Selection of Ideal Maintenance Strategies in a Network-Level Bridge Management System

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A modular bridge management system (BMS) is being developed to select ideal scopes of maintenance work on the basis of the condition states of bridge segments. The maintenance and repair (M&R) scopes and condition modules, which are two of seven modules that make up the BMS are the major focus of this paper. A companion paper in this Record completes the overview of this network-level BMS. The condition module uses surveyed condition ratings to develop composite condition indexes (CCI) that characterize the condition of each structural element within a segment. The CCI values are further refined to derive condition states, which characterize the overall condition of each segment on the basis of the condition levels of its constituent elements (deck, substructure, and superstructure). When the condition state of a bridge segment is known, engineering judgment can be used to select ideal maintenance activities from the M&R scopes module. The M&R scopes describe the intensity level—routine maintenance, repairs, rehabilitation, or replacement—of various M&R actions, each with a defined effect on condition level. When the condition state and the M&R scope effects are provided, the condition state resulting from a certain scope of work can be determined, and the feasible M&R scopes can be ranked from the ideal (most recommended) to the least recommended course of action.

Many bridges are in urgent need of repair, rehabilitation, or replacement. Sudden catastrophic failures caused by unpredictable events (e.g., flooding) cannot be accurately predicted, and their prevention is difficult. However, bridges exhibiting normal, progressive structural damage can be maintained, repaired, rehabilitated, or replaced under an effective bridge management system (BMS), similar in concept to the widely used pavement management systems.

A modular network-level BMS is under development. The structure of this Markovian-based BMS is shown in Figure 1. The system uses surveyed condition ratings in the condition module and levels of maintenance strategies in the maintenance and repair (M&R) scopes module to define core condition states for each segment of a bridge. Ideal M&R scopes can then be selected to restore the segment to good condition. The prediction and optimization modules are described by Harper et al. in a companion paper in this Record.

This BMS is part of an overall highway maintenance management system, which integrates a pavement management system, a nonpavement management system, and a bridges and structures management system (B&SMS). The B&SMS includes optimization of bridges, tunnels, and culverts. The BMS described here is the bridge portion of the B&SMS.

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BMS METHODOLOGY

Various bridge systems (*1–8*) were reviewed. None of these systems completely satisfied the objectives for this BMS, which are as follows:

- Objective 1. To maximize information collection that could be used in a network-level BMS,
- Objective 2. To make provisions for the stochastic nature of bridge degradation,
- Objective 3. To provide a systematic mechanism for updating degradation models,
- Objective 4. To perform a multiyear optimization,
- Objective 5. To link the project-level plan (detailed individual bridge plan) to the guidance from a network-level optimization, and
- Objective 6. To provide feedback mechanisms that allow system performance and implementation to be reviewed.

Bridges are constructed of one or more spans that vary in length and width from bridge to bridge and can exhibit considerable variations in condition from span to span. To meet Objective 1, bridges are rated and modeled in segments (a superstructure span with an abutment or pier). The many components of a bridge are individually rated on a span-by-span basis and modeled as three structural elements (deck, superstructure, and substructure) at the network level. Functional deficiencies such as inadequate load capacity and insufficient deck width may also be included.

This approach maximizes the capture of data that accurately reflect structural conditions for which realistic, timely, and cost-effective corrective actions can be taken. Models that use some type of cumulative index to rate either the entire bridge or its structural elements (e.g., a bridge deck rating over the entire structure) can have misleading results, both in evaluating and predicting structural conditions and in determining the cost of the requisite maintenance. This BMS is not dependent on having network data on spans, but the system is designed to accommodate such data. If information is available only for the entire structure, which is common in the United States, the BMS will not have the same discrimination ability on the network level.

