BRIDGE MANAGEMENT TO THE YEAR 2000 AND BEYOND

Arunprakash M. Shirole,
New York State Department of Transportation

ABSTRACT

The momentum of Bridge Management System (BMS) development activities increased significantly during the 1980s. These activities have continued to accelerate with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. This paper reviews the status of BMS development and the difficulties it faces. It also discusses the rapid advances taking place in automation and communications technologies and their beneficial impact on the developments in bridge management. The application of these technologies to bridge management data collection, data analysis and decision-support functions will provide dramatic improvements in BMS capabilities in terms of its comprehensiveness and cost-effectiveness. However, these developments must occur within the context of intermodalism and interface with other ISTEA mandated management systems.

INTRODUCTION

Efforts to develop comprehensive BMS were initiated in the 1980s and aroused the curiosity of many transportation-managers. However, strong interest developed only among a few of them. In fact by the late 1980s, only the state Departments of Transportation (DOTs) in Pennsylvania and North Carolina, and some transportation agencies abroad had major portions of their BMS in operation while a handful of other state DOTs and local agencies had minor development efforts underway. The American Association of State Highway and Transportation Officials through its National Cooperative Highway Research Program (NCHRP) started a project to develop a generic, network-level BMS in 1985. Completion of this comprehensive effort is expected shortly. During this period, the Federal Highway Administration (FHWA) provided active and visionary support for the concept and development of comprehensive bridge management. The passage of ISTEA provided a further boost to these development activities and added an even broader dimension by calling for BMS interface with the other mandated management systems. Besides these influences, continuing advances in automation and communications technologies have and will continue to provide dramatic improvements in the area of comprehensive bridge management. The decade of the nineties, therefore, promises to be a period of rapid BMS implementation activities throughout the nation. Consistent with the theme of this conference, this paper addresses the future of bridge management in the context of data and data collection, data analysis and bridge management decision-support.

DATA AND DATA COLLECTION

Current data and data collection activities have their origins in FHWA's National Bridge Inspection Standards (NBIS) that were implemented in the late 1960s following the 1967 catastrophic collapse of the Point Pleasant Bridge in West Virginia. While these NBIS data requirements were updated in 1990, their purpose continues to focus on Federal funding apportionments on a national level. Therefore, they are of little benefit to state DOTs trying to better manage their bridge network. Many transportation agencies have recognized the need for more detailed data. Data that would enable tracking of span-by-span bridge element condition and vulnerability to catastrophic failure have been accepted by many agencies as necessary to long-term bridge preservation and improvements. Physical deterioration of bridge structure components is a multi-variable function. The influence of most of these variables is quantitatively very difficult to define. Probabilistic approaches are often based upon some type of expert system. These systems are of questionable value since factors affecting rates of deterioration vary by region and have a complex relationship with environmental variables. Many agencies have recognized these limitations in predicting rates of deterioration and projecting future needs, and are now taking steps to ensure that appropriate data are being collected to provide historical information. Prediction of service-life expectancy of different improvement alternatives is also difficult and problematic. Nationwide research by NCHRP and the Strategic Highway Research Program (SHRP), and ongoing research at state agencies have been directed at solving these problems. Promising analytical techniques have been developed and sufficient quantities of necessary data should be available by the year 2000 to validate their accuracy. Transportation agencies can expect to have significant historical data available along with suitable analytical techniques by the end of this decade. Bridge managers will then be able to predict, with reasonable precision, future preservation needs and the service-life expectancy of the variety of bridge improvement actions.

Data Storage and Retrieval

Advancements in data storage and retrieval activities will be supported by the ongoing technological revolution in the automation and communications industries. If one extrapolates the past few years growth in microcomputer capabilities, by the year 2000, the extent of bridge management data storage capabilities can be expected to include:

- Ability to electronically store and retrieve all data (numeric, text, picture, video, CAD drawings, etc.) from a distributed database;
- Availability of all bridge related data from any location, via LAN, WAN, modem, cellular, satellite, etc.;
- Ability for geographically distributed users to interactively work together;
- High resolution screens;
- One gigabyte as typical desktop computer RAM memory;
- Multiple-optical drives using gigabyte-size replaceable cartridges as typical disc storage;
- Graphic User Interface (GUI) driven by pen and voice; and
- Application programs that automatically work together.

