

Towards a Uniform Bridge Management System for Australia and New Zealand

Graham D Rummey, B.Sc (Hon), M.Eng Sc, MICE

and

Laurie B Dowling, B.E (Civil, Honours), FIE Aust

SYNOPSIS

Austrroads has sponsored a study of the information data needs to support effective agency management of bridge infrastructure assets. Overall objectives of the study were to develop national inventory and condition datasets, and an integrated approach to the determination of bridge condition indices that could be used for budgetary planning, prioritisation of maintenance activities, benchmarking and performance review.

At workshops involving bridge asset personnel from 9 participating agencies the current status of bridge management systems as developed throughout Australasia was confirmed. Those systems were compared and formed the basis to establish common sets of bridge identification and structure inventories suitable for adoption in a uniform bridge management system. Inspection frequencies and bridge condition assessments of those systems were also compared and reviewed for adoption in the uniform system as being representative of current practice. Findings would be presented in the format of a guideline.

The guideline produced from the study proposes a minimum basic set of bridge inventory detail, the frequency of 4 levels of inspection and criteria by which to determine the condition of bridge elements. Consensus on a method to interpret the condition of a bridge from the condition of its element was not achieved. However, examples of algorithms used by VicRoads and by RTA of NSW are provided to indicate how that interpretation may be achieved, and a third simple method is suggested.

1 INTRODUCTION

1.1 Background

Within Australia and New Zealand there are approximately 50,000 road bridges in public ownership, managed by over 800 national, state and local agencies. Each of those agencies is required to select an approach to bridge management that satisfies its particular circumstances and for which it has resource capabilities.

The challenge in bridge management is to ensure that all bridges within a road network remain fit for their intended purpose over long periods of time at minimum life cycle cost.

Against that background, Austrroads commissioned two projects to develop a minimum set of bridge inventory items, condition descriptors, inspection regimes, and indicators of bridge

condition and reliability for use in management of bridge structures throughout Australasia. Beneficiaries from defining those items would likely be any owners of public bridge assets.

Those two projects were BS.B.C.024 – *Develop National Data set for Bridge Inventory and Condition* and BS.B.C.008 – *Consistency in Bridge Condition Indices*.

1.2 Austroads Project No BS.B.C.024

The charter for BS.B.C.024 was to develop and implement a national data set for bridge inventory and condition indicators. The scope of the project involved a review of existing bridge inventory and condition data held by member agencies, determination of what would be essential data requirements for a national set of indicators, and development of a process to compile information on a national basis as needs demanded.

1.3 Austroads Project No BS.B.C.008

The charter for BS.B.C.008 was to develop a consistent approach and methodology for determination of indices to represent bridge condition which could then be used to determine funding priorities, to indicate performance of the bridge stock and to measure agency performance. The scope of the project involved a literature review of existing practices, rationalisation of bridge condition indices in use by the Austroads' member agencies, and canvassing the relevant needs for input into management programs and for output to review performance.

1.4 Bridge Management Guideline

From those two projects, Austroads(1) is producing a guideline suggesting an inspection regime, and a minimum dataset covering bridge inventory and condition, and outlining current approaches to the use of inspection results in managing a stock of bridges.

As indicated by Austroads(2), the degree of sophistication to which a bridge management system is developed is governed by:-

- the amount of bridge stock to manage;
- how quickly systemic management is desired, ie to have a total system immediately or one that can be developed as time related data are collected;
- the amount of resources, both time and personal input, that can be committed to its development and upkeep; and
- whether engineering control over the process is considered essential.

Those criteria should be respected when following the guideline suggestions.

2 WORKSHOPS

2.1 Introduction

The two Austroads projects were conducted jointly. Two workshops enabled extensive consultation with the 9 operational member agencies of Austroads and established consensus on the content for the guideline to assist asset managers in creating a Structure Information

system. The guideline is not a manual from which to build a complete bridge management system.