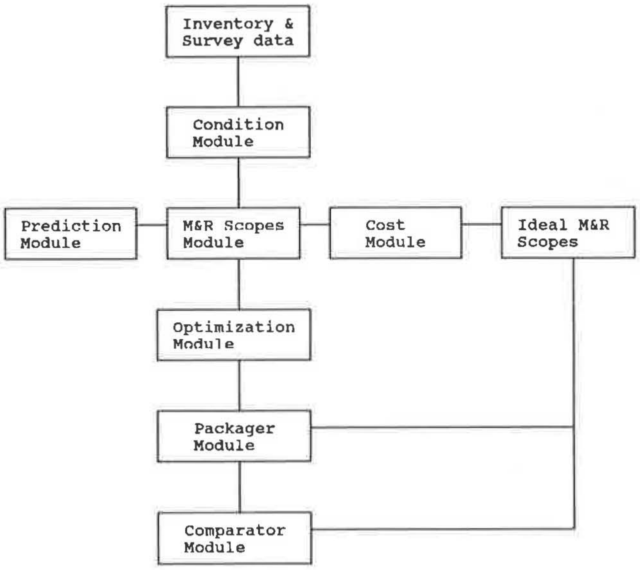

FIGURE 1 Structure of a modular bridge management system.

The prediction module that addresses Objectives 2 and 3 and the network-level optimization models that pertain to Objective 4 are described in the companion paper in this Record. A packager module provides the link between overall network-level guidance and the detailed project-level needs of the individual bridge (Objective 5). A comparator module provides the quality-control feedback to highlight areas of concern in either the system's predictions or its implementation (Objective 6).

CONDITION MODULE

Condition modeling begins with the surveyed condition ratings (SCRs) assigned to the various bridge features. The following scale is being used by the Kingdom of Saudi Arabia; however, any similar scale, such as the 0–9 scale used by FHWA, can be accommodated.

Rating	*Definition*
7	Like new
6	Good condition
5	Insignificant deterioration
4	Structurally adequate
3	Not functioning as designed
2	Structurally inadequate
1	Potentially hazardous
0	Beyond repair

The SCR values of the components of the deck, superstructure, and substructure are used to derive composite condition indexes (CCIs) for each structural element. The CCIs are then translated into condition levels. The various configurations of condition levels are used to construct the core condition states, for which feasible M&R scopes can be identified and selected from the M&R scopes module using some combination of engineering judgment and the BMS optimization module.

Equations such as the following convert the SCR values to CCIs. User-defined thresholds can be incorporated in order to modify the CCI or assign it the value of the lowest SCR. Different equations are used for certain bridge types.

For bridges with the deck separate from the superstructure, the deck index is calculated as

$$\mathrm{DI} = 0.10A + 0.90B \quad (1)$$

where

DI = numerical CCI of deck,
A = numerical SCR of deck surface, and
B = numerical SCR of deck structure.

For bridges with separate decks and superstructures, the superstructure index is calculated as

$$\mathrm{SPI} = 0.75C + 0.15D + 0.10E \quad (2)$$

where

SPI = numerical CCI of superstructure,
C = numerical SCR of primary members,
D = numerical SCR of secondary members, and
E = numerical SCR of bearing devices.

If the deck is part of the superstructure, the superstructure index incorporates the SCR value (A) of the deck surface:

$$\mathrm{SPI} = 0.10A + 0.70C + 0.10D + 0.10E \quad (3)$$

If the substructure consists of a pier, the substructure index is calculated as

$$\mathrm{SBI} = 0.10F + 0.30G + 0.30H + 0.30I \quad (4)$$

where

SBI = numerical CCI of substructure,
F = numerical SCR of pedestals,
G = numerical SCR of capbeam,
H = numerical SCR of column (stem), and
I = numerical SCR of footings.

If the substructure consists of an abutment, the substructure index is calculated as

$$\mathrm{SBI} = 0.10F + 0.30I + 0.10J + 0.20K + 0.30L \quad (5)$$

where

J = numerical SCR of backwall,
K = numerical SCR of wingwall, and
L = numerical SCR of breastwall.

