Bridge Management Systems

Advancing the Science

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It might be considered an evolution in thinking—or possibly a revolution in thinking. Whatever the terms used to describe it, bridge management is changing. The visible signs of change are most noticeable in the day-to-day activities of state highway agencies. States are revising bridge inspection practices, revamping computer facilities, reorganizing bridge units, and often adding a position with the title BMS Engineer—a specialist in bridge management systems (BMS)—to their ranks. What is not visible, but is important, is the changing philosophy of bridge management. For more than a decade, the states and the Federal Highway Administration (FHWA) have been in search of better tools for bridge management. Tired of the old, reactive, "squeaky wheel" style of management, in which problems are simply patched up as they surface, bridge managers have sought to develop new analytical tools—tools that provide better insight on how to head off problems before they occur and determine the most cost-effective uses for available funds. Until recently, the appropriate tools have not been available. Now, however, new, sophisticated tools are becoming available to aid in bridge program decision making. These technical advancements in BMS, coupled with new federal mandates for states to implement BMS, have set the stage for the revolution that is now taking place in bridge management.

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The shift to "management systems" thinking was nowhere more apparent than at the Transportation Research Board (TRB) 7th Conference on Bridge Management in Austin, Texas, in November 1993. The 2-1/2-day conference, cosponsored by TRB, the Texas Department of Transportation, and FHWA, provided an opportunity for federal, state, and local bridge management officials to exchange information on the management systems approach to bridge management. The conference was a valuable resource for the participants—bridge maintenance and management professionals who must address the multitude of issues involved in the implementation of a state or local BMS. Although many different opinions were expressed, the consensus of the bridge managers and engineers was that BMS are the way of the future and continued exchange of ideas is vital.

One might expect that such a major change in management philosophy and practices would be met with strong resistance, but this generally has not been the case with BMS. Convinced of the value of BMS, state officials have taken a proactive role in initiating studies at both the national and state levels. Early state efforts contributed immensely to the development of new methods and tools for BMS. According to Jimmy Lee, State Bridge Maintenance Engineer for North Carolina, the BMS provides a more rational approach to bridge management with high credibility. "It improves the decision-making process tremendously," he said in a telephone conversation with the author. He described how decisions have traditionally been a result of input and recommendations from field personnel. Although this input is valuable for improving the structural condition of an individual bridge, level-of-service conditions and network considerations have not been taken into account. The North Carolina BMS is now in operation, and the volume, nature, and condition of the inventory are assimilated statewide to provide input for optimization techniques that will provide meaningful feedback for highway engineers.

Guidelines for BMS

The proactive posture of the states toward BMS is reflected in the work of the National Cooperative Highway Research Program (NCHRP), which is sponsored by the American Association of State Highway and Transportation Officials (AASHTO). The *AASHTO Guidelines for Bridge Management Systems*, published in 1993, were developed under an NCHRP project. These guidelines present an overview of principles and concepts of bridge management, including recommended minimum requirements. They are especially helpful in detailing the important steps that should be followed for proper implementation of a BMS as a decision support tool in transportation agencies and describing alternatives to be considered in the establishment of a BMS. The roles of the data collection, data processing, optimization techniques, and various other models that support optimization are also described. In addition to explaining the various approaches to analysis, the guidelines also explain how the analysis fits into the overall process of decision making. As Figure 1 suggests, a BMS is not simply an analytical tool that works independently.

Federal Requirements for BMS

Federal recognition of the value and importance of management systems to guide decisions on infrastructure investments is reflected in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Under ISTEA, the responsible federal agencies were directed to issue regulations requiring states to develop, establish, and implement six management systems and a traffic monitoring system. The management systems are for pavements, bridges, safety, congestion, intermodal facilities, and public transit. In the case of bridges, ISTEA requires the management systems to include bridges on and off Federal-aid highways.

In developing its regulations, FHWA obtained input from the states and others through two rulemaking notices that provided opportunity for comment. Among the issues addressed were the role of state and local governments in BMS and how the data collection requirements for BMS should be integrated with data collection requirements under the current National Bridge Inspection Program.