2.2 Workshop Output

It was clear from the outset that despite differences between agency systems it would be possible to establish in relation to bridge information currently being recorded:-

- common data readily available from each agency;
- data that would be appropriate for an Austroads data set; and
- the use of that data for decision making.

Various concepts and practices of management systems were examined. To reach a consensus on the viability and the merit of those ideas, agency participants were asked to test those concepts with their specific data and to assess how relevant the outputs would be to management of their organisation's assets.

By the time of the second workshop it was quite clear on which items there would be agreement, and on which items the guideline could only provide indicative direction. Where there was a divergence of practice, the guideline would indicate the nature of information to collect and provide examples of how member agencies were deriving management decisions from that information.

3 BRIDGE MANAGEMENT SYSTEMS

3.1 Introduction

Before designing a dataset it is essential to consider the bridge management process and to understand data needs. The objective for all management systems should be to identify bridge asset needs and to measure the effectiveness of applied maintenance strategies. The framework of a generic, comprehensive bridge management system is shown in Figure 1.

3.2 Data Collection

Collection of relevant quality data is the crux of any successful bridge management system. The quality of information and how that information is recorded and manipulated are foremost decisions in the discernment of data collection. Database analysis capabilities are becoming more sophisticated to the point that optimisation and prioritisation of projects are becoming a realistic feasibility. As those techniques improve then so must the quality and range of data expand to fully complement the process.

In the early stages of compiling any system it is important to establish management objectives. For data collection, the ultimate aim should be to gather data that are both objective and consistent with measuring asset and manager performance. Collection of unnecessary data is a waste of resources, and its storage takes up valuable computer space.