The various combinations of CCI ratings for the structural elements making up each segment are used to define core condition states that represent the overall condition of that segment. To reduce the number of condition states to a workable number, the numerical CCI values are translated into one of four condition levels (good, fair, poor, and critical) for each of the three elements, according to the following scheme:

Range of CCI Values	*Condition Level*
6 to 7.00	Good
4 to 5.99	Fair
2 to 3.99	Poor
0 to 1.99	Critical

Core condition states are defined as possible combinations of condition levels for the elements that make up the structural segment. There are 64 (4^3) possible core condition states. To these three core condition state parameters (deck, superstructure, and substructure) are added additional parameters reflecting the needs of the organization implementing the BMS. Typical examples include element-age parameters (e.g., superstructure age) or various functional deficiency parameters (e.g., insufficient deck width). The selection of these parameters depends on the proposed use of the system. In Saudi Arabia, most bridges are new and functional deficiencies are rare. Element age was added to their system to enhance the prediction models. In the United States, where it is important to address functional deficiencies, the government agency would be more apt to include several parameters to capture the possible functional deficiencies, including inadequate load capacity and insufficient vertical clearance.

The following example demonstrates the procedures for deriving CCIs, condition level descriptors, and core condition states for Span 2 of a hypothetical bridge using a rating form such as that shown in Figure 2. From this figure, the SCR values for Span 2 are as follows:

Elements of Span 2	*SCR Values*
Deck surface, A	7
Deck structure, B	6
Superstructure primary members, C	7
Superstructure secondary members, D	7
Superstructure bearings, E	6
Substructure pedestal, F	7
Substructure cap beam, G	7
Substructure column stem, H	5
Substructure footing, I	U (Unknown)

The CCIs for this segment are calculated as follows:

Deck:

$$\begin{aligned} \text{DI} &= 0.10A + 0.90B \\ &= 0.10(7) + 0.90(6) \\ &= 0.70 + 5.4 \\ &= 6.10 \end{aligned} \tag{1}$$

Superstructure:

$$\begin{aligned} \text{SPI} &= 0.75C + 0.15D + 0.10E \\ &= 0.75(7) + 0.15(7) + 0.10(6) \\ &= 5.25 + 1.05 + 0.60 \\ &= 6.90 \end{aligned} \tag{2}$$

Substructure:
Because the footing is unknown, a change must be made in Equation 4.

$$\begin{aligned} \text{SBI} &= 0.10F + 0.30G + 0.60H \\ &= 0.10(7) + 0.30(7) + 0.60(5) \\ &= 0.70 + 2.10 + 3.00 \\ &= 5.80 \end{aligned} \tag{4}$$

The CCI values are translated to condition levels through the conversion table.

DI (deck) = 6.25 (good)

SPI (superstructure) = 6.90 (good)

SBI (substructure) = 5.80 (fair)

Condition State 17 from Table 1 describes this segment.

M&R SCOPES MODULE

The M&R scopes module contains 40 possible types of work for repairing, rehabilitating or replacing the structural elements of bridge segments. These are broad scopes of work, rather than specific M&R tasks. The M&R scopes are selected on the basis of their relationship to existing structural conditions and their implicitly defined effect on the improvement of these conditions. The following rationale is used to construct these M&R scopes.

Bridge maintenance strategies can be categorized by four generic descriptors: routine maintenance, repairs, rehabilitation, and replacement. These categories can be broadly defined as follows.

- Routine maintenance consists of tasks such as cleaning and lubricating bearings. The BMS assumes that all elements receive routine maintenance as well as any other maintenance that may be selected.
- Repairs are those activities that do not require relieving dead loads, which can be performed while maintaining traffic flow.
- Rehabilitation represents more advanced repairs requiring special efforts. Closure of the bridge to traffic may be required.
- Replacement is defined as a complete replacement of one or more major elements.

The repair, rehabilitation, and replacement scopes are coupled with each structural element, yielding the composite M&R scopes in the following list. The impact of each scope may be determined from Table 2.

- Routine maintenance,
- Deck repairs,
- Deck rehabilitation,
- Deck replacement,
- Superstructure repairs,
- Superstructure rehabilitation,
- Superstructure replacement,
- Substructure repairs,
- Substructure rehabilitation, and
- Substructure replacement (which is equivalent to segment replacement in most cases).

