Decision Support Tool for Bridges: User Requirements Specification

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Contents

List of Figures

List of Tables

1 Introduction

1.1 Purpose

1.1.1 This document provides the User Requirements Specification (URS) for a Decision Support Tool (DST) for the management of highway structures.

1.1.2 A DST is a computer software tool intended to support bridge engineers and managers to make rational decisions. It is not a decision making tool or an "Expert System".

1.1.3 The user requirements are specified from the perspective of bridge engineers, bridge managers and other senior managers involved in making policy, planning and funding decisions for the stock of highway structures within an organisation (a highway authority, a railway authority or other transport undertaking).

1.1.4 The URS does not specify the functional design for the DST. It is intended that the detailed functional and technical specifications for the DST which are necessary to deliver the user requirements defined in this document will be developed in a follow-up Phase 2 of the project, including the development of a "proof of concept" software tool. In Phase 3 the Bridges Board may consider the development of selected software components of the DST and make these available for use by highway authorities and other bridge owners in the UK.

1.1.5 Although the specification has been written from the perspective of highway structures, the majority of the requirements equally apply to structures on other networks, e.g. railways and waterways, given appropriate extensions and amendments where required.

1.2 Structures Management Framework

1.2.1 Highway structures should be managed within an overall asset management framework for transport infrastructure assets. The framework should support and enable integrated management of all transport assets owned/managed by the organisation. The overall requirements for asset management are stipulated in the British Standards Institution's *PAS 55: Asset Management: Specification for the optimised management of physical infrastructure assets*. Specific requirements and guidance for the highway assets is given in the CSS document *Framework for Highway Asset Management*.

1.2.2 In compliance with the above documents an organisation is assumed to have in place:

1. A policy and a strategy for managing all its transport assets in an integrated manner to support the delivery of its corporate strategy and the business plan.

2. Levels of Service agreed with its stakeholders, and possibly derived in consultation with users of the transport service, that are aligned with the corporate strategy and the asset management strategy.

3. Where appropriate, Route Management Strategies and Route Performance Targets for the management of specific routes in the transport network that are aligned with the Levels of Service.

4. Asset management objectives and Asset Performance Targets for highway structures (and also other assets) that are aligned with the Route Performance Targets and Levels of Service.

1.2.3 Since the scope of this DST is limited to highway structures, the DST is designed to enable bridge managers to deliver the asset management objectives and Asset Performance Targets for highway structures that have been derived as above. The DST will facilitate the adoption of the processes and guidance given by *Management of Highway Structures: A Code of Practice* published in September 2005 (hereafter referred to as the Structures Code).

1.2.4 The URS has been written to be relatively independent of the management structure, procedures and specific arrangements for planning, budgeting and funding in different organisations. However, the DST will need to work within these arrangements specific to an organisation. It is intended that each organisation will develop a procedure that will set down how the DST will be used within its own organisation. This procedure will detail who will use the DST, for what purposes, with which associated systems and how the results from the DST should be used in the overall management of highway structures.

1.3 Linkage to Bridge Management Systems

1.3.1 It is intended that the DST will work with a Bridge Management System (BMS) and will not duplicate the functionality provided by a BMS. The DST should be able to work with any suitably configured BMS that an organisation may already have in place.

1.3.2 The assumed "baseline" functionality for the BMS is defined in Section 2.2. The baseline is based on a review of functionality provided by a range of currently available commercial BMSs. The BMS can be a standalone system or a module within a wider Asset Management System used by the organisation.

1.3.3 It is recognised that some of the bespoke BMSs used by organisations may not provide all of the baseline functionality assumed here. In this case the organisation will need to enhance its BMS to provide the necessary functionality or determine if it would be advantageous to switch over to a new system that satisfies the baseline functionality.

1.3.4 The BMS will provide the master database which will hold all of the data required for the management of highway structures. The baseline data necessary for the operation of the DST is set down in Section 2.3. If an organisation does not have some of the data it will be necessary to collect this data and populate this onto its BMS before they utilise the DST. The DST will provide default values for some of the data items (e.g. unit rates) where it is felt that such data is not generally available at present. Such default data can be manually overwritten by the user when specific information is available.

1.3.5 The DST will retrieve the necessary data from the BMS, perform the necessary calculations as specified by the user and output the results back to the BMS, if necessary. The DST will also have the functionality for graphical presentation of results and the data. The specific data exchange protocol between the BMS and the DST will need to be established for each BMS and is expected to support a number of formats such as CSV, XML, etc.

1.3.6 Additional data that are specific to the calculations being performed by the DST will be input by the user and will be held within the DST.

2 User Requirements Specification - Overview

2.1 URS Summary

2.1.1 The overall objective of the management of highway structures is to ensure structures are *safe for use* and *fit for purpose*, thereby ensuring their continued structural accommodation of the required function of the highway network. The bridge manager has a duty to identify the alternative management strategies that achieve this objective when bidding for the funding, highlighting the advantages and disadvantages of alternative strategies, and to represent the consequences of failure to provide this funding. This involves many complex decisions, for example, at an individual structure or scheme level the bridge manager needs to assess:

- What is the best option to address the need out of the several alternatives available?
- Should the work be completed immediately or can it be deferred to a suitable date in the future? What are the safety, traffic and economic consequences of delaying the work?
- How can the work on different structures be combined to achieve economies of scale?
- How can the work on structures be combined with other works on the road to minimise disruption to traffic?

At the structure stock level the bridge manager needs to evaluate:

- What performance levels should be achieved by structures to support the overall route and network performance targets?
- What level of funding is optimal and necessary to deliver the performance targets? What will be the consequences of under-funding on structures and network performance?
- How best to prioritise the identified needs for work and target the limited available funding to derive maximum performance benefits?
- How best to balance the longer term funding and resource needs to prevent the accumulation of maintenance backlog on structures?

2.1.2 In consultation with the DST Steering Group (a sub-group of the UK Bridges Board) and detailed interviews with 14 organisations, the following functional areas have been identified for the DST. Each area is detailed in the next section.

