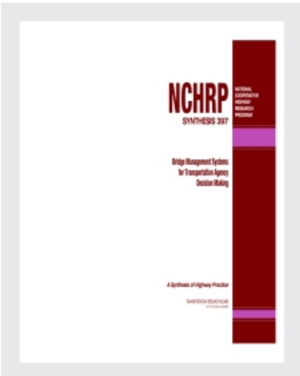

Bridge Management Systems for Transportation Agency Decision Making

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 397

Bridge Management Systems for Transportation Agency Decision Making

A Synthesis of Highway Practice

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SUBJECT AREAS
Planning and Administration, and Bridges, Other Structures, Hydraulics and Hydrology

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TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Jon Williams
Program Director
Transportation Research Board

This study gathers information on current practices that senior managers at transportation agencies use to make network-level decisions on resource allocations for their bridge programs. In particular, the study explores how agency bridge management systems are employed in this process.

Information was gathered through a review of literature on U.S. and international bridge management, a survey of U.S. and Canadian transportation agencies, and 15 in-depth interviews with state DOT executive and bridge managers.

Michael J. Markow, Consultant, Teaticket Massachusetts, and William A. Hyman, formerly of Applied Research Associates, Inc., Elkridge, Maryland, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

BRIDGE MANAGEMENT SYSTEMS FOR TRANSPORTATION AGENCY DECISION MAKING

SUMMARY

The objective of this synthesis study has been to gather information on current practices that agency chief executive officers and senior managers use to make network-level investment and resource allocation decisions for their bridge programs, and to understand how they apply their agency's bridge management capabilities to support these decisions. The following areas of planning, programming, and performance-based decision making have been addressed:

- Condition and performance measures that are used to define policy goals and performance targets for the bridge program
- Methods of establishing funding levels and identifying bridge needs
- Methods and organizational responsibilities for resource allocation between the bridge program versus competing needs in other programs (pavement, safety, etc.)
- Methods of allocation among districts and selection and prioritization of projects
- The role of automated bridge management systems (BMS) in planning, programming, resource allocation, and budgeting
- Use of economic methods in bridge management
- Methods to promote accountability and communication of the status of the bridge inventory and the bridge program.

The study has also considered recent trends and events that could influence future bridge program management. Several state departments of transportation (DOTs) that were interviewed for this study described ongoing, leading-edge enhancements of their bridge management processes and systems that provide examples for other agencies to apply in the future. The increasing application of asset management principles among state DOTs is another such influence, encompassing bridges, pavements, and a growing set of other transportation assets. Several actions following the collapse of the I-35W bridge in Minneapolis in August 2007 also promise to reshape bridge management practices in the future, with increasing emphasis on program performance, federal oversight and accountability, inspection qualifications and procedures, use of innovative inspection technology, and research needs to improve BMSs, procedures, and technology.

Information on these topics was gathered through a review of literature on U.S. and international bridge management, a survey of U.S. and Canadian agency bridge management practices and assessments, and 15 in-depth interviews with state DOT executives and bridge managers. Twenty U.S. agencies and four Canadian agencies responded to the survey.

Bridge management in the United States has taken major strides in the past 40 years, with significant accomplishments at the federal and state levels. The National Bridge Inspection Standards (NBIS), which were implemented in the 1970s, established a single, unified method of collecting data on the nation's public-highway bridges. These data are submitted annually by state DOTs to the FHWA, which compiles them within the National Bridge Inventory database. The NBIS have enabled the FHWA and state DOTs to monitor bridge condition and performance nationally on a consistent basis, identify bridge needs,

define criteria of project eligibility for federal bridge funding, and thereby promote public safety through better stewardship of bridge assets. Following the implementation of the NBIS, substantial advances have occurred in bridge management at the national and state levels. Today, all state DOTs have a bridge management process. Most employ some type of automated BMS with an associated database of bridge-related information, including NBIS data and ratings, but often incorporating more detailed element-level data or additional, customized data.