The federal regulations on management systems were published in the *Federal Register* December 1, 1993, in the form of an Interim Final Rule. The BMS regulation calls for a state-maintained centralized data base and network analysis procedures capable of analyzing data for all bridges in the inventory or in any subset, including the inventories within a metropolitan planning organization jurisdiction or a local jurisdiction. The regulation describes the required components of a BMS as (a) a data base and an ongoing program for the collection and maintenance of the inventory, cost, and supplemental data needed to support the BMS, and (b) a rational and systematic procedure for applying network level analysis and optimization to the bridge inventory. The regulations go on to specify the capabilities that need to be incorporated in the network analysis procedure. They include the ability to

- Predict the deterioration of bridge elements with and without intervening actions;
- Identify feasible actions to improve bridge conditions, safety, and serviceability;
- Estimate the cost of actions;
- Estimate expected user cost savings for safety and serviceability improvements;
- Determine least-cost maintenance, repair, and rehabilitation strategies for bridge elements using life-cycle cost analysis or a comparable procedure; and
- Perform multiperiod optimization. [Multiperiod optimization, as defined in the regulation, means a procedure that optimally allocates limited funds among alternative actions over a planning horizon (both short and long term) using an optimization procedure such as minimizing life-cycle and user costs.]

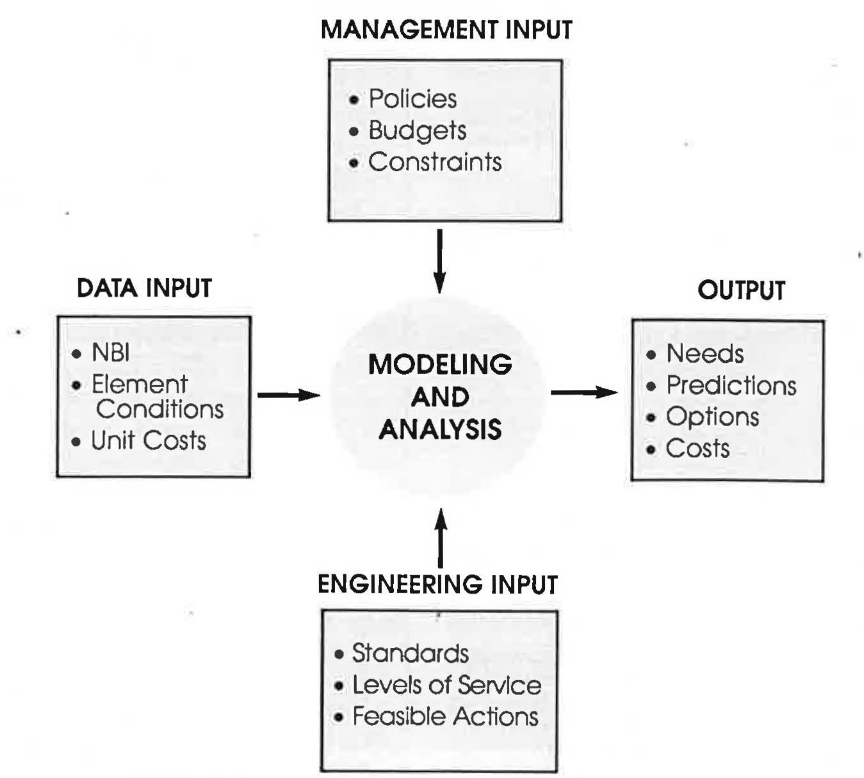

FIGURE 1 BMS Prototype.

The regulation does not require cities and counties or other local bridge owners to implement a BMS that is separate from the state BMS. They may, however, supplement the state's BMS with one of their own. The deadline for states to implement BMS is October 1, 1998. With the recent advancements in management system tools, this deadline should provide the states sufficient time to implement a system. However, the time period allowed is not excessive considering the range and magnitude of the tasks that states must accomplish before implementation. For

States will require bridge condition information for BMS that is more detailed than that required for National Bridge Inspection Program.

example, most states will need to revise their inspection programs to collect element level data. This schedule also allows time for the states to restructure inspection programs, inventory bridge elements, train inspectors, and complete two full cycles of inspections on at least half of the bridge inventory. Although it is not absolutely essential, data from two full cycles of inspections for a large sample of bridges are desirable for the estimation of deterioration models. A number of states are well ahead of this schedule.