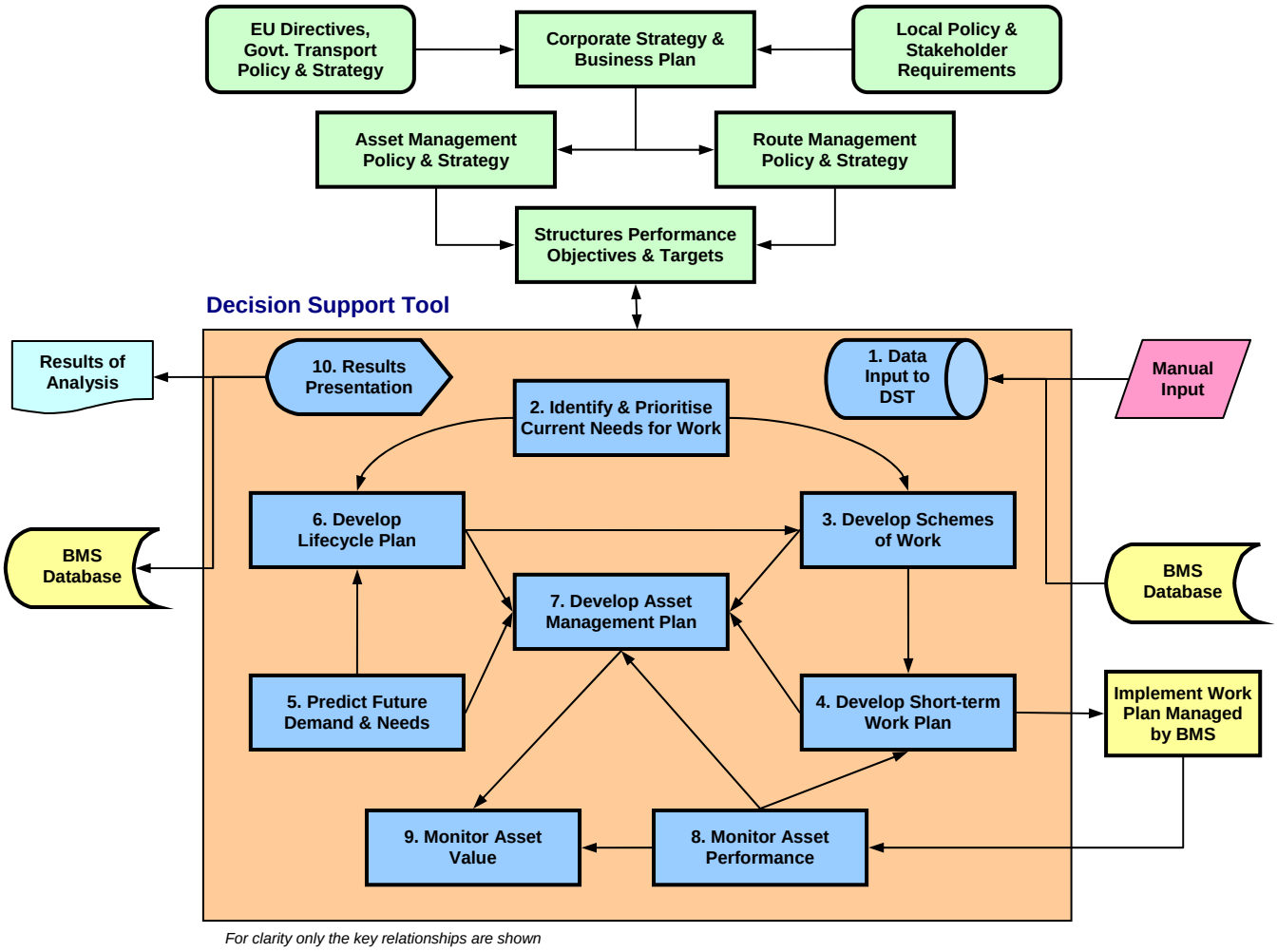
1. Data input to DST
2. Identify and prioritise current needs for work
3. Develop schemes of work
4. Develop short-term work plan
5. Predict future demand and needs
6. Develop lifecycle plan

7. Develop Asset Management Plan
8. Monitor asset performance
9. Monitor asset value
10. Results presentation

2.1.3 The following areas of functionality were considered but were agreed as outside the current scope of the DST:

1. Risk ranking of parapet upgrade, pier protection and road-and-rail intersection improvement works using nationally agreed procedures.
2. Ranking of bridges for assessment and strengthening using nationally agreed procedures.
3. Sustainability and environmental impact assessment.

2.1.4 It should be noted that the above functional areas are interrelated. The primary relationships are shown schematically in Figure 1.



For clarity only the key relationships are shown

Figure 1: Relationship between the DST functional areas

2.2 Baseline for the Bridge Management Systems

2.2.1 Chapter 10 of the Structures Code, *Framework for a Bridge Management System*, sets out the functionality for a BMS to support the implementation of the processes and guidance given in the Code. The schematic of the BMS framework presented in the Structures Code is replicated below.

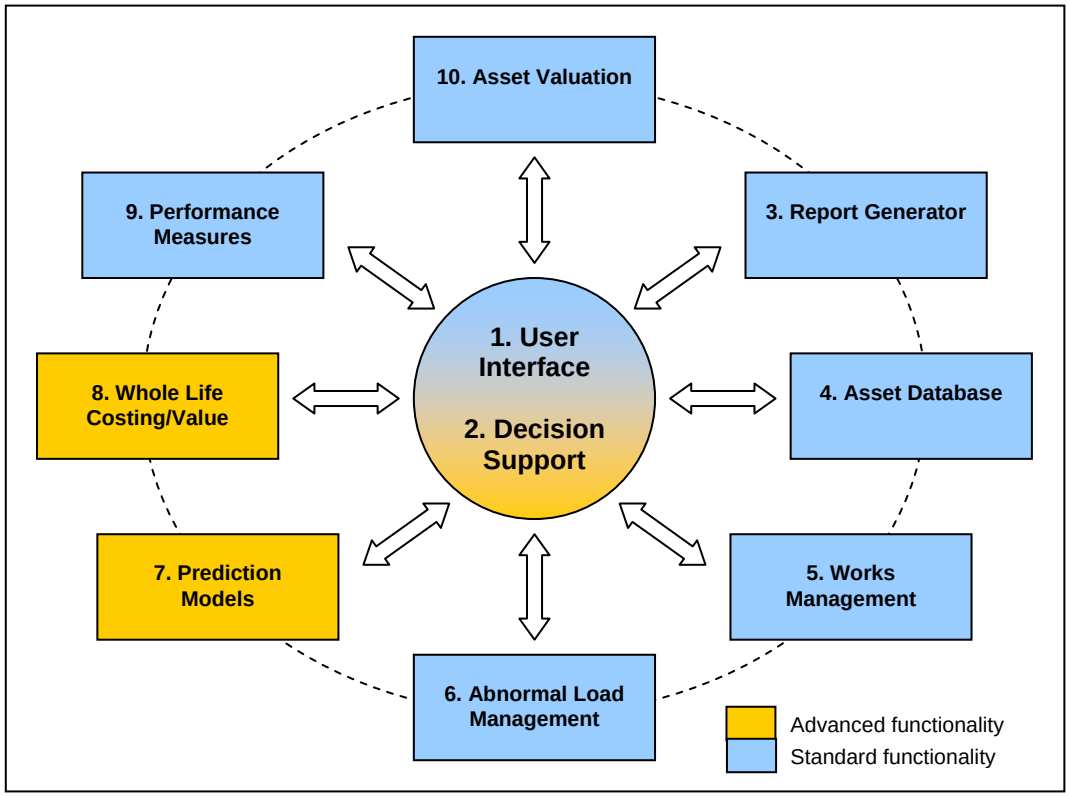


Figure 2: Framework for a BMS

2.2.2 The DST will provide the "advanced functionality" shown in the above figure but will need to interface with an existing BMS for the remainder of the functionality to provide the full capability required for the management of highway structures.

2.2.3 The baseline (or minimum) functionality that is necessary to support the operation of the DST includes:

1. A comprehensive and user configurable database based on an advanced relational database system such as Oracle, MS-SQL, etc. that can hold and manage all of the data on the organisation's structures stock as listed in Section 2.3.

