – 4E	Severe	1A	0	12	22	27	30
Cast Iron and Wrought Iron	Mild	Carbonation and/or other defect causes	Rusty/corroded; corrosion: section loss	Paint: Wet/dry surface preparation and re-application of paint system	2B – 2E	N/A	1A	0	10	20	30	40
				Metalwork repair	3B – 4E	N/A	1A	0	10	20	30	40
				Element replacement 1	3C – 5E	N/A	1A	0	10	20	30	40
	Moderate	Environmental factors	Rusty/corroded; corrosion: section loss	Metalwork repair	3B – 4E	N/A	1A	0	10	20	30	40
				Element replacement 1	3C – 5E	N/A	1A	0	10	20	30	40

Material or Component type	Existing Exposure	Defect Cause/Maintenance Driver	Defect Type	Maintenance Activity	Relevant condition range?			Exposure after application	Condition after application	1A	2B	3B	4B	5B
	Severe	Chloride ingress (due to failed joints)	Rusty/corroded; corrosion: section loss	Metalwork repair	3B	–	4E	N/A	1A	0	10	20	30	40
				Element replacement 1	3C	–	5E	N/A	1A	0	10	20	30	40
	N/A	Beam/deck slab sub-standard due to design/deterioration		Deck strengthening	1A	–	4E	N/A	1A	0	50	90	110	120
		Element sub-standard due to design/deterioration		Element replacement 1	1A	–	4E	N/A	1A	0	50	90	110	120
Weathering Steel	Mild	Carbonation and/or other defect causes	Rusty/corroded; corrosion: section loss	Paint: Application of paint system	2B	–	2E	N/A	1A	0	10	20	30	40
				Metalwork repair	3B	–	4E	Mild	2B	0	10	20	30	40
				Element replacement 1	3C	–	5E	Mild	1A	0	10	20	30	40
	Moderate	Chloride ingress (due to traffic spray)	Rusty/corroded; corrosion: section loss	Paint: Application of paint system	2B	–	2E	N/A	1A	0	10	20	30	40
				Metalwork repair	3B	–	4E	Moderate	2B	0	10	20	30	40
				Element replacement 1	3C	–	5E	Moderate	1A	0	10	20	30	40
	Severe	Chloride ingress (due to failed joints)	Rusty/corroded; corrosion: section loss	Paint: Application of paint system	2B	–	2E	N/A	1A	0	10	20	30	40
				Metalwork repair	3B	–	4E	Severe	2B	0	10	20	30	40
				Element replacement 1	3C	–	5E	Severe	1A	0	10	20	30	40
		Element sub-standard due to design/deterioration		Element replacement 1	1A	–	4E	N/A	1A	0	50	90	110	120
Masonry	Mild	Carbonation and/or other defect causes	Mortar loss	Masonry repairs (minor)	2B	–	2E	Mild	1A	0	20	35	45	50
			Missing masonry unit	Masonry repairs (moderate)	3B	–	3E	Mild	1A	0	20	35	45	50
			Missing masonry unit	Masonry repairs (major)	4B	–	4E	Mild	1A	0	40	70	90	100
			Missing masonry unit	Element replacement 1	3D	–	4E	Mild	1A	0	80	140	180	200
	Moderate	Freeze thaw action	Mortar loss	Masonry repairs (minor)	2B	–	2E	Moderate	1A	0	10	25	35	40
			Missing masonry unit	Masonry repairs (moderate)	3B	–	3E	Moderate	1A	0	10	25	35	40
			Missing masonry unit	Masonry repairs (major)	4B	–	4E	Moderate	1A	0	20	35	45	50
			Missing masonry unit	Element replacement 1	3D	–	4E	Moderate	1A	0	40	70	90	100
	Severe		Mortar loss	Masonry repairs (minor)	2B	–	3C	Severe	1A	0	10	17	23	25
			Missing masonry unit	Masonry repairs (moderate)	3B	–	3D	Severe	1A	0	10	17	23	25
			Missing masonry unit	Masonry repairs (major)	3C	–	4E	Severe	1A	0	10	25	35	40
			Missing masonry unit	Element replacement 1	3C	–	4E	Severe	1A	0	20	35	45	50
	N/A	Beam/deck slab sub-standard due to design/deterioration		Masonry strengthening measures	1A	–	4E	N/A	1A	0	40	70	90	100
		Element sub-standard due to design/deterioration		Element replacement 1	1A	–	4E	N/A	1A	0	80	140	180	200
Invert/River Bed	Mild	Carbonation and/or other defect causes		Invert repair	3B	–	4C	Mild	1A	0	50	100	150	200
	Moderate	Abrasion/erosion		Invert repair	3B	–	4C	Moderate	1A	0	25	50	75	100
	Severe	Scour		Scour monitoring	2B	–	2E	Severe	N/A	–	0	10	20	30
			Scour or scour hole	Scour or scour hole repair	3B	–	4C	Severe	1A	–	0	10	20	30