Tools for BMS

Although some states will elect to develop their own BMS tools, the majority, it appears, will adopt an off-the-shelf software package. The choices appear to be AASHTO's Pontis or NCHRP's BRIDGIT.

Pontis, funded under an FHWA Demonstration Project, was developed jointly by FHWA, six participating states, and two private consultants. Under an agreement with FHWA, the California Department of Transportation administered a contract and managed the initial project, which produced Version 1.0 in December 1991. Following an extensive beta test phase involving 13 states, FHWA produced version 2.0, an updated public domain version of the software, in March 1994. Version 2.0 was subsequently turned over to AASHTO for incorporation into the AASHTO Library of Cooperative Computer Software Products as AASHTOWare. During 1993, AASHTO solicited participation from its member departments for a project to provide ongoing support and enhancements to Pontis, and in March 1994, it began a 12-month project to enhance Pontis. The project includes a list of enhancements aimed at improving the ease of operation and versatility of the software. Among the planned enhancements are conversion to Microsoft Windows (extendable to Microsoft Windows NT) and use of the Open Database Connectivity standard to provide access to several relational data base managers, such as Foxpro, Access, Paradox, Oracle, and Sybase. A total of 40 states contributed funds to the project, the largest response to an AASHTOWare project to date.

BRIDGIT was developed through NCHRP by a private consulting firm. Its optimization routines are patterned after North Carolina's BMS. A project panel of representatives of state and federal governments and others provided oversight; four highway agencies assisted in the development and initial testing of the system. Developed through the use of Microsoft Foxpro, the software provides a flexible data base and many user-friendly data entry and reporting features. A beta version of the software is currently being tested.

An obvious advantage of using these off-the-shelf systems is an initial major savings in development costs. With such systems, the opportunity exists for cooperative pooled fund projects, such as the AASHTOWare project for Pontis. Such pooled fund projects can reduce a state's costs for software upgrades to a fraction of the cost of a state-sponsored project. An additional benefit is the ability to share data more readily with other states and draw from their experiences.

Data Needs

The most time-consuming and costly task for most states probably will be setting up data collection systems to support BMS, even though all states currently have an established data base and an ongoing bridge inspection program. Although most of the data now being collected will be useful for BMS, states will, in most cases, require more detailed information on the condition of bridge elements. The major reason is that under National Bridge Inventory (NBI) reporting, one rating value from 0 to 9 is assigned for each major component of the bridge: deck, superstructure, and substructure. (In the case of culverts, a single rating for the entire structure is all that is reported.) Although the ratings provide a general idea of the overall condition, they provide no details on the type of deficiencies that may be present or their extent. Quite simply, a low rating does not begin to describe what is actually wrong with the bridge; it only identifies that a problem exists.

A major departure from the NBI condition rating scheme came about in the development of Pontis. To provide additional details in reporting on condition, the major components of the bridge were categorized into more easily described "elements." A range of possible condition states was defined for each element. An element is a basic functional unit of the bridge, such as a girder, bearing pad, column, pier cap, deck, or joint. More detail is derived by separating these elements by material. Each element has a set of three to five condition states that are described using engineering language applicable to that particular element. For example, the following are the condition states for the painted steel open girder element.

1. There is no evidence of active corrosion and the paint system is sound and functioning as intended to protect the metal surface.
2. There is little or no corrosion. The paint system may be chalking, peeling, curling, or showing other evidence of paint system distress, but there is no exposure of metal.
3. Surface or freckled rust has formed or is forming. The paint system is no longer effective. There may be exposed metal, but there is no active corrosion causing section loss.
4. The paint system has failed. Surface pitting may be present, but any section loss due to active corrosion does not yet warrant structural analysis of either the element or the bridge.
5. Corrosion has caused section loss and is sufficient to warrant structural analysis to ascertain the impact on the ultimate strength or serviceability of either the element or the bridge.

States that have already begun using element level inspections report no significant increase in the time required to perform an inspection. The inspector observes the same basic information as in the normal NBI inspections. The difference is in the method of reporting.

To inspect under an element inspection scheme, all of the elements in each bridge have to be inventoried and measured. A typical bridge will have 6 to 10 elements, although some of the more complicated bridges will contain a larger number of elements. In recording the condition, the inspector reports the percentage or quantity of the element in each condition state.