It is important to note that none of the capabilities listed need any new advances in automation or communications to become reality. As automation and communications technologies advance, the available technologies will be absorbed into day-to-day operational activities of the transportation agencies. By the year 2000 a bridge manager, using a BMS, can expect to:

- Access all bridge related information at any time, from any location, without having to be a computer expert;
- Analyze a selected bridge population easily for any chosen characteristic;
- Teleconference from a bridge site with bridge inspectors, bridge maintenance and design engineers, steel repair experts, etc.;
- Locate relevant drawings, design needed repairs, send modified drawings to fabricators, and include required checks for inspections of other similar bridges, etc.;
- Present video simulations ("virtual reality") of proposed project work and consequences of not doing it; and
- Use Geographic Information System (GIS) information to combine and analyze all relevant data (highway, bridge maintenance, accident, construction, topographic, weather, etc.).

It must be emphasized that, while technology makes possible these advances in bridge management capabilities, only organizational foresight and effective planning and action will turn them into reality.

Data Collection

Data collection activities will undergo advances similar to those in data storage and retrieval activities. Recent advances in pen-based and hand-held computers and in communications technology have improved the collection and reporting of bridge inspection data. The size of microcomputer memory, speed of operation, improved screen resolution and potential for pen and voice driven Graphic User Interface (GUI) can improve the efficiency and capabilities of the bridge inspector. The field inspector will have immediate access to prior inspection reports, photographs, video records and relevant parts of inspection manuals. Some state DOTs have pilot projects underway to determine how to most effectively use these technologies to electronically collect and store bridge inspection data. Since many of these technologies are available and efforts are underway to determine how best to use them, the expanded use of automation for bridge inspection is certain. Significant advances in remote sensing and communications technologies will provide decision-support capabilities in emergency situations. It is technically possible to have real-time audiovisual communications between bridge-sites and agency-main office. This will result in prompt assessment of problem areas and effective decision-making for remedial actions. These remote-sensing techniques also will enable agencies to have automated data collection and real-time monitoring of scour, behavior of fatigue-prone details, etc. This will support timely actions. By the year 2000 widespread use of automation technologies will facilitate field bridge inspection reporting, and data collection and storage systems that will include numeric data, text, photographs, videos and field sketches.

DATA ANALYSIS

Many analytical tools and techniques are available to manage the bridge infrastructure. Their effectiveness, however, has been limited by the absence of historic data on bridge-element condition deterioration, factors affecting rate of deterioration, total costs of improvement and maintenance actions, and service-life implications of improvement and maintenance alternatives. While reliable deterministic modeling has not been possible, the probabilistic approaches tried have had serious limitations. As historic databases build over the next few years, agencies will find the use of analytical tools and techniques to be more beneficial in providing appropriate and reliable decision-support. The analysis of a large body of historic data will either prove the worth of these analytic techniques or that they need to be revised or replaced with other methods. By the year 2000 the use of sophisticated analytical techniques such as linear programming, dynamic programming, fuzzy set theory, Markov chains, etc. are likely to become more prevalent. This will provide the bridge manager realistic life-cycle costs and improve the quality of bridge management decisions.

DECISION-SUPPORT

The goal of comprehensive bridge management is to determine and implement an infrastructure preservation and improvement strategy that best integrates capital and maintenance activities at the lowest possible life-cycle cost. So far, this has been only a dream for the bridge manager. Bridge managers have done a good job of managing individual bridges with available resources. However, they have experienced difficulties in trying to cost-effectively manage a large network of aging and deteriorating bridges. The challenging area in bridge management decision-support has been in determining the most cost-effective, long- and short-term capital improvement and maintenance program strategies in the face of severe fiscal constraints. There is a need for stronger decision-support capabilities in this area of bridge management.

There have been several major efforts to develop tools to support the bridge managers' assessment of network-level bridge conditions, vulnerability and serviceability based needs. Bridge failures in recent years have resulted in efforts to systematically assess and evaluate the vulnerability of bridges to catastrophic failures due to hydraulic, steel fatigue, seismic and other similar causes. Current research and relevant data collection activities can be expected to provide improved understanding and capabilities in dealing with these issues. Future bridge inventory and inspection reports will include detailed information of these types that in turn will help in risk assessment and identification of higher priority activities needed to assure public safety. The assessment of network-level condition needs has been possible for some time. However, the NBIS data does not have sufficient detail to indicate bridge element and span condition. Many agencies are supplementing the NBIS data with information on the extent and nature of element deterioration. With the collection of this information, the quality of the condition-based needs assessment can be expected to significantly improve.