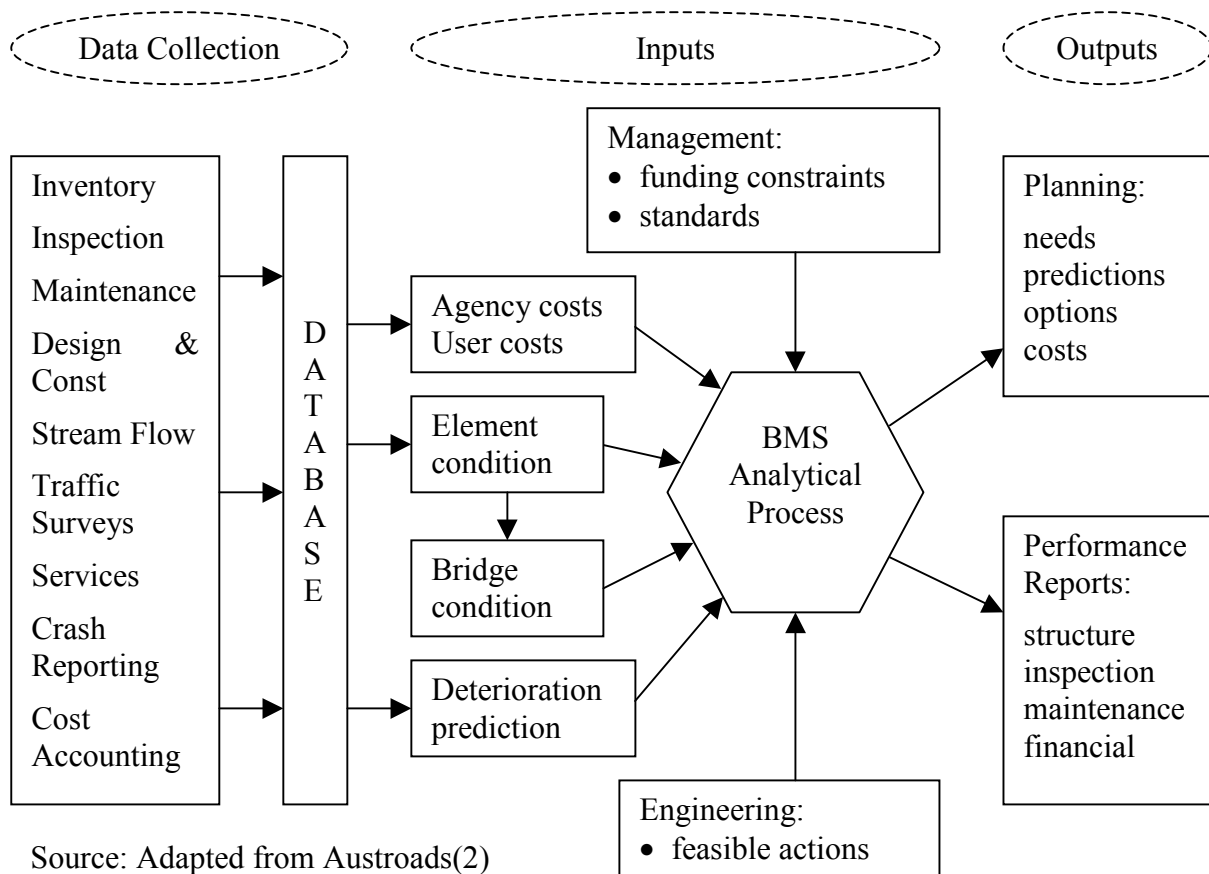


Figure 1: Structure of a comprehensive BMS

3.3 Data Analysis

The objective for data analysis may be summarised as:

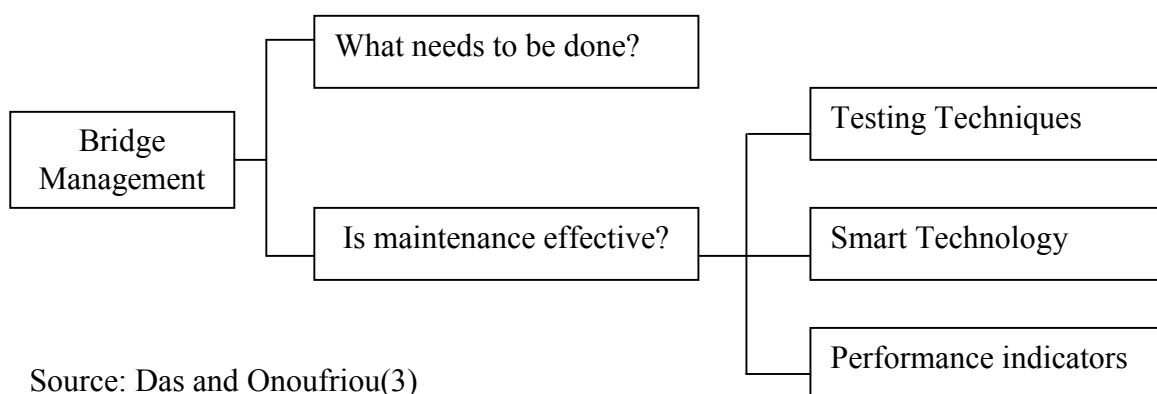


Figure 2: The overall aims of bridge management

“What needs to be done?” is derived from planning analysis outputs, and “Is maintenance effective?” may be assessed from performance reports.

The ultimate aim for Austroads would be to produce guidelines for a total system but, as noted in the introduction, work to date has been confined to providing a basis for consistency between agencies in minimum data sets and in condition reporting.

4 GUIDELINE DEVELOPMENT

4.1 Introduction

Figure 1 indicates the type of data used to feed comprehensive bridge management systems. The workshops concentrated on deriving consistent system aspects for inventory detail, inspection frequencies and condition ratings.

The overall status of system development was that agencies could claim ownership of modules in which to store bridge inventory information. Some systems had modules to retain inspection records, and modules for repair actions and costs. Bridge condition monitoring and condition analysis procedure for prioritisation of maintenance programs was steadily being improved. However, it was safe to assume that no system had the capacity to analytically predict condition deterioration or to determine budgetary requirements. That aspect of management still relied upon engineering knowledge and expertise.