TABLE 1 RANKING OF FEASIBLE COMPOSITE M&R SCOPES FOR SEGMENTS OF BRIDGES WITH SEPARATE DECKS

CORE COND. STATE NO.	COND. LEVELS SUB.	SUP.	DECK	FEASIBLE COMPOSITE M&R SCOPES RANK	DESCRIPTION	SCOPE NO.	RESULTING CORE COND. STATE NO.	RESULTING COND. LEVELS SUB.	SUP.	DECK
1	G	G	G	1	Routine Maintenance	1	1 or worse	G	G	G
2	G	G	F	1	Deck Repairs	2	1	G	G	G
				2	Routine Maintenance	1	2 or worse	G	G	F
3	G	G	P	1	Deck Rehabilitation	3	1	G	G	G
				2	Deck Replacement	4	1	G	G	G
				3	Deck Repairs	2	2	G	G	F
				4	Routine Maintenance	1	3 or worse	G	G	P
4	G	G	C	1	Deck Replacement	4	1	G	G	G
				2	Deck Rehabilitation	3	2	G	G	F
				3	Routine Maintenance	1	4 or worse	G	G	C
5	G	F	G	1	Superstructure Repairs	5	1	G	G	G
				2	Routine Maintenance	1	5 or worse	G	F	G
6	G	F	F	1	Superstructure & Deck Repairs	6	1	G	G	G
				2	Deck Repairs	2	5	G	F	G
				3	Superstructure Repairs	5	2	G	G	F
				4	Routine Maintenance	1	6 or worse	G	F	F
7	G	F	P	1	Superstructure Repairs & Deck Rehabilitation	7	1	G	G	G
				2	Superstructure Repairs & Deck Replacement	8	1	G	G	G
				3	Deck Rehabilitation	3	5	G	F	G
				4	Deck Replacement	4	5	G	F	G
				5	Superstructure & Deck Repairs	6	2	G	G	F
				6	Deck Repairs	2	6	G	F	F
				7	Superstructure Repairs	5	3	G	G	P
				8	Routine Maintenance	1	7 or worse	G	F	P
8	G	F	C	1	Superstructure Repairs & Deck Replacement	8	1	G	G	G
				2	Deck Replacement	4	5	G	F	G
				3	Superstructure Repairs & Deck Rehabilitation	7	2	G	G	F
				4	Deck Rehabilitation	3	6	G	F	F
				5	Routine Maintenance	1	8 or worse	G	F	C
9	G	P	G	1	Superstructure Rehabilitation	9	1	G	G	G
				2	Superstructure Replacement	13	1	G	G	G
				3	Superstructure Repairs	5	5	G	F	G
				4	Routine Maintenance	1	9 or worse	G	P	G
10	G	P	F	1	Superstructure Rehabilitation & Deck Repairs	10	1	G	G	G
				2	Superstructure Replacement	13	1	G	G	G
				3	Superstructure Rehabilitation	9	2	G	G	F
				4	Superstructure & Deck Repairs	6	5	G	F	G
				5	Superstructure Repairs	5	6	G	F	F
				6	Deck Repairs	2	9	G	P	G
				7	Routine Maintenance	1	10 or worse	G	P	F
11	G	P	P	1	Superstructure & Deck Rehabilitation	11	1	G	G	G
				2	Superstructure Rehabilitation & Deck Replacement	12	1	G	G	G
				3	Superstructure Replacement	13	1	G	G	G
				4	Superstructure Repairs & Deck Rehabilitation	7	5	G	F	G
				5	Superstructure Repairs & Deck Replacement	8	5	G	F	G
				6	Superstructure Rehabilitation & Deck Repairs	10	2	G	G	F
				7	Superstructure & Deck Repairs	6	6	G	F	F
				8	Deck Rehabilitation	3	5	G	P	G
				9	Deck Replacement	4	5	G	P	G
				10	Deck Repairs	2	10	G	P	F
				11	Superstructure Rehabilitation	9	3	G	G	P
				12	Superstructure Repairs	5	7	G	F	P
				13	Routine Maintenance	1	11 or worse	G	P	P

TABLE 1 (*continued*)