Another hurdle in assuring maximum benefit from budgeted expenditures has been the bridge manager's difficulty to forecast, with reasonable accuracy, network and project-level bridge conditions when considering various capital or maintenance improvements. Current research and data collection activities should help in better prediction of deterioration rates with and without improvements, and also in better prediction of service-life expectancies of different improvement methods. The developments in these areas will improve the assessments of life-cycle cost effectiveness of options, thus facilitating the selection of options that assure maximum benefit from available resources.

As historical information and the additional data become available and improved algorithms emerge, analytical tools and techniques to analyze this information will also expand. Current analytical tools and techniques will have been tested in terms of their validity and utility. Advancements in automation will further increase processing capabilities, and these improvements will enable "what if studies" through improved algorithms. This will make sensitivity analyses possible thus enabling identification of cost-effective life-cycle strategies at the project and network levels.

With the improvements and advances in data collection and availability of additional data, there will be more historic information available at the initial scoping of capital improvement projects. Also available electronically will be photos and videos for better understanding of individual project needs. In addition, there will be easy access to information on what was done to similar bridges, and the service life and cost-effectiveness of different work alternatives. There may also be interstate linkages to share bridge data across jurisdictional boundaries. This type of linkage will lead to more common terminology between agencies and expose bridge managers to areas of commonality in the diverse bridge activities of different agencies.

Another advancement will occur through the linkage of engineering software to bridge management decision-support. A bridge management system cannot be considered comprehensive without having engineering components incorporated within its operational framework. This is especially important for project-level bridge management. The BMS of the future will have load rating, bridge design and drafting as essential components. The load rating capability will allow for prompt load capacity evaluations and will be helpful in accident damage assessments. It also can be used in comparing and selecting appropriate repair/retrofit work strategies and cost estimates, and to help in the efficient routing of overload vehicles.

Innovations in bridge designs and their implications in terms of construction sequencing will be beneficial in managing phased bridge construction. Realistic multi-year bridge maintenance programs and more cost-effective project mixes in the capital improvement program also will be possible. Detailed graphic displays of a variety of design alternatives can be prepared to visually display the implications of these alternatives in regard to their aesthetic appeal, changes in profile and effects on adjacent terrain or property. Developments in virtual reality will make it possible to visually depict to legislative bodies and the public the impact of different levels of public investment on the bridge deterioration process. Bridge engineers have come to realize the impacts of deferred remedial actions but have had limited success in convincing the policy makers. This will no longer be difficult to demonstrate. The multimedia techniques that exist today, when applied to bridges, will, through a sequence of compiled video clips, succinctly show the progression of bridge condition deterioration. No longer will the proponents of deferred maintenance be able to ignore the dire consequences of postponing maintenance activities.

IMPLICATIONS OF ISTEA

The ISTEA of 1991 mandated the development of management systems and emphasized intermodal transportation efficiency as the principal goal for surface transportation agencies. This clearly requires bridge managers to broaden their management perspective to ensure compatibility between BMSs and other ISTEA mandated systems. Pavement Management Systems (PMSs) and BMSs have been under development for some time and the need for compatibility and interface between them has been recognized by most agencies. Other management system developments are being initiated in response to rules recently promulgated by the FHWA. The BMS interface with these other management systems, therefore, will evolve. The emphasis on multimodalism will require coordinated transportation investment decisions to improve the safety and efficiency of the multimodal movement of people and goods. Future BMSs will be able to effectively show the comparative importance and long-term cost effectiveness of public investment in bridges within the context of multimodal transportation efficiency.

CONCLUSION

Starting in the 1980s, BMS development activities have increased in intensity and effectiveness. Advances in automation and communications technologies will support dramatic improvements in bridge management practices. Data collection, storage and retrieval activities will benefit from the rapid growth in microcomputer capabilities and multimedia techniques thereby dramatically improving bridge management practices. Current efforts to build comprehensive and historic bridge condition databases will enable validation of analytic techniques and/or evolution of improved techniques. The most significant improvements will be in the area of decision-support. These will enable the bridge manager to determine the most cost-effective, long/short term capital improvement/maintenance program strategies. The ISTEA legislation will support and shape the future of bridge management through interfaces with other management systems and the need to demonstrate public investment in bridges within the context of multimodalism.