2. Ability to interface with and exchange data with third party systems via XML and other formats to enable the BMS to link with the DST, a Geographical Information System, and other systems.

3. Work ordering, scheduling and management functionality based on the high level plans produced by the DST (highly desirable but not essential).

2.2.4 It is assumed that the organisation's existing BMS will have the above baseline functionality. If this is not the case then the organisation will need to consider either enhancing its BMS or switching over to a new system that meets the baseline functionality.

2.3 Baseline Data and Information Requirements

2.3.1 The baseline (or minimum) data that will be provided by the BMS to the DST includes:

1. Structure identification data giving details of the ownership, manager/maintainer, area/territory, location coordinates, route carried, obstacle crossed, etc. and a Unique Identification number (UID) for each structure. All data relating to a structure should be referenced through the UID.

2. Inventory data detailing the structural form, material and make up of the structure and all of its main components presented in a hierarchical manner down to a practicable level (called the *maintenance element*) at which inspection results are recorded and maintenance and renewal activities are carried out. For example, for a bridge the description should give 3-span, simply supported, composite beam and slab deck. The components may be organised hierarchically as span 1, superstructure, steel beams, beam 1, etc.

3. A standard list of all structural elements and components used in recording inspection results and work carried out, e.g. as given by the CSS Inspection Recording proforma.

4. Where available, a standard list of work types likely to be carried out on structural elements and components, e.g. painting of steel beams, patch repair and silane application for concrete crossheads, bearing replacement, etc.

5. Condition of each component of the structure. It is preferred that the condition reporting system follows the CSS scheme as a minimum. The DST should support other equivalent or more comprehensive systems, for example the SCMI system from Network Rail or the SMIS component inspection and defect recording system from the Highways Agency.

6. Structure capacity (assessed or as designed) to support imposed traffic loads for HA, HB, SV and SOV loads. Preferably information on the critical load cases, structural elements and governing limit states should be recorded.

7. Restrictions on the structure – weight, height, width etc. compared with current national standards.

2.3.2 It is assumed that the organisation's BMS holds the above data in a well-structured format. Where some data is missing, the organisation may need to undertake surveys to collect the missing data or supply 'assumed' values to the DST.

2.3.3 The user will need to supply the following additional data to the DST which will be input through suitably designed screens. In the first instance, the DST should provide default data for these but it will be the responsibility of the user to review this data and if necessary change it manually.

1. Where not defined in the BMS, a standard list of work types likely to be carried out on structural elements and components, e.g. painting of steel beams, patch repair and silane application for concrete crossheads, bearing replacement, etc.

2. Unit rates for the pre-defined work types, where these may be taken from the BMS or the DST.

3. Output rates for the predefined work types, i.e. work carried out in unit time.

4. Rates for alternative traffic management arrangements that may be required while the works are being carried out.

5. The exposure environment of the bridge component/element.

6. Service lives of limited life components such as expansion joints, bearings, water proofing, paint systems, etc. Including details of the work types relevant to each component and when they are applicable, i.e. prior, at or after the service live is reached.

7. Condition and performance deterioration profiles for bridge elements such as concrete beams, columns, etc. including details of the work types relevant to each element/material type and when, with regard to the deterioration mechanisms, they are applicable to.

8. The effect an intervention (work type) has on the component/element, both in terms of immediate condition/performance and subsequent service life/deterioration profile.

9. Limits of applicability (e.g. condition threshold, elapsed time etc.) for each intervention type, if any.

10. Class of the road carried and the road crossed (for a bridge), for example motorway, A, B or Unclassified.

11. Average Annual Daily Traffic (AADT) and the proportion of cars, LGVs, HGVs and abnormal vehicles in the traffic mix for each class of road.

12. Average increase in journey length (kms) and journey time (hours) if vehicles were to be diverted due to restrictions on the road carried or road crossed by each structure.

13. Cost of possessions and penalties for overruns if possession of a railway line is required for carrying out work on structures. The rates should relate to the class of the railway.

14. Discount rate.

2.3.4 In addition, specific data will be needed depending on the type of analysis carried out by the user. Such data is identified in Section 3 relating to each DST URS.

2.4 Structure of the URS

2.4.1 A User Requirements Specification (URS) defines *precisely and clearly what the user expects the system to do*. The URS for the structures DST covers the requirements listed in Section 2.1; the overall purpose of each requirement is discussed and the associated specification defined. The specification is described in terms of the relevant Inputs, Processes and Outputs; these are shown schematically in Figure 3.

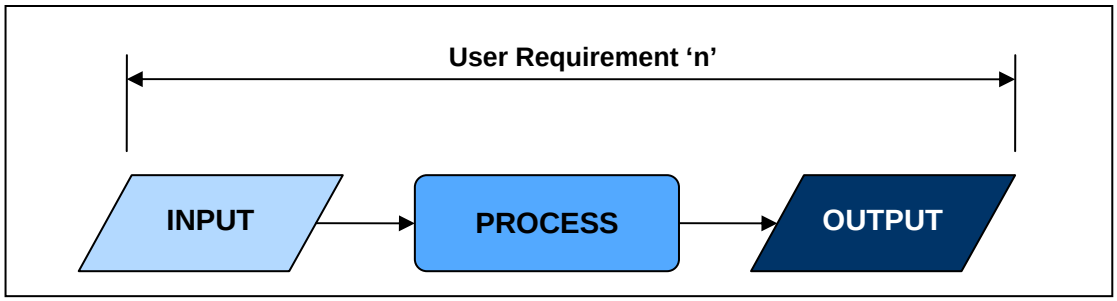


Figure 3: Defining User Requirement Specifications

2.4.2 The following provides an explanation of the general content/format of the Purpose, Input, Process and Output sub-sections.

Purpose

2.4.3 Provides a summary of why the functionality is required for managing highway structures and, where appropriate, explains how the results will be used and defines key relationships to other areas of functionality.

2.4.4 Where appropriate, references to the relevant sections of the Structures Code are included. In general the DST seeks to support the processes described in Sections 3, 4 and 5 of the Structures Code.

2.4.5 The Structures Code can be freely downloaded from www.ukroadsliaisongroup.org or www.roadscodes.org.

Input

2.4.6 A list of data specific to supporting this component of the DST is provided. Only data items that are additional to those listed in Section 2.3 are identified.

Process

2.4.7 This section gives the steps such as calculations, data manipulations and analysis required for producing the required outputs. The DST will need to perform these functions and, where appropriate, support activities the user will need to undertake during the processing. The URS summarises the broad approach to be taken while the detailed algorithms for the analysis will be developed as part of the functional design in the next phase of the project.

Output

2.4.8 The results of analysis and expected outputs from each user requirement are identified.

3 User Requirements Specification - In Detail

3.1 URS-1: Data Input to DST

3.1.1 The input data used by the DST includes (i) data automatically retrieved from the organisation's BMS; (ii) built-in default data; and (iii) data entered manually by the user.

3.1.2 The DST will retrieve the baseline data (see Section 2.3) for all structures in the stock from the BMS and store this on an internal DST database. The DST should protect the integrity of this data and should allow only the specified users to change this data. The DST should retrieve data from the internal database as and when required by the analysis in question.