CORE COND. STATE NO.	COND. LEVELS SUB.	SUP.	DECK	RANK	FEASIBLE COMPOSITE M&R SCOPES DESCRIPTION	SCOPE NO.	RESULTING CORE COND. STATE NO.	RESULTING COND. LEVELS SUB.	SUP.	DECK
12	G	P	C	1	Superstructure Rehabilitation & Deck Replacement	12	1	G	G	G
				2	Superstructure Replacement	13	1	G	G	G
				3	Superstructure Repairs & Deck Replacement	8	5	G	F	G
				4	Deck Replacement	4	9	G	P	G
				5	Superstructure & Deck Rehabilitation	11	2	G	G	F
				6	Superstructure Repairs & Deck Rehabilitation	7	6	G	F	F
				7	Deck Rehabilitation	3	10	G	P	F
				8	Routine Maintenance	1	12 or worse	G	P	C
13	G	C	G	1	Superstructure Replacement	13	1	G	G	G
				2	Superstructure Rehabilitation	9	5	G	F	G
				3	Routine Maintenance	1	13 or worse	G	C	G
14	G	C	F	1	Superstructure Replacement	13	1	G	G	G
				2	Superstructure Rehabilitation & Deck Repairs	10	5	G	F	G
				3	Superstructure Rehabilitation	9	6	G	F	F
				4	Routine Maintenance	1	14 or worse	G	C	F
15	G	C	P	1	Superstructure Replacement	13	1	G	G	G
				2	Superstructure & Deck Rehabilitation	11	5	G	F	G
				3	Superstructure Rehabilitation & Deck Replacement	12	5	G	F	G
				4	Superstructure Rehabilitation & Deck Repairs	10	6	G	F	F
				5	Superstructure Rehabilitation	9	7	G	F	P
				6	Routine Maintenance	1	15 or worse	G	C	P
16	G	C	C	1	Superstructure Replacement	13	1	G	G	G
				2	Superstructure Rehabilitation & Deck Replacement	12	5	G	F	G
				3	Superstructure & Deck Rehabilitation	11	6	G	F	F
				4	Routine Maintenance	1	16 or worse	G	C	C
17	F	G	G	1	Substructure Repairs	14	1	G	G	G
				2	Routine Maintenance	1	17 or worse	F	G	G
18	F	G	F	1	Substructure & Deck Repairs	15	1	G	G	G
				2	Deck Repairs	2	17	F	G	G
				3	Substructure Repairs	14	2	G	G	F
				4	Routine Maintenance	1	18 or worse	F	G	F

Abbreviations:
Sup. = Superstructure
Sub. = Substructure
G = Good
F = Fair
P = Poor
C = Critical

TABLE 2 COMPOSITE M&R SCOPE DESCRIPTIONS AND IMPACTS ON CONDITION LEVEL

NO.	DESCRIPTION	IMPACT ON CONDITION LEVEL
1	Routine Maintenance	No improvement; condition may worsen
2	Deck Repairs	Improve Deck by one level: From Fair to Good, OR From Poor to Fair
3	Deck Rehabilitation	Improve deck by two levels: From Poor to Good, OR From Critical to Fair
4	Deck Replacement	Restores any deck to Good condition
5	Superstructure Repairs	Improves superstructure by one level: From Fair to Good, OR From Poor to Fair
6	Superstructure Rehabilitation	Improves superstructure by two levels: From Poor to Good, OR From Critical to Fair
7	Superstructure Replacement	Restores Critical superstructure to Good condition and replaces the deck at the same time.
8	Substructure Repairs	Improves substructure by one level: From Fair to Good, OR From Poor to Fair
9	Substructure Rehabilitation	Improves substructure by two levels: From Poor to Good, OR From Critical to Fair
10	Substructure Replacement (Segment Replacement)	Restores entire segment to Good condition since this scope constitutes replacement of all elements.

The various combinations of these scopes (e.g., deck repair plus superstructure rehabilitation) constitute the basis of the 40 possible M&R scopes that could be applied to a bridge segment. These scopes are input to the optimizer module and may be assigned to any segment to which they might feasibly apply. In the packaging module, the detailed actions under each scope are determined.