Assets to be included in a structures database would be:-

- bridges where the clear span is not less than 1.8 metres;
- culverts where the waterway area is not less than 3 square metres;
- tunnels;
- large sign support structures;
- retaining walls; and
- other structures such as noise barriers, buildings at roadside rest areas and weigh stations, pollutant traps, etc.

The determining factor for inclusion of assets in the database is whether or not engineering expertise is required to determine if the structure is satisfactorily capable of performing its specific function within the road network. The schedule above should alert asset owners to any structures not presently under observation or managed.

4.2 Bridge Definition

Initially it was important to establish whether or not agencies were referring to a similar structure type when reporting on bridges. To achieve the objective of consistency a common definition of which assets were bridges was required.

The definition for a bridge as accepted by each agency for adoption in the guideline is:

*a structure with a clear span or diameter not less than 1.8m or
with a waterway area not less than 3 sq m.*

4.3 Bridge Identification Inventory

Bridge inventory comprises two distinct sets of data; data by which to identify a structure and data from which to analyse maintenance requirements.

An examination of agency data sets established that, though the range of information stored was large, it was possible to select common items of identification inventory. General headings for the classification of identification inventory are:

- name, location and function of the structure;
- design details of the structure;
- loading capacity characteristics of the structure;
- attachments;
- environmental and historical listings; and
- geometric layout and clearance details.

The minimum set of identification inventory is provided in the guideline. Specific asset owners may consider additional information desirable but, in general, further detail is not considered essential.

4.4 Bridge Structure Inventory

The various data sets of the member agencies were also examined to establish the nature of information being recorded in regard to structural characteristics of a bridge. Those items are the inventory by which a bridge is inspected and condition rated.

To achieve the consistency that Austroads was seeking it was evident that a common format for defining structural inventory would be necessary as there is a significant difference between agencies in the manner by which structural inventory is captured. Bridge structure inventory can be progressively categorised by its design type, its material classification and its structural function. The order in which those descriptors are selected determines the possible number of inventory items and explains the range between agencies of from less than 60 to more than 260 in the number of structural inventory items.

A multi-tiered framework consisting of a series of levels by which an element is progressively defined was favoured. Careful analysis of the various systems in use, and investigative application of the resulting categories by the agencies, identified 5 definitive levels for the framework as shown in Table 1. An example of how the framework may be applied to capture bridge structure inventory is included in the guideline. Application of the framework to other structural assets has yet to be developed.

Level	Name	Description	Examples
Level 1	Asset type	structure description	Bridge, culvert, retaining wall, noise barrier, sign support structure
Level 2	Structure group	structural function	deck, span, joint, bridge safety barrier
Level 3	Structural element	element design category	Girder, beam, arch, truss
Level 4	Element description	material properties	concrete, steel, timber
Level 5	Comment	special details	other details including dimensional size, proprietary names, special treatments, etc

Table 1: Five level framework for an inventory of structural elements

4.5 Bridge Inspection

Effective bridge management can only be achieved through a disciplined approach to bridge inspection. Inspections are used to gather functional information, including condition, about the operating environment of bridges. The depth of information obtained during an inspection and the frequency with which that information is gathered will vary depending on the reason for which it is required. Ultimately, managers are responsible for assessing the risk involved by not obtaining the appropriate knowledge for decision making.

The issues that may determine inspection frequencies include:-

- strategic importance of a route or bridge;
- risk management of known defects;
- risk management of material degradation;
- events, viz. floods, bushfires, earthquakes;
- traffic crashes that may have damaged a critical structural element;
- notification from the public; and
- availability of special equipment and/or resources.

On first examination, agency inspection policies appeared to be diverse. However, once scope and responsibilities had been defined a common approach to inspections could be specified.

A four tiered level of inspections was adopted as the standard. Those levels reflect degrees of frequency, scope and responsibilities related to structure type and deteriorated condition. The levels are by no means limiting. They indicate the period within which an inspection of specific scope should be undertaken to maintain quality data within the bridge management system.