3.1.3 For data supplied by the user, the DST will allow inputs to be manually entered by the user or selected by the user from predefined lists. This should be in the form of windows-style screens specific to the analysis in question.

3.1.4 The DST will contain built-in default data[1], both for the data items listed under paragraph 2.3.3 and other default data items specified in Sections 3.2 to 3.10. The DST will enable the user to review and modify default values but will also have the facility to 'reset' data to the original default values, when required. A clear audit trail of such changes to the data should be maintained by the DST.

3.1.5 The default values should be clearly identified on all outputs and reports so that these can be taken into account in the interpretation and use of results.

[1] The default data contained with in the DST will be based on current thinking and recognised good practice, drawing on research and development carried out by organisations such as the Highways Agency and LoBEG.

3.2 URS-2: Identify and prioritise current needs for work

Purpose

3.2.1 Bridge engineers and managers are normally provided with large quantities of inspection, assessment and other information from which to identify current needs for work. It is becoming increasingly important to be able to demonstrate that these needs have been identified in an objective, robust and defensible manner; whereby the benefits of undertaking the work and associated risks of deferring/not undertaking the work are clearly identified, assessed and recorded.

3.2.2 By gathering identified needs from the BMS and setting criteria to help identify additional needs (e.g. intervention triggers and thresholds), the DST will be able to quickly interrogate large quantities of data and produce a *workbank* of current needs. The needs in the workbank can then be scored, using pre-selected/defined criteria, to produce a *prioritised workbank*. The prioritised workbank is an input to scheme analysis (URS-3) and the short-term work planning (URS-4).

3.2.3 Further information on the identification and prioritisation of needs can be found in the following sections of the Structures Code. This URS supports short-term maintenance planning as defined in the Structures Code.

Section 5: Maintenance Planning and Management	
Section 5.4	Overview of Maintenance Planning
Section 5.5	Classification of Work Types
Section 5.6	Inputs to the Planning Process
Section 5.10	Identification of Needs
Section 5.11	Value Management

Input

3.2.4 The system will enable the user to:

- Select the group of structures the analysis will cover. In the majority of cases this should be the entire stock of structures, but in some cases the user may wish to select specific groups, for example, based on structure type, structural form or location.

- Select and/or define the sources of information that will be used to identify needs[2], e.g. inspection data (including the engineer's comments/recommendations), assessment data, rolling improvement programmes (e.g. parapet upgrades), weight/height/width restrictions, changes to standards/regulations, lifecycle plans (if developed, see URS-6), new knowledge or information etc.

- Select and/or define, where appropriate, the intervention triggers/thresholds that will be used to automatically identify needs for inclusion in the workbank[3], e.g. condition of element 'x' falls below 3C, capacity of bridge 'y' falls below 40 tonne capacity.

[2] It is expected that many of the needs will be held in the organisation's BMS, e.g. strengthening works, upgrade works. The DST will retrieve the necessary information from the BMS and include it in the workbank.
[3] Including the ability to carry out sensitivity/what-if analysis using the intervention triggers/thresholds to assess/compare the impact, e.g. on work volumes, backlog etc.

- The default settings in the DST will include 'essential' safety intervention levels (similar in nature to those used for road pavements) that would help identify the minimum work required to maintain structures in a state that is safe for use.

- Input additional needs that are not automatically identified through the aforementioned sources and/or triggers/thresholds, e.g. regeneration schemes.

- Select and/or define the criteria that will be used to prioritise needs. As a minimum the DST will include:

  - The default prioritisation criteria (and associated contributing factors) shown in Table 1 below, allowing the user to select those that will be used.

  - Functionality to present the data, algorithms and rules associated with each prioritisation criterion, enabling the user to modify these where appropriate.

  - Functionality that enables the user to define, within practical computing constraints, additional prioritisation criteria.

Table 1: Default Prioritisation Criteria used by the DST

Criterion	Contributing Factors
Safety	Evaluate Risk to Public Safety taking account of factors such as: Likelihood = f(defect/condition, load rating/reserve capacity, substandard element, restrictions/mitigation measures, usage, vehicle overload, vehicle impact, scour, resilience etc.) Consequence = f(structure type, element type, route served, obstacle crossed, local or global failure, structure dimensions, etc.)
Functionality	Evaluate loss of service in terms of user delay and disruption costs and increased cost of accidents due to restrictions on the structure taking account of factors such as: Functionality = f(restrictions on the structure, AADT of route supported, AADT of obstacle crossed, diversion characteristics, social/economic importance of the route, etc.)
Condition	Evaluate the Condition of the structure using for example the CSS BCI: Condition = f(element severity/extent, element and structure importance)
Local Factors	Defined by user, for example, political factors, heritage structure, etc.

Table Notes:

- The factors contributing to the *Safety* and *Functionality* criteria are similar to those used by the *Reliability* and *Availability PI* respectively.

- Select and/or define how the criteria will be weighted and combined. The DST will have a number of inbuilt prioritisation techniques that the user could select from; see the baseline requirements in Table 2 below. The system will support the development of criteria weightings using techniques such as Multi-Criteria Decision Analysis (MCDA).

Table 2: Inbuilt DST Prioritisation Techniques

Prioritisation Technique	Description of Technique
All criteria consolidated into one prioritisation score	Each prioritisation criterion has a weighting (e.g. established through MCDA) and the scores are combined together to give an overall score (e.g. on a 0 to 100 scale); but the local factor can override.
Criteria scored separately and ranked using rule sets	Each criterion has its own scale (e.g. 0 to 100) and rule sets are used to produce the prioritised list, e.g. Safety score of 80+ always takes preference, functional score of 80+ is equal to a Safety score of 60 to 80 etc.

- Select and/or define the work categories under which the needs will be classified; as a minimum the system will have the classification described in the Structures Code.

Process

3.2.5 The processes carried out by the system will include the following:

- Identification of the selected structures and retrieval of the appropriate data
- Evaluation of prioritisation criteria values as defined in Table 1
- Evaluation of prioritisation scores for structures/needs by combining the criteria values as defined in Table 2
- Classification of the current needs under defined work categories.

3.2.6 Further information on the identification and prioritisation of needs can be found in Section 5 of the Structures Code.

Output

3.2.7 The identification and prioritisation of current needs will provide the following outputs:

- A prioritised list of needs and associated information, e.g. overall priority score and/or the priority score for each criterion.
- Presentation of the prioritised needs by work category (to inform and/or compare against the work volumes and phasing defined in the Asset Management Plan).
- A list of errors where there was insufficient data to calculate a priority score (providing the user with the ability to select each instance and address any data gaps).

3.2.8 The system will enable the user to group the needs by appropriate criterion, e.g. needs arising on the same structure, similar needs (e.g. same defect), needs arising on the same route, needs arising on a similar group of structures etc.

3.2.9 It is envisaged that the prioritised workbank will be reviewed by appropriate staff within the organisation. The presentation of the prioritised workbank will support this review (i.e. Value Management workshop as discussed in Section 5.11 of the Structures Code) and enable:

- *Local Factor* criterion to be added/scored, e.g. criteria based on engineering judgement such as local importance, social and economic impact.
- Calculated priorities to be amended based on engineering knowledge/judgement.
- Explanatory comments and rationale to be captured for changes made to the priorities.