One major concern about element level inspection is that it duplicates condition rating data collected for NBI. In an effort to eliminate this duplication, FHWA is developing a process for converting element level inspection data to NBI condition ratings. The process is based on a common set of element descriptions known as commonly recognized (CoRe) elements. States can still derive NBI ratings in the traditional way if desired.

Challenges

In addition to changes in inspection reporting methods, bridge inspectors will soon be required to use metric units in reporting the data. Consequently, a metric NBI coding guide is being reviewed by state and federal transportation agencies and is expected to be in use during the next year. Pontis will also become metric compatible through its enhancement as a new AASHTOWare product. BRIDGIT is undergoing a metric conversion in its final stage as an NCHRP project. The much-needed refinement of various agency cost models used by BMS is also being explored. For example, the models need to take into consideration the wide variations in the magnitude of traffic control costs associated with lane or bridge closures. These costs are typically much greater on heavily traveled urban freeways than on lightly traveled rural roads. Labor, equipment, and material rates also vary widely from site to site and from region to region. To aid in the development of agency cost models, FHWA and the South Carolina Department of Transportation are jointly sponsoring research at Clemson University to examine methodologies for estimating unit costs. The outcome of that work will be a data base of unit costs associated with maintenance, repair, and rehabilitation of CoRe elements. A methodology will also be for-

To collect data for BMS, inspectors will inventory and measure all of the elements in each bridge.

mulated for capturing unit cost data in each state. Finally, the identification of project- and element-specific factors that affect unit costs will be generated.

Better estimation of user costs is also needed. Accident data for narrow bridges have been studied to some extent, but greater effort is needed to determine costs incurred by motorists from bridges with these and other deficiencies. As more data are collected and data collection efforts are increasingly computerized, these data should become easier to obtain. Efforts are under way to use the technical advances in data collection, processing, and assimilation.

Future Directions

Even as the current challenges are met, thoughts about the direction for the future are being conceived. Some of these futuristic ideas involve incorporating BMS information into a more comprehensive transportation management system. It may be well worth the effort to link or mesh BMS with, for example, pavement management systems in order to optimize pavement and bridge rehabilitation and improvement projects. Safety improvements and maintenance management may also eventually be consolidated with a bridge and pavement management system. A number of states are pursuing an integrated management systems approach. Organizational issues that must be overcome center mostly on the tendency of each unit responsible for a management system to have a singular point of view. This is usually not an intentional force but a natural one. The major impetus toward integration is the conservation of time and money by preventing duplication of effort. With all the management systems coming on line and the obvious tightness of budgets there is a great advantage to incorporating the systems into one system. Other encouragements toward integration are common data bases and common reference systems.

Concepts are being developed to include both NBI and BMS data into a geographic information system. This will aid in the merging of management systems and add data acquisition capabilities to BMS to enhance their functioning. For example, approach roadway features, although given some data fields in NBI, could be detailed to a greater extent and provide important information to the improvement modeling of BMS. (Is the roadway wide enough to warrant a wider bridge? Will the number of accidents be reduced? Is the geometry favorable for widening or strengthening?)

As an improvement to the location of bridges, the use of a global positioning system (GPS) is being considered by many states. This will help any work done in cooperation with other systems with items located by GPS. It will also aid in specific areas such as accident identification as GPS units are more commonly used to locate accidents. This use will make BMS capable of picking up more detailed accident rates for use in improvement models.

Other improvements and technological advances in bridge management are being considered for incorporation into the BMS environments. Computer notepads and voice-activated collection systems that would increase the efficiency of data collection are being tested. Research is also being done to examine various nondestructive testing procedures and their possible inclusion in inspection data and, ultimately, BMS. In addition, extending the BMS concept to a nationwide scale by using optimization technology to aid in policy decisions at the federal level is being attempted.

The true worth of BMS will not be fully realized for many years to come, but it is clear that the states will not continue to manage bridges in the United States from a reactive position. As each state adopts a BMS, funding decisions will rely more on what adds value to the system instead of what is best for the individual structure. States will likely find that, in a reversal of the 55-mph speed limit slogan, a BMS is not just the law, it's a good idea.