State DOTs differ in their specific procedures for bridge program-related management, funding, and resource allocation. This variability is driven by several factors, among them (1) different philosophies of bridge management; (2) different approaches to planning, programming, and budgeting; (3) the characteristics of each agency's transportation system and its infrastructure; and (4) the policy, financial, technical, and institutional environment in which each agency operates. Despite the diversity of their practices, agencies that were addressed in this study appear to have integrated their bridge management procedures and systems well within their individual planning, resource allocation, programming, and budgeting processes. Philosophies of bridge management may contrast across agencies (e.g., centralized vs. decentralized decision making; use vs. nonuse of prediction models to forecast bridge network condition). Nonetheless, in each case that was studied in this synthesis, the agency has configured its bridge program management to fit within its organizational, financial, managerial, and technical modes of operation. It has tailored its internal communications of information, as well as its institutional relationships with other agencies, accordingly.

In interviews conducted under this study, state DOTs stressed the importance of repeated consultations to seek agreement between central office and district personnel, regardless of which management approach they used. In many agencies, the management style is mixed, with centralized techniques often applying to bridge replacement and rehabilitation [i.e., projects that are eligible for federal Highway Bridge Program (HBP) funding], and more decentralized responsibility typically applying to bridge maintenance and repair (i.e., projects tending to be funded more often by state money). Decisions thus flow both top down and bottom up. Even in decentralized organizations, the central office often handles major bridge projects and may retain responsibility for bridges on "trunk line" or "backbone" networks that have statewide significance.

Further insight into the decision-influencing role of bridge management may be gained by considering how agencies use their BMS. The systems vary in analytic capabilities and sophistication, ranging from straightforward repositories of bridge data to full-fledged management systems that include such tools as forecasting models, comparative analyses (scenario testing), and optimization procedures or decision rules. Full-featured systems operate at both the program or network level and at the level of individual bridges or projects. Those agencies that have a full-featured BMS thus *have the ability* to apply higher-end analyses such as project planning, network-level budget scenarios, trade-off analyses, and economic analyses of agency and user costs and benefits. However, *the actual use* of these capabilities is by no means a given. As a general statement, BMS capabilities are underutilized, a situation that has been observed by other studies as well for at least 10 years.

For example, many agencies—including those with sophisticated products—use their BMS solely to manage bridge inspection data. Those agencies that have applied more advanced functionality may still take advantage of only a subset of available features. To establish a benchmark for the current state of practice, interviews were conducted in this study with agencies that do use virtually the full set of available BMS features, including economic analyses and scenario testing. These DOTs might thus be viewed as leading-edge BMS practitioners. In addition to using a full set of BMS capabilities, several of them try to understand bridge program investments in a broad context—for example, considering impacts on different classes of road users and effects on local economic situations.

More generally, however, the characteristic use of BMSs for state DOT decision making is toward more limited ends, including the following:

- Compilation and display of current and near-term information rather than long-term analyses
- A focus on technical results such as bridge condition and performance rather than also considering economic comparisons of benefits and costs
- A preference for straightforward calculations and analyses, including database management and computations of bridge ratings and indexes, rather than more sophisticated modeling such as forecasting, scenario analyses, trade-off analyses, and optimization.

Likely components of agencies' databases regarding bridge condition and performance include the results of their bridge inspection program and computed NBIS ratings—Structural Deficiency, Functional Obsolescence, and Sufficiency Rating. Agencies may also define custom measures of condition or performance to reflect local bridge, traffic, and transportation system characteristics. Many DOTs reserve more comprehensive, sophisticated, long-term analyses for major bridge projects. In considering applications more broadly to the entire bridge network, these types of analyses tend to be the purview of the subset of agencies that routinely employs more advanced BMS features, as discussed earlier.