3.3 URS-3: Develop Schemes of Work (Value Engineering)

Purpose

3.3.1 The purpose of scheme analysis (or Value Engineering) is to develop the optimal solution to the needs, including the reduction of waste and inefficient aspects of delivery. Development of the optimal solution requires analysis of the long-term (30+ years) performance and needs of the structure, comparison of alternative solutions (option appraisal), and the packaging of needs into cost effective schemes. Given the range of performances and needs that may be associated with an individual structure, route and/or group of structures, scheme analysis is a complex and multi aspect decision problem.

3.3.2 The DST will support bridge engineers/managers to develop well-considered schemes, systematically capturing the information required to demonstrate that the selected scheme is the optimal solution. Schemes will primarily be constructed to address the needs listed in the prioritised workbank (URS-2) and the developed schemes will be used to produce the short-term work plan (URS-4). There is also considerable synergy between the functionality required to develop lifecycle plans (URS-6) and scheme analysis.

3.3.3 Further information on the identification and prioritisation of needs can be found in the following sections of the Structures Code. This URS supports short-term maintenance planning as defined in the Structures Code.

Section 5: Maintenance Planning and Management	
Section 5.4	Overview of Maintenance Planning
Section 5.12	Value Engineering

Input

3.3.4 The system will enable the user to:

- Select the need(s)/structure(s) from the prioritised workbank that will be analysed in the scheme analysis, i.e. grouping/packaging of needs to deliver more cost effective schemes. The system will enable the user to select and combine needs when defining a scheme, e.g. from the prioritised workbank via a drag-and-drop facility. The system will also enable the user to remove (deselect) needs from the scheme.

- Select, define and/or amend[4] the alternative options for addressing the identified need(s) on the selected structure(s). The information for each option should include the structural elements and work type to be undertaken, estimated cost (i.e. work, access[5], TM etc.), work duration, work pattern (e.g. day/night working), associated weight/lane restrictions[6], the year in which the work will be undertaken and impact of the work on performance/condition.

- Select, define and/or amend[7] the projected work on the structure(s) over a defined time horizon (typically 30 to 60 years), i.e. develop a Lifecycle Plan for each structure (see

[4] Amend – the system will include default rules, algorithms and data that will enable, when requested, intervention options to be automatically assigned to the identified needs.
[5] Access – including the definition of the possession duration when a railway line is affected.
[6] Restrictions - in some cases restrictions may apply to both the road supported and the road/railway crossed.
[7] Amend – the system will include default rules, algorithms and data that will enable, when requested, lifecycle plans to be automatically generated for the structure(s) under consideration.

URS-6). The information for each option should be as described in the previous bullet point plus service life, deterioration rate and impact on subsequent deterioration rate/service life.

- Select, define or amend the criteria that should be used to compare the alternative scheme options. As a minimum the DST will include:
    - The default scheme assessment criteria shown in Table 3 below, allowing the user to select those that will be used for the comparison.
    - Functionality to clearly present the data, algorithms and rules associated with each criterion, enabling the used to modify these where appropriate.
    - Functionality that enables the user to define, within practical computing constraints, to define additional criteria.
    - Functionality that enables the user to define how the alternative assessment criteria are used to compare scheme alternatives (utilising techniques and approaches such as those described in Table 2 of URS-2).

Table 3: Default Scheme Assessment Criteria

Criterion	Description
Safety, Functionality, Condition and Local Factors	Scheme analysis involves a whole life assessment of each alternative; as such the initial prioritisation criteria are retained in order to assess how they change for each alternative. Note: additional information may be available during scheme analysis, compared to that used in URS-2, so it may be appropriate to use more refined algorithms at this stage.
Socio-economic (and political and legal)	To assess the impacts and/or benefits to road users, residents, communities, businesses etc., and take account of route criticality, programmed events etc.
Environmental	To assess environmental issues, sustainability (carbon footprint), noise pollution etc.
Present Value of Costs (PVC)	To calculate the total discounted cost of all future direct costs (e.g. labour, plant, material etc).
Net Present Value (NPV)	NPV is calculated as the total discounted value (Benefits – Costs) over the analysis period. Note: to support NPV the above costs/benefits need to be monetised and as such the DST would include default monetised scales (within reason) for the aforementioned criteria. It is frequently difficult to monetise benefits, therefore it is common practice to monetise the dis-benefits (e.g. traffic delay costs) and use these, along with the direct costs, as an alternative to the benefits.
Economic Indicator/Econo mic Frontier etc.	The ratio of NPV to Cost would be used as an Economic Indicator when assessing alternative options for a scheme, i.e.: $\frac{NPV\ option\ 1 - NPV\ option\ 2}{Cost\ option\ 1 - Cost\ option\ 2}$ If the incremental NPV/Cost ratio is greater than a predefined the limit, then the more expensive scheme can be justified

Criterion	Description
Multi-Criteria Decision Analysis	To support a MCDA approach that weights the influencing criteria and combines using a utility scale (thereby avoiding the need to monetise benefits/dis-benefits).

- Record the supporting rationale wherever appropriate, e.g. selection of treatment options, selection of work patterns, unit rates etc.

- Develop a minimum of five alternatives for each scheme; including a "do minimum" option.

Process

3.3.5 The processes carried out by the system will include the following:

- Automatic and/or user assignment of work to be performed to address the selected needs based on inbuilt rules and algorithms. This will include information relevant to the assigned work, e.g. work type, estimated cost (i.e. work, access, TM etc.), work duration, work pattern (e.g. day/night working), weight/lane restrictions, the year in which the work will be undertaken and impact of work on performance/condition.

- Automatic and/or user assignment of alternative lifecycle plans (see URS-6) depending on key parameters considered in developing the lifecycle plans.

- Ranking of scheme options based on the criteria given in Table 3 and shortlisting those that should be considered during short-term work planning and long-term asset management planning.

- Determination of the optimal time (i.e. the year) for undertaking the works for the shortlisted options.

- Generate a unique reference number for the schemes and include this reference in the Workbank against the needs addressed by this scheme.

Output

3.3.6 The scheme analysis will provide the following outputs:

- Scheme cost and associated spend profile (over defined time horizon) for each option; presented as direct work costs, consequence/disruption/penalty costs, monetised benefits, total costs etc.

- Whole life cost/value, Net Present Value and appropriate Economic Indicators for each option.

- Identification of the optimal (preferred) option and the optimal time for undertaking the works.

- The increase in direct costs and whole life costs if the work is delayed by a specified number of years from the optimal time

3.3.7 The outputs will be presented in a manner that allows the user to readily compare up to five alternative options with regard to the aforementioned measures/indicators. The system will also enable the user to alter specific parameters within the scheme analysis (e.g. discount rate, rate of traffic growth etc.) to assess the sensitivity of the proposed options to such changes.

3.3.8 The system will allow the user to select a sub-optimal solution and provide the facility to capture the rationale that supports this selection.