SELECTING IDEAL M&R SCOPES FOR CORE CONDITION STATES

The selection of an ideal M&R scope for each set of structural segment conditions is an integrative process linking the methodologies used to define core condition states for the segments and the feasible M&R scopes for the structural elements. The derived results can be readily modified to incorporate different additional condition state parameters such as those involving functional deficiencies. These two sets of information are now integrated to accomplish the following:

1. Derive a list of feasible scopes that could be applied for each core condition state;
2. Rank the feasible scopes for each condition state in preferential order, from the most recommended to the least recommended; and
3. Select the ideal M&R scope from the list of ranked feasible scopes.

The ideal M&R scope is defined as the scope that will restore a segment to Core Condition State 1 (all elements in good condition) for the lowest relative implementation cost. This definition is liberal; in practice, other considerations come into play (e.g., traffic loading and detour options, budget constraints, scheduling, user priorities, and agency policies). Some of these other considerations, however, may be incorporated into the selection process.

The information necessary to complete these tasks has been incorporated into the development of core condition states and feasible M&R scopes. The condition levels of each constituent element for that segment define the core condition

BRIDGE NO._______________ INSPECTION DATE:___________________

INSPECTED BY: ___________________

LOCATION:____

CONDITION RATINGS	SPAN NUMBERS 1	2	3	4	5	6	7	8	9	10
DECK										
Surface	5	7	7	6	7	6	5	7	6	7
Structure	4	6	6	5	6	6	6	7	7	6
SUPERSTRUCTURE										
Primary members	6	7	7	5	5	6	6	7	7	5
Secondary members	6	7	7	6	6	6	6	3	7	6
Bearings	6	6	7	7	7	6	5	7	6	6
SUBSTRUCTURE										
ABUTMENTS										
Pedestals	5									
Backwall	6									
Breastwall	6									
Wingwall	7									
Footing	U									
PIERS										
Pedestals	6	7	6	7	5	5	7	7	6	6
Cap beam	5	7	7	6	7	7	6	7	7	6
Stem/Column	5	5	5	4	3	7	6	5	4	7
Footing										

RECOMMENDED FURTHER ACTION:

EVALUATE FOR MAINTENANCE REPAIRS: YES

EVALUATE FOR REHABILITATION/REPLACEMENT? YES

CURB: 6 inches UNDERCLEARANCE: 12 feet POSTED LOAD CAPACITY 20 tons

REMARKS:
1. Serious deterioration pier breastwall, span no. 5
2. Concrete girder shows serious cracks, span no. 8
3. Drainage system has failed in span no. 9

FIGURE 2 Sample bridge inspection and condition report.

states. In defining the composite M&R scopes, the effect of each scope on structural element conditions is defined. The feasible M&R scopes are the scopes that represent realistic alternatives for a given core condition state.

When the condition levels that define the condition state are known and the effect of each M&R scope on each condition level is determined, the effect of each feasible scope can be defined in terms of the condition state that could result if the scope were implemented. The extent to which a feasible M&R scope would improve a condition state can now be used as one of two criteria for comparing the scopes and selecting the ideal. The second criterion is the implementation costs of feasible M&R scopes, when two or more scopes would restore the segment to Core Condition State 1.

Two other criteria were used as part of the engineering assessment applied to rank the scopes that did not restore the segment to Core Condition State 1. These criteria evaluated which elements would contribute most to further degradation of the structure and would have the greatest effect on user inconvenience and safety.

If all elements cannot be restored to good condition by the selected M&R scope because of budget constraints or other priorities), the most important element to remedy is the one with the lowest condition level rating. User-defined priorities can be set to determine which element receives attention first.

The following precedence rules were employed in the ranking scheme. If two or more elements are in the same condition (less than good), the deck element will take precedence over the others. If the deck is not one of those elements, the substructure is more important, followed by the superstructure. Using these precedence rules, if the substructure, superstructure, and deck are in poor condition, deck improvement takes precedence over the substructure improvement. Improving the substructure, in turn, takes precedence over the superstructure. The scope ranked first would remedy all three elements and is the ideal; the succeeding scopes to remedy these conditions would be ranked according to these precedents.