An important way to adapt bridge management to an agency's business and decision processes is through *customization*—the ability to define new BMS data, performance measures, analytic procedures, and reports. Among agencies that were interviewed in this study, these customizations are important to ensuring that bridge management information remains relevant to agency decisions across all affected organizational units and levels. In particular, customized performance measures such as deficiency-point calculations and custom bridge health indexes in several cases were believed to be critical to advancing state-specific practices technically, managerially, and procedurally. These new indicators were supported and used by upper management and served bridge-office as well as executive-level informational needs for investment planning, resource allocation, and budgeting. Some agencies also saw customized bridge rating indexes as a way to get better guidance on bridge investment needs and benefits, to compensate for what they believed were shortcomings in the Sufficiency Rating as a criterion for bridge replacement and rehabilitation.

Organizational responsibilities for decision making vary to some degree by agency, but the following statements generally hold. An agency's bridge office is substantially involved in all programming decisions that deal specifically with bridges, but this authority is shared with other groups within and outside the agency. For example, major bridge projects involve strong participation by agency executives and, in some states, the oversight transportation board or commission. Regional and local officials will also be involved for major bridge projects in urban areas. Local bridge programs engage important roles by local and regional bodies together with the state agency's local or municipal assistance office. Districts (or regions or divisions) generally have a strong say in decisions involving all categories of bridge projects within their jurisdictions, including local, state owned, and major bridges.

One programming decision for which the bridge unit does not have a dominant role among reporting agencies is in the allocation of resources among competing agency programs: bridge versus pavement, safety, maintenance, and so on. Leadership on this decision is seen either as an executive-level function, with transportation board or commission involvement as well in several states, or as a broader departmental decision involving units such as planning, investment management, policy and strategy, project management, and (in a Canadian province) the director of highway design and construction. In two of the states responding to the survey, this decision is decentralized, with program allocations made by districts. In some states, this decision may be moot if bridge funding is allocated "off the top" or is reserved in a noncompeting set-aside. Even with off-the-top or set-aside bridge program funding, however, resource allocation may present issues if the total amount of bridge funding has remained level or declined over time and is now significantly less than current bridge needs.

Agencies use economic methods to varying degrees in bridge management, but overall, the practices do not represent wide use. Common examples of applications to individual structures include the use of benefit-cost analysis for major bridge projects, and life-cycle cost comparisons of rehabilitation versus replacement options for specific structures. Agencies that have full-featured BMSs are more likely to employ economic analyses in network-level bridge management, but the practice is not yet widespread; also, some agencies may have reservations about the transparency of these analytic procedures or disagreements with the methods' assumptions. FHWA division offices have encouraged greater use of economic analyses in bridge management, and several agencies interviewed in this study plan to apply such analyses to a greater degree in the future.

Several factors that have been identified in this synthesis project point to coming changes in bridge program management, including likely revisions to the NBIS specifically. These factors will shape how advances in bridge management practices, systems, and information will inform future investment and resource allocation decisions. Although these factors are still evolving and their outcomes are not yet determined, it appears likely—based on the numerous and significant federal and state actions that are described in this report—that changes will occur in state DOT bridge inspection and condition assessment, bridge program management, and application of the NBIS. It also appears likely that federal (i.e., FHWA) oversight of these activities, and particularly over the correction of structurally deficient and functionally obsolete bridges, may be strengthened. There may also be a greater focus on accountability to relate funding to performance, quality assurance, quality control, and increased compliance reporting among state DOTs, the FHWA, the U.S.DOT, and Congress.

Potential influences on future management practices stem in part from ongoing activities such as BMS enhancements by selected state DOTs, which advance the state of the art to the benefit of peer agencies—for example, customized additions or improvements in BMS data and database processing, new bridge condition and performance indexes, and custom BMS models to estimate near-term and long-term impacts of bridge investments. Other influences on future practice derive from activities such as state DOT, TRB, and FHWA participation in several recent peer exchanges on ways to improve asset management through better planning, programming, budgeting, and use of data and information. Still other activities have identified and reinforced exemplary methods in infrastructure management—for example, a U.S. domestic scan on best practices in asset management, and an FHWA initiative on systemwide bridge preservation.