3.3.9 The system will allow the user to assign the selected option(s) to the short-term work plan (URS-4).

3.4 URS-4: Develop short-term Work Plan

Purpose

3.4.1 The short-term work plans comprise of the Forward Work Plan and the Annual Work Plan. The Forward Work Plan is a programme of work for the next 1 to 3 year period; it provides details of the schemes to be undertaken and their phasing. The Annual Work Plan provides a detailed schedule (start and finish dates and other significant milestones) for works to be undertaken in the next financial year.

3.4.2 The Annual and Forward Work Plans are constrained/influenced by a number of criteria, including available budget, network occupancy/minimisation of disruption (and occupancy opportunities), possessions, providing a balanced programme of works, combining works with other schemes, e.g. pavement schemes. These criteria, plus the relevant costs, benefits and dis-benefits of the proposed schemes, need to be assessed in a formalised framework to produce robust and defensible short-term plans that are prioritised and/or optimised. That is, the initial prioritisation (URS-2) needs to be revisited in light of the developed schemes and the priority scores now re-calculated and assigned at 'scheme' level rather than 'need' level.

3.4.3 The schemes used to develop the short-term plans will come from the scheme analysis (URS-3). Also, the statistics/characteristics of the work types, phasing, volumes and costs in the short-term plan are checked and compared against those provided in the long-term Asset Management Plan (URS-7), i.e. to deliver the goals, objectives and targets set down in the Asset Management Plan (AMP) it is important that, in general, the works described in the short-term plan align with those in the long-term plan.

3.4.4 This URS supports short-term work planning as explained in Section 5 of the Structures Code.

Section 5: Maintenance Planning and Management	
Section 5.4	Overview of Maintenance Planning
Section 5.13	Prepare Forward Work Plan
Section 5.14	Work Scheduling

Input

3.4.5 The 'first cut' work plan will be produced through the compilation of the schemes developed using URS-3, i.e. after the preferred option for a scheme is identified it is added to the work plan. The system will enable the user to:

- Select and/or define the criteria that will be used to prioritise/optimise the schemes that constitute the short-term work plan, e.g. safety/risk, functionality, consequence, benefits, cost, environment and sustainability[8].
    - The scheme assessment criteria used for the Scheme Analysis (see URS-3) would also be used to prioritise/optimise the short-term work plan. As a minimum the DST will include:

[8] The DST should provide linkage/synergy between the criteria used at this stage and those used in URS-2.

- The default scheme prioritisation criteria shown in Table 3 (see URS 3), allowing the user to select those that will be used within the short-term prioritisation/optimisation.

- Functionality to clearly present the data, algorithms and rules associated with each criterion, enabling the used to modify these where appropriate.

o This approach would enable the prioritisation/optimisation to select a sub-optimal strategy from URS-3 when the optimal strategy cannot be adopted. Thereby the sub-optimal strategy may have different "scores" for each criterion, when compared to the optimal strategy, and these would alter how it is treated by the prioritisation/optimisation algorithm.

- Select and/or define the weightings, algorithms and/or techniques that will be used to prioritise and/or optimise the short-term work plan, e.g. prioritise using an Efficient Frontier/Boundary, optimise using Neural Networks or Genetic Algorithms. This system will support the development of relative weightings using techniques such as Multi-Criteria Decision Analysis. As a minimum the DST will include prioritisation techniques, such as those described in Table 2 of URS-2; and optimisation techniques, and in both circumstances include functionality to clearly present the data, algorithms and rules associated with the technique.

- Select and/or add data relevant to the defined prioritisation/optimisation criteria for a specific scheme.

- Bring forward, defer and/or remove a scheme in the short-term plan, including the facility to capture the rationale for this.

- Add details of other (non-structures) relevant schemes on the network (e.g. scheme type, location, programme etc.) that help justify a structure scheme on the basis of synergies and network opportunities.

- Select and/or define rules for the development of the short-term work plan, e.g. non-working periods (holidays), non-occupancy periods, scheme lead-times, supply chain, i.e. mix and volumes of work types that can be undertaken at any given time.

- Select and/or define the constraints/targets that apply to the short-term work plan, e.g. defined budget and network occupancy targets.

Process

3.4.6 The processes carried out by the system will include the following:

- Automatically calculate the priority score/Economic Indicator for each scheme using the defined criteria.

- Automatically produce a prioritised/optimised short-term work plan based on the prioritisation/optimisation technique, the defined rules for work programming and any defined constraints (the system will seek to produce a smooth work/expenditure profile unless otherwise constrained by the user).

Output

3.4.7 Short-term work planning will provide the following outputs:

- Prioritised and/or optimised Forward Work Plan (1 to 3 years).
- Prioritised and/or optimised Annual Work Plan (1 year).
- Presentation, in both plans, of the relevant information for each scheme, including details of work, costs, timing, priority score, makeup of priority score etc.
- Presentation of the work types, volumes, costs etc. associated with each work plan in appropriate graphical and tabular format.

3.4.8 The system will support sensitivity/'What-if' analysis of the short-term plan whereby the user can amend the predefined constraints/targets and/or add new ones. The system will allow the user to readily run these alternative criteria and present the outputs in a format that allows easy comparison of these with the 'base case'.

3.4.9 Where a Geographical Information System (GIS) is available, the DST should provide data for the GIS to present programmed works, services, routes used by emergency services etc to enable the impact of programmed works to be assessed.

3.4.10 The system will enable the user to manipulate the plans, this will include the ability to :

- Change the scheduling/programming of work; be this specific start/finish dates in the Annual Work Plan or year of work in the Forward Work Plan. Providing the facility to capture the supporting rationale for such changes.
- Add/remove schemes from the plans.
- 'Lock' schemes as fixed, thereby if the analysis is re-run these schemes are not altered in terms of their programming/scheduling.

3.4.11 In all instances the system will update the presentation outputs to enable the user to quickly assess the impact of any changes, e.g. on spend profiles.

3.4.12 The finalised work plan details would be returned to the BMS, or other system if required, which would issue the appropriate work orders.

3.5 URS-5: Predict Future Demand and Needs

Purpose

3.5.1 Future investment and management are directly influenced by the future demands and needs of the network, e.g. increased traffic flow and major capital works such as road widening. The DST should enable future demands/needs to be identified and linked to the relevant structures, thereby enabling their short and long-term management strategies to be developed accordingly.

3.5.2 This URS provides input to lifecycle planning [URS-6] and asset management planning [URS-7].

Input

3.5.3 The system will enable the user to:

- Record the date and type of future demand/need changes. The system will include as a minimum the following criteria, with default values where appropriate, for the user to select from and include functionality for the user to add/amend the values and record their supporting rationale:
    - Demand changes:
        - Change in traffic[9] volume, e.g. % annual change.
        - Change in traffic mix proportions, e.g. % annual change in HGV proportion.
        - Change in vehicle/axle loads.
    - Need changes:
        - Route widening/narrowing.
        - Route upgrade (to high and or heavy load route).
        - Bypass and associated impact on related routes.
        - Change of use.
- Record the date and type of future needs, e.g. route widening, route upgrades, bypasses etc.
- Link the demands/needs to the relevant structures and select/define the impact it will have on them, e.g. reduced service lives, increased rates of deterioration, replacement in year x, major works in year x etc.

[9] Where traffic should be taken to refer to all modes of traffic, including non-motorised traffic.