Some M&R scopes are not feasible for certain condition states and would not be selected. Scopes are considered infeasible (or inappropriate) when the condition levels do not warrant remediation, the cost-benefit considerations do not justify a particular scope, or the structural conditions are so severe that a low-level scope (e.g., repairs) would achieve little benefit.

For example, if a structural segment is in Core Condition State 1, all its elements are in good condition and require no maintenance. If a deck, superstructure, or substructure is rated as critical, repair activities would at most improve the element to poor condition; in these instances, rehabilitation (at a minimum) would logically be selected. The process for selecting an ideal M&R scope for a particular condition state is demonstrated in the following example.

Consider a bridge segment that has been assigned Core Condition State (Table 1). The condition levels of this condition state are good for the deck and substructure, poor for the superstructure. Only those feasible M&R scopes that would affect the superstructure need to be considered. The substructure and deck are in good condition and do not require any remedial work. The following feasible scopes for Core Condition State 9 would be drawn from Table 1.

1. Routine maintenance (M&R Scope 1). If this scope were selected, the segment would receive only routine maintenance. The condition state would remain at 9 (or worse if the segment deteriorates over time).
2. Superstructure repairs (M&R Scope 5). This scope could improve the superstructure by one level. If implemented, the resulting condition levels would be good for the deck and substructure and fair for the superstructure. This scope could restore the segment to Core Condition State 5.
3. Superstructure rehabilitation (M&R Scope 9). This scope would improve the superstructure condition by two levels. If implemented, the resulting condition levels would be good for all three elements. This scope could restore the segment to Core Condition State 1.
4. Superstructure replacement (M&R Scope 13). This scope would improve the superstructure condition by two levels. If implemented, the resulting condition levels would be good for all three elements. This scope could restore the segment to Core Condition State 1; however, it would (on the average) cost more to implement than rehabilitation.

On the basis of the precedence rules and the new condition states that might result if each of the M&R scopes were implemented, these scopes can be ranked from the most recommended to the least recommended as follows:

Original Condition State No.	*Feasible Scope No.*	*Improved Core Condition State No.*
9	9	1
9	13	1
9	5	5
9	1	9 (or worse)

If the segment actually deteriorates further in time, the core condition state number could become greater than 9.

All of the information obtained in the ranking process for Core Condition States 1 through 18 is presented in Table 1. The M&R scope listed first is the ideal scope; the remaining scopes are ranked using the decision process outlined previously.

USE OF IDEAL M&R SCOPES IN THE BMS

The procedures to derive ideal M&R scopes constitute the engineering-based selection of maintenance activities. The previously presented scopes are ideal when the budget is unrestricted. However, few agencies operate under such a scenario. The ideal M&R scopes can still be used by the BMS in several ways.

- The ideal engineering-based scopes can constitute alternative policy considerations to be accessed by the optimization, packaging, and comparator modules.
- The engineering-based solution can be compared with the solutions of the optimization module. If the optimized solutions and the engineering-based solutions are very different, which can result from insufficient budget or other modeling considerations, the optimized solutions can be reassessed.
- The ideal M&R scopes can be used in the comparator module for quality control and to cross check the optimized solutions and their performances.

Once the ideal engineering-based solutions have been selected, the M&R tasks necessary to implement them need to be specified. In the BMS, this is handled by the packaging module, using a variety of data not used by the optimization module, including data obtained during the condition surveys that evaluate the type and cause of damage, and recommend specific maintenance tasks.

SUMMARY

This BMS is being developed to address the six goals listed earlier. Formulas are used to transform the component survey ratings into element CCIs on a segment-by-segment basis to provide a more informative base for the network optimization models. The M&R scope module selects the feasible scopes for each core condition state. These feasible scopes are ranked, and the ideal scope is chosen on the basis of specific criteria. The network optimization models may select from any of the feasible M&R scopes (not just the ideal) for a given condition state.

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