4.6 Element Condition

System analysis relies upon element condition information as shown in Figure 1. Element condition recorded when completing Level 2 bridge inspections is rated in terms of the four condition states defined in Table 2. Condition is recorded as the quantity, or the percentage of the element's total quantity, in each of the four condition states. It is common for a proportion of the total quantity of an element to be in all of the four condition states. A style of inventory database in which to store condition information has been suggested in the guideline.

With a systematic inspection regime in place, monitoring condition over time is a sensitive indicator to the performance of an element and ultimately of the bridge. Change in condition is a clear indicator of element deterioration, or change in condition may be exploited to demonstrate the effectiveness of applied maintenance strategies.

4.7 Bridge Condition

Bridge condition is assessed from bridge element condition information. The form of algorithm used to derive bridge condition is not unique. Appendix A contains examples of bridge condition algorithms developed by VicRoads and RTA NSW, and a modified version of the RTA method now suggested by the authors. Generally, using a combination of the

conditions of critical elements the algorithm is designed to generate a prioritised list of candidate projects needing more urgent maintenance repairs.

The guide does not favour any particular method. Application of this technology within Australasia is in its infancy and managers would be expected to select the appropriate algorithm or its equivalent that best fits their data format to provide acceptable prioritised listings of candidate projects.

As well as identifying bridges in the network that require early maintenance management, bridge condition may be used as an indicator of the overall health of the total bridge stock, or of a subset of bridges in the network, that over time can reflect management performance.

Element Condition State		Description
1	As-built	The element is in good condition with little or no deterioration. Superficial cracks and discolouration may be present, but without effect on strength and/or serviceability.
2	Good	The element shows deterioration of a minor nature. Minor surface defects may be present but without loss of section or effect on the serviceability of the element.
3	Fair	The element shows advancing deterioration. Some minor loss of section may be present, but insufficient to significantly affect the strength and/or serviceability of the element.
4	Poor	The element shows advanced deterioration and loss of effective section. Deterioration is to the point that there is concern a structural analysis is warranted to ascertain impact on the strength and/or serviceability of the element.

Table 2: Element condition states

4.8 Maintenance Priority Indicators

Bridge condition is one indicator used to rank the order of projects for maintenance. Some other indicators in use are:

- reliability reflecting a management shift away from using condition as an indicator. Repairs are assessed from the capacity of the bridge to safely provide a continued service.
- risk using consequence and probability factors to indicate risk associated with bridge failure. High risk bridge sites receive early maintenance funding.
- socio-economic bridges with special needs related to social and economic issues such as environmental, cultural (eg heritage), and aesthetic values.
- sufficiency a set of indicators dictated by route standards, eg bridge width, bridge vertical clearance, load carrying capacity and barrier design standard.

In essence, those projects that return the highest benefits form the basis of a works program.

5 SUMMARY

The art of bridge management system design is evolving all the time as any literature survey will show. As more data are collected, predictive capability modules incorporated within those systems will become more refined and, as a consequence, the results more acceptable from an engineering point of view. A document has been prepared to provide guidelines for collecting and manipulating structural information.

Austroads(2) has recognised that system modules need to be developed to:

- predict deterioration rates for structural elements;
- reassess deterioration rates following repairs; and
- carry out optimisation and prioritisation by an iterative process.

Development of these and other modules will inevitably take time. Meanwhile, it is desirable that agencies establish a basic form of bridge management system, and begin collecting a time series of condition data and maintenance costs. Until time related data are available, meaningful development of analytical system modules will not happen.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

- 1 AUSTROADS (2004). "Guidelines for Bridge Management – Structure Information". No AP-R2??/04. Austroads, Sydney, NSW.
- 2 AUSTROADS (2002). "Bridge Management Systems - The State of the Art". No AP-R198/02. Austroads, Sydney, NSW.
- 3 DAS P., and ONOUFRIOU T. "Examination of uncertainties in bridge management". *Bridge management 4: inspection, maintenance, assessment and repair*, THOMAS TELFORD, 2000, pp 231-245.

appendix a: **BRIDGE CONDITION EVALUATION PROCEDURES**

Bridge (BCN) and Culvert (CCN) Condition Numbers

Developed and used by VicRoads(A1), the BCN is determined from empirically derived formulae based on information within its bridge dataset. The value, a number, is a summing of condition state percentages for elements of a structure. It applies factors to account for the element's exposure environment, and for the element's importance to the structure.