Material or Component type	Existing Exposure	Defect Cause/Maintenance Driver	Defect Type	Maintenance Activity	Relevant condition range?			Exposure after application	Condition after application	1A	2B	3B	4B	5B
				Scour protection measures	3C	–	4E	Moderate	2B	–	0	25	50	75
				Corrugated culvert: Preventative maintenance	3C	–	4E	Severe	2B	–	0	10	20	30
Expansion Joints	Low CV	Joint type: Multi Element Elastomeric In Metal Runners	Debonding; degraded; missing	Expansion joint: Replacement of moving components	2D	–	3C	Low AADT	1A	Applies only to Multi Element Elastomeric In Metal Runners, service life of moving parts: 5 years. It has no impact on subsequent deterioration. Assume that the moving parts of Multi Element Elastomeric In Metal Runners joints will be replaced every 5 years throughout the service life of this type of joint at which time the entire joint should be replaced.				
	Moderate CV	Joint type: Multi Element Elastomeric In Metal Runners	Debonding; degraded; missing	Expansion joint: Replacement of moving components	2B	–	3C	Moderate ADDT	1A					
	High CV	Joint type: Multi Element Elastomeric In Metal Runners	Debonding; degraded; missing	Expansion joint: Replacement of moving components	2B	–	3C	High ADDT	1A					
	Low CV	N/A		Expansion joint: Replacement	3C	–	4E	Low AADT	1A	Use deterioration profiles provided in Table 1, depending on the type of expansion joint.				
	Moderate CV	N/A		Expansion joint: Replacement	3C	–	4E	Moderate ADDT	1A					
	High CV	N/A		Expansion joint: Replacement	3C	–	4E	High ADDT	1A					
Bearings	Mild	Non-leaking expansion joints		Bearings: Replacement	3C	–	4E	Mild	1A	Use deterioration profiles provided in Table 1, depending on the type of bearing. Assume that associated elements (e.g. leaking joints, etc) are also repaired.				
	Moderate	Previously exposed to a severe environment		Bearings: Replacement	3C	–	4E	Mild	1A					
	Severe	Leaking expansion joints		Bearings: Replacement	3C	–	4E	Mild	1A					
Parapets	N/A	Service life (and or sub-standard due to deterioration)		Parapet: Replacement	3C	–	4E	N/A	1A	Use deterioration profiles provided in Table 1, depending on the type of parapet.				
				Parapet: Protection system installation/ replacement	3C	–	4E	N/A	1A					
Water-proofing	N/A	Service life		Waterproofing: Replacement	3C	–	4E	N/A	1A	Use deterioration profiles provided in Table 1, depending on the type of waterproofing.				

NOTE: If a maintenance activity is not listed in the above table then the deterioration profile followed by the element after application of the maintenance/treatment will be same as the deterioration profile of the component/material itself, as given in Table A.4 and Table A.5.

Table A.8: Base Unit Rates

Maintenance Activity	Unit	Maintenance Activity Cost Type	Fixed Rate (£)	Constant Unit Rate (£)	Variable Unit Rate (£)			Comments
					Severity 2	Severity 3	Severity 4	
Anti-carbonation coatings	m^2	Constant		£35				Applies to full element area
Application of impregnants	m^2	Constant		£40				Applies to full element area
Bearings: Replacement	m	Constant		£750				
Carriageway Surfacing	m^2	Constant		£40				
Cathodic protection (Installation)	m^2	Variable			£350			Can only be applied to elements in Severity 2
Cathodic protection (Monitoring)	item/year	Fixed	£2,000					Applies where a CP system has been installed
Cathodic protection (Maintenance)	m^2	Constant		£300				Applied every 25 years where a CP system has been installed
Concrete repairs	m^2	Variable			£250	£1,000	£1,500	
Corrugated Culvert: Preventative Maintenance	m^2	Variable			£750	£1,500		Can only be applied to elements in Severity 2 - 3
Corrugated Culvert: Relining (Strengthening)	m^2	Constant or Variable		£1,000	£1,075	£1,338	£1,863	
Deck strengthening (Concrete)	m^2	Constant or Variable		£700	£750	£925	£1,275	
Deck strengthening (Metal)	m^2	Constant or Variable		£1,000	£1,075	£1,338	£1,863	
Drainage Replacement	m	Constant		£20 - £50				
Element replacement	m^2	Constant		£4,000				
Expansion Joint Replacement: Asphaltic Plug	m	Constant		£187				
Expansion Joint Replacement: Buried Joint	m	Constant		£116				
Expansion Joint Replacement: Cantilever Comb and Tooth Joint	m	Constant		£3,916				
Expansion Joint Replacement: Elastomeric/Reinforced Elastomeric Joint	m	Constant		£902				
Expansion Joint Replacement: Multi Element Elastomeric In Metal Runners	m	Constant		£500				
Expansion joint: Replacement of moving components	item/year	Fixed	£1,500					Applies to 'Multi Element Elastomeric In Metal Runners', every 5 years
Expansion Joint Replacement: Nosing Joint	m	Constant		£552				
Expansion Joint Replacement: Roller Shutter	m	Constant		£500				
Expansion Joint Replacement: Single Element Elastomeric In Metal Runners	m	Constant		£500				
Expansion Joint Replacement: Sliding Plate	m	Constant		£500				
Footway Surfacing	m^2	Constant		£20 - £150				Unit rate varies according to the footway material type.
Interim Measures: Edge Protection	m	Constant		£950				
Interim Measures: Monitoring	item/year	Fixed	£2,500					
Interim Measures: Propping	m^2	Constant		£500				Applies to the full deck area
Invert Repair	m^2	Constant		£35				
Masonry repairs	m^2	Variable			£300	£1,200	£1,800	
Masonry strengthening measures	m^2	Constant or Variable		£850	£890	£1,030	£1,310	