Process

3.5.4 The processes carried out by the system will include the following:

- Evaluation of future traffic volume/mix.
- Evaluation of future upgrade/strengthening needs.
- Updating of the structure characteristics to ensure the other DST components use the appropriate information when analysing future work needs and priorities.

Output

3.5.5 Prediction of future demands and needs will provide the following outputs:

- Details of the future demands and needs.
- A list of structures influenced by the demands/needs.

3.6 URS-6: Develop Lifecycle Plans

Purpose

3.6.1 A lifecycle plan describes a long-term strategy for managing an asset, or group of similar assets, with a view to minimising whole life costs (or maximising whole life value) while providing the required levels of performance. The development of these long-term strategies (30 to 60 years) requires an analysis and assessment of alternative options in a formalised framework that suitably captures the supporting rationale/thinking. Within the DST framework, lifecycle plans will be used to:

- Support the identification of needs (URS-2) by defining optimum intervention triggers/thresholds identified through lifecycle analysis.
- Support scheme analysis (URS-3) by providing predefined long-term alternatives and/or the facility to amend existing or develop new lifecycle plans.
- Capture the strategies and information (e.g. service lives, deterioration rates, maintenance treatment effects etc.) that support the development of the long-term Asset Management Plans (URS-7) and the associated 'sensitivity/What-if' analysis.

3.6.2 There is close synergy between scheme analysis (URS-3) and lifecycle planning, whereby lifecycle planning provides functionality that can be called upon when undertaking a scheme analysis[10] to determine the projected future work. As such, the system will ensure this synergy is appropriately represented by the user interface and linkages between the two functionalities.

3.6.3 This functionality supports long-term and short-term maintenance planning as defined in Section 3 and 5 of the Structures Code.

Section 3: Asset Management Planning	
Section 3.6	Overview of AM Planning for Highway Structures
Section 3.7	Highway Structures AM Planning Process (para. 3.7.33 to 3.7.44)
Section 5: Maintenance Planning and Management	
Section 5.4	Overview of Maintenance Planning
Section 5.10	Identification of Needs

Input

3.6.4 The system will enable the user to:

- Select the structure(s) for which lifecycle plans are to be developed; this will support the grouping of structures, for example by route, where this enables more cost effective plans to be developed.

[10] Lifecycle Planning is identified as a separate functionality for the DST because users must be able to create these at any time, their development must not be dependent upon first identifying a suitably prioritised need.

- Select, define and/or amend[11] the projected work on the structure(s) over a defined time horizon (typically 30 to 60 years), i.e. define alternative intervention strategies for each structure (also see URS-3). The information for each option that the user can select, define and/or amend will include the work location (e.g. structural elements), work type, estimated cost (i.e. work, access[12], TM etc.), work duration, work pattern (e.g. day/night working), weight/lane restrictions[13], the year in which the work will be undertaken and impact of work on performance/condition, service live, deterioration rate and impact on subsequent deterioration rate/service life.

- Select, define and/or amend the monetised benefits and penalties that should be considered for each option, e.g. environmental, sustainability, noise pollution and benefits to road users/local businesses.

    - Note: these would be the same as those presented for URS-3.

- Record the rationale wherever appropriate, e.g. selection of treatment options, selection of work patterns, unit rates etc.

- Develop a minimum of five alternative intervention strategies for each structure.

- Define and amend the default data that supports lifecycle planning, i.e. deterioration rates, service lives, treatment selection unit rates etc.

Process

3.6.5 The processes carried out by the system will include the following:

- Based on the input information provided, the system will automatically determine:

    - How the structure(s) (and the constituent elements) will deteriorate / degrade in performance and condition over time.

    - When needs arise and what are the appropriate works/treatments.

    - The impact of works/treatments on performance/condition.

    - The consequences of delaying/deferring works both in terms of performance and condition of the structure, and also traffic delays, risk of failure, restrictions, diversions and other penalties.

    - How works may be most cost effectively packaged.

- Evaluation of the Whole Life Cost/Value, Net Present Value, Economic Indicators (as appropriate) for each intervention strategy and determining the optimum lifecycle plan for the structure.

[11] Amend – the system will include default rules algorithms and data that will enable, when requested, lifecycle plans to be automatically generated for the structure(s) under consideration.
[12] Access – including the definition of the possession duration when a railway line is affected.
[13] Restrictions - in some cases restrictions may apply to both the road supported and the road crossed.

Output

3.6.6 Lifecycle planning will provide the following outputs:

- A suit of alternative intervention strategies for the selected structure(s) which include spend profiles (over a defined time horizon) for each; presented as direct work costs, disruption/penalty costs, monetised benefits, total costs, consequences etc.
- Whole life cost/value, Net Present Value and appropriate Economic Indicators for each intervention strategy.
- Identification of the optimal lifecycle plan.

3.6.7 The system will support sensitivity/'What-if' analysis of the intervention strategies whereby the user can amend specific criteria, e.g. service lives, deterioration rates, costs etc. The system will allow the user to readily run these alternative criteria and present the outputs in a format that allows easy comparison of these with the 'base case'.

3.6.8 The system will enable the user to identify a sub-optimal solution as the preferred option and provide the facility to capture the rationale that supports this selection.

3.7 URS-7: Develop Asset Management Plan

Purpose

3.7.1 An Asset Management Plan (AMP) is an optimised long-term plan (typically up to 5 or 10 years) of work and expenditure for the overall structure stock, based on a 30 to 60 year look ahead, which delivers the required performance and service levels defined by the organisation. It is not a detailed plan of works like the short-term plan (URS-4); instead the AMP provides the indicative work types, volumes, phasing, expenditure and associated performance over the defined time horizon.

3.7.2 The system will support the bridge engineer/manager to produce the work and financial plans for the AMP by performing a number of different analyses, including:

- *Unconstrained Analysis* – there are no budget, resource, occupancy or other constraints placed on the development of the work/financial plan, it is thereby a straightforward summation of the optimised lifecycle plans (developed under URS-6) for individual structures.

- *Constrained Analysis* – the user can place constraints and targets on the analysis (i.e. budget, occupancy, minimum standards of performance, consequences etc.) to assess the impacts to produce the 'base case' AMP.

- *Sensitivity and What-if Analysis* – the user can alter the constraints/targets on the base case to assess the impact this has on certain criteria, i.e. budget required and/or performance delivered.

3.7.3 The work and financial plan produced by this analysis for structures will form key inputs to the organisation's overall Transport Asset Management Plan as explained in Section 3 of the Structures Code.

Input

3.7.4 The system will enable the users to:

- Select and/or define the structures that will be included in the analysis.

- Define the time period for whole life cost analysis (typically 30 or 60 years) and the planning horizon for the AMP (typically 5, 10 or 20 years).

- Select a constrained or unconstrained analysis.

- Select and/or define the criteria that will be used to constrain and/or drive the analysis.

- Select and/or define the performance measures (URS-8) and associated target values that should be considered when developing the work and financial plan.

- Select and/or define the technique to be used for analysis, i.e. prioritisation or optimisation techniques.