A BCN is derived from the following expressions:-

$$ACR = \Sigma (\text{condition state number} \times \text{condition \%})/100;$$

$$AGR = \Sigma (2 \times ACR + E^{1/2}) / \text{Number of components}; \text{ and}$$

$$BCN = \Sigma [AGR \times W_b]$$

where E is an exposure factor; and
 W_b is an importance weighting factor applied to the element group.

BCN values have no direct engineering significance, but are useful indicators of relative condition between structures. Over time, they are useful for illustrating changes in condition of individual structures or of the overall bridge stock.

A CCN is determined in a similar fashion.

Bridge Health Indicator (BHI)

Developed by RTA NSW(A2), the Bridge Health Indicator (BHI) is a method used to sieve its bridge dataset based upon bridge element conditions.

Depending on an element's function and material type, RTA NSW uses 3, 4 or 5 condition states to assess the condition of bridge elements. Within the process, elements are also given a factor of importance directly related to their structural function within the bridge.

Applying engineering logic to analyse condition records for bridge elements in its database, RTA derived a relationship between element importance and the percentage of element quantity in specific condition states that would reflect an acceptable rating of the condition of its bridges as either 'good', 'fair' or 'poor'. Using that relationship, the condition of a bridge is determined from the least favourable condition of any of its elements. Unlike derivation of BCN, BHI is not determined from a combination of element conditions.

BHI is a direct interpretation of bridge condition and not a relative bridge order ranking.

Comment

BCN determines a set of numeric values reflecting the condition of the network. BHI provides a direct descriptive indication of the network condition. Within the context of indicating the condition of a structure as 'good', 'fair', or 'poor', the range of BCN values

would need to be determined for the total network and bandwidths set within which to categorise each structure. Those bandwidths, though based on an engineering assessment, may be somewhat subjective and may realistically be pertinent only to the particular network from which they were derived.

The BHI philosophy provides a more direct, objective method of evaluating bridge condition. Its relative bridge condition levels are established using more general, less subjective terms.

A Proposed Method for Bridge Condition Assessment

A modified version of the RTA NSW method for assessing bridge condition from element condition states is proposed for possible use by road agencies. Four bridge condition states have been defined to complement the four element condition states favoured by the guideline. The relationship for determining bridge condition from element condition states is shown in Table A1.

Proposed values of percentage limits for each bridge condition should be tested against a known dataset to confirm that the resulting bridge condition ratings reflect what would be an acceptable engineering assessment of those bridge assets.

The method has not been adopted in the guideline in preference to other methods available. It remains for individual asset owners to decide how best to interpret bridge condition to suit their objectives.

Bridge Condition	Element Importance		
	High	Medium	Low
Poor	% in Condition State 4 > 0, or % in Condition State 3 > 25	% in Condition State 4 > 20, or % in Condition State 3 > 40	% in Condition State 4 > 40, or % in Condition State 3 > 60
Fair	% in Condition State 3 ≤ 25	% in Condition State 4 ≤ 20, or % in Condition State 3 ≤ 40	% in Condition State 4 ≤ 40, or % in Condition State 3 ≤ 60
Good	0% in Condition States 3 or 4		
As-built	100% in Condition State 1		

Table A1 – Proposed Bridge Condition descriptor based on Element Condition States

References:

- A1 “Bridge and Culvert Condition Numbers”. (no date). (handout). (Available from VicRoads, Melbourne).
- A2 “Bridge Health Index”. (no date). (handout). (Available from RTA NSW, Sydney).