Maintenance Activity	Unit	Maintenance Activity Cost Type	Fixed Rate (£)	Constant Unit Rate (£)	Variable Unit Rate (£)			Comments
Metalwork repair	m^2	Variable			£0	£1,500	£2,250	
Paint: Application of paint system	m^2	Constant		£30				Applies to full element area
Paint: Re-application on top of existing paint system	m^2	Constant		£60				Applies to full element area
Paint: Wet/Dry surface preparation and re-application of paint system	m^2	Constant		£120				Applies to full element area
Parapet: Protection System Installation/Replacement	m	Constant		£950				
Parapet: Replacement	m	Constant		£426				
Parapet wall expansion joint (sealant)	m	Constant		£10				
Pier Strengthening	m^2	Variable			£1,250	£1,425	£1,775	
Scour monitoring	item/year	Fixed	£750					Applies to scour susceptible structures
Scour or scour hole repair	item/bridge	Fixed	£25,000					Applied at a specific point in time if scour defects are present
Scour protection measures	item/bridge	Fixed	£10,000					Applied at a specific point in time if scour defects are present
TSA protection measures	m^2	Constant		£50				Applies to full element area
Void Grouting	m^2	Variable			£100	£200	£300	
Waterproofing: Application only	m^2	Constant		£150 - £200				Applies to full element area
Waterproofing: Replacement	m^2	Constant		£325				Includes removal of existing waterproofing system, deck preparation (including up-to 5% concrete repairs to the deck) and application of new waterproofing system. Also includes surfacing removal and reinstatement and reinstatement of kerbs/footways/paved areas and traffic signs and markings.

Table A.9: Engineering Difficulty of Work Activities

Engineering Difficulty of Activity
Confined space
Railway - Electrified
Railway – Non-electrified
Working over water (navigable)
Working over water (non-navigable)
Working over water (tidal)
Working over water (non-tidal)
Working over Motorway or A Road
Working over B, C or Unclassified
Ground conditions
Working between 2 and 5m
Working between 5 and 8m
Working above 8m
COSHH
Accommodating STATS – Water
Accommodating STATS – Gas
Accommodating STATS – Electricity
Accommodating STATS – Communication Cables
Accommodating STATS – Other

Table A.10: Work Patterns and Uplift Factors

Work Pattern	Description	Hours Worked
Daytime	Monday to Friday 06.00 to 19.00	8
Night-time	Monday 00.01 to 06.00 Monday to Thursday 19.00 to 06.00 Friday 19.00 to 00.00	8
Restricted daytime	Monday to Saturday 10.00 to 15.00	5
Weekend/Public Holiday (8hr)	Saturday, Sunday and Public Holidays – only one 8hr shift per day	8
Weekend/Public Holiday (24hr)	Saturday, Sunday and Public Holidays – with consecutive 8hr shifts	24
Weekday (24hr)	Weekday with consecutive 8hr shifts	24

Table A.11: Traffic Management Arrangements and Rates

TM Arrangement Type	Description	TM Rate (£/day)
Single way working (uncontrolled)	Represents base case	£600
Single way working (controlled) - shuttle working		£1200
Convey working		£2000
Lane closure (one lane)		£1800
Lane closure (two lanes)		£3600
Lane closure (three lanes)		£5400
Contra-flow		£3000
Hard-shoulder closure		£800
Pedestrian Traffic Management		£500
Road closure (full) with diversion		£5500
Carriageway closure (no pedestrian diversion)		£5500
Speed restrictions		£500
Re-phasing traffic signals		£800
Parking restrictions		£600
Railway Possession		£8000

Table A.12: Engineering Difficulty of Scheme

Engineering Difficulty of Scheme
Remoteness of site from access location
Site security (or lack of)
Rural
Private Land (wayleaves/easements)
Listed
Other

e-mail: publications@lobeg.com
web: http://www.lobeg.com