- Select, define and or amend the criteria and constraints to be used for prioritisation/optimisation (and the associated weightings and algorithms if these differ from or have not been defined under URS-2 or URS-4).

Process

3.7.5 The activities carried out by the system will include the following:

- Automatically produce the work and financial plan.
- Automatically calculate the predicted performance measures and defined consequences (e.g. number of weight restricted structures) arising from the work plan.

3.7.6 The approach to be used for the development of Asset Management Plan is explained in Section 3 of the Structures Code.

Output

3.7.7 Asset Management Planning will provide the following outputs:

- Presentation of the work and financial plans and associated performance measures in appropriate graphical and tabular format.
- Details of the sensitivity/'What-if' analyses that were carried out and presentation of the outputs in a format that supports easy comparison of alternatives (using appropriate graphical and tabular formats).

3.7.8 The system will allow the user to save analysis outputs.

3.8 URS-8: Monitor Asset Performance

Purpose

3.8.1 To be the dedicated module for defining the performance measures/targets and monitoring, in real time, how these change over time; whereas URS-7 would use these measures/targets during Asset Management Planning to demonstrate the impact of different investment strategies/constraints/targets. As such, this module would be used to monitor performance between consecutive AMP updates, i.e. to check if the targets are being delivered and to identify if plans need to be amended.

3.8.2 This module would also support the bridge manager in translating corporate/route objectives and targets into structure performance requirements.

3.8.3 The level of detail at which the performance measures/targets are applied will influence how they link to other parts of the DST, for example:

- *Component/Structure Level* – defined for an individual structure, or a specific type of structure, based on known performance requirements, e.g. required load carrying capacity, constraints on lane closures/restrictions.

- *Route Level* – defined for a specified route, whereby the structures on the route must deliver the defined performance, e.g. high load route, abnormal load route, defined availability/occupancy target.

- *Group/Network Level* – whereby the structures in the group/network are assessed, set targets, collectively, e.g. Condition Performance Indicator.

3.8.4 As such, performance measures are of greatest benefit when combined with a 'What-if' analysis (URS-7), whereby they are able to demonstrate the impact that different levels of expenditure have on performance and vice versa. The system will need to cater for a wide range of measures, both predefined and user specified, for example:

- *Predefined Performance Measures* – Condition, Availability and Reliability Performance Measures, Backlog, number of structures with load restrictions, benefits/dis-benefits, consequences, lane occupancy, ratio of preventative to reactive work (or revenue to capital), cumulative whole life costs, work volumes etc., whereby these may be used at one or more of the above levels.

- *User Defined* – other measures that may be specific to an organisation or what the bridge engineer/manager considers is best suited to demonstrate and justify work plans and budgets. It is envisaged that these would be simple measures (e.g. counts) in order to avoid complex and excessive programming to support user defined measures.

3.8.5 This URS supports long term asset management planning as given in Section 3 of the Structures Code.

Section 3: Asset Management Planning	
Section 3.7	Highway Structures AM Planning process (para. 3.7.2 to 3.7.32)
Section 3.8	Performance Measurement for Highway Structures

Input

3.8.6 The system will enable the user to:

- Select and/or define the performance measures that will be used for their network. The system would include the following measures as default:
    - Condition, Availability and Reliability Performance Indicators
    - Backlog, cumulative Whole Life Cost, cumulative consequences, etc.
    - Number of restricted structures, e.g. load, height and width.
    - Lane occupancy/number of lane closures associated with structures
    - Number of substandard/deficient structures.

  As a minimum the DST will include (i) functionality to clearly present the data, algorithms and rules associated with each performance measure; and (ii) functionality that enables the user to define additional straightforward performance measures (including the ability to identify the input information that supports any additional measure).
- Select and/or define the level at which each performance measure applies, e.g. component, structure, route and network.
- Define the relevant performance targets.
- Retrieve information from the BMS that supports the calculation of performance measures.
- Enable the entry of data required for the calculation of the Performance Measures that is not available from the BMS or has not been captured elsewhere.

Process

3.8.7 The processes carried out by the system will include the following:

- Calculate the performance measures based on the specified algorithms.
- Note: a number of BMS already have one or more of the bridge/structure performance measures (or indicators). It is the responsibly of system providers to determine if the routines for the performance measures that are held in their BMS can be effectively utilised by the DST or whether the routines also need to be held within the DST to support effective/speedy analysis.

Output

3.8.8 Performance measures/targets will provide the following outputs:

- Presentation/report of the selected/defined performance measures and targets.

3.9 URS-9: Monitor Asset Value

Purpose

3.9.1 To support the calculation of the gross and depreciated asset value, and future depreciation charges, in accordance with the CSS/TAG Guidance Document[14] for local authority highway structure stocks[15]. Important functions of this module will be to monitor how the asset value will change over time for alternative management strategies analysed under URS-7 and to monitor changes in asset value between financial years.

Input

3.9.2 The system will enable the user to:

- Select and/or define the classification used for the bridge stock, i.e. to create the groups/sub-groups specified in the CSS/TAG Guidance. The system would include a default classification.
- Select and/or define the replacement unit rates that apply to each group/sub-group, including default values for the predefined classification.
    - Including the ability to enter construction scheme details that are used as a basis for deriving replacement unit rates.
- Select and/or define the adjustment criteria that influence the replacement cost, e.g. location, access etc., including a default list of adjustment criteria and associated default factors.
- Select and/or define appropriate price indices (the system should have the Baxter and ROADCON indices as default options).
- Select and/or define the depreciation/impairment relationships. As a minimum the system should have an inbuilt depreciation relationship based on the Condition Indicator and estimated maintenance costs.

Process

3.9.3 The system will calculate the gross and depreciated asset value, and future depreciation charges, in accordance with the CSS/TAG Guidance Document.

3.9.4 Note: a number of BMS already cater for the CSS/TAG process. It is the responsibly of system providers to determine if this functionality can be effectively utilised by the DST or whether it also needs to be held within the DST to support effective/speedy analysis.

[14] CSS/TAG Guidance Document for Highway Infrastructure Asset Valuation (TSO, July 2005).
[15] This module does not require asset valuation functionality in accordance with the approaches used by the Trunk Road authorities, Network Rail and other non-local authority bridge owners.

Output

3.9.5 This module will provide the following outputs:

- Presentation/report of the asset value (GRC, DRC and depreciation, both in-year and changes between financial years, all amended to the current year to take account of changes in price indices).

3.10 URS-10: Presentation of Results

3.10.1 The results from the analysis carried out should be stored on the internal DST Database with appropriate references to the 'analysis case' and the 'name of the analyst'.

3.10.2 The results should be presented to the user in an appropriate format (e.g. graphical, GIS, tabular, report etc.) with all the relevant information for ease of interpretation.

3.10.3 Where specified, the DST should allow information to be exported to Excel or other software for further manipulation by the user.

3.10.4 A range of standard reports would be provided, including:

- Workbank and prioritised workbank report
- Scheme Analysis reports
- Short-term Work Plan
- Lifecycle Plan reports
- Asset Management Plan reports (illustrating base case and alternatives)
- Performance Measures report
- Efficiency savings report
- Asset Valuation Report
- Reports, for each analysis type, that identify where missing, default and user defined data have been used.