The collapse of the I-35W bridge in Minneapolis in August 2007 catalyzed a number of more far-reaching, national-level influences on future directions in bridge program management. It should be noted that the causes of the I-35W collapse and the completion of the subsequent bridge replacement project were not within the scope of work of this study and have not been addressed in this report. However, this tragedy launched several actions that may significantly enhance and refocus bridge program management and the NBIS, specifically. These factors, which are summarized here, are discussed in chapter four:

- A comprehensive review of the NBIS that is now being conducted by the U.S.DOT's Office of the Inspector General. This three-phased review will consider (1) FHWA's progress in meeting previous recommendations for oversight of structurally deficient bridges nationwide, (2) state DOT use of federal bridge funding to correct structural deficiencies, and (3) FHWA oversight of the safety of National Highway System (NHS) bridges nationwide.

- Public reaction following the I-35W bridge failure, which indicated confusion over the meaning of "structural deficiency" and its implications for bridge condition and public safety.
- Changes in HBP procedures and criteria that were proposed in congressional testimony. State DOT executives, some of whom represented both their respective departments and AASHTO, recommended several updates to federal HBP decision making and to how the NBIS sufficiency and deficiency ratings are applied as program criteria. Hallmarks of this testimony included proposals for greater flexibility in program funding decisions and greater reliance on systematic, data-driven, performance-based methods in lieu of arbitrary criteria. Several other aspects of federal and state bridge program funding were also covered, as were topics of bridge inspection, innovative inspection technology, materials performance, and research needs.
- A recent U.S. Government Accountability Office (GAO) report on the federal HBP, the data and techniques available for bridge management, and results to date in correcting structurally deficient bridges. The GAO recommended several actions: (1) to define the national goals of the HBP, (2) to determine HBP performance in relation to these goals, (3) to identify and evaluate bridge management best practices that can improve HBP performance, and (4) to investigate ways to align HBP funding more closely with performance, supporting a more focused and sustainable federal bridge program.
- Legislation now before Congress that will affect the future practice and technology of bridge management. Current bills before the House and Senate define several actions to be undertaken by federal and state agencies with respect to bridge program management and resource allocation. Although provisions of these bills are subject to further congressional deliberation, if passed substantially in their current form they will mandate a number of items, for example, (1) state DOT use of BMSs; (2) establishment of state 5-year performance plans for bridge inspections and correction of structurally deficient and functionally obsolete bridges, with such plans to be approved by the FHWA; (3) enhancements of the national bridge inspection program with specific requirements for dealing with critical findings and for strengthening inspection team training and qualifications; and (4) a number of other provisions.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Bridges are one of the most visible and important components of a transportation system. By providing crossings at critical locations, bridges maintain network continuity, traversing natural and manmade features that otherwise would add significant travel time and cost. Designing, building, maintaining, repairing, and replacing bridges involve critical investment decisions for agencies because of the high cost of these investments, the need to sustain an appropriate level of investment throughout the considerable life of a bridge, and the important structural and functional implications of the selected investments. Agencies therefore try to get these investments right, both to minimize life-cycle cost (LCC) and to provide safe and efficient mobility to transportation system users. Agencies must at the same time account for the revenue stream that is available to fund transportation programs, the project eligibility rules and degree of flexibility afforded by different funding sources, and the competition between the bridge program and other transportation needs for the limited dollars available.

Decision making regarding the funding of state and provincial bridge programs occurs at different organizational levels within departments of transportation (DOTs). The ways in which these decisions are reached, and with what data, depend on an agency's philosophy and approach to bridge management as well as broader processes for long-range planning, revenue projection, capital and maintenance programming, and budgeting. These more broad-based functions set the levels of investment and the allocation of resources among agency programs, geographic districts or regions, and support activities. This synthesis study was motivated by a desire among DOTs to understand how their peer agencies conduct bridge management, and how this information supports upper-management decisions affecting the bridge program.

All state DOTs (for brevity, "state" will be understood in this report to refer to both "state" and "provincial" unless noted otherwise) have a bridge management process in place. Later chapters will show that this process can vary considerably from one agency to another. There is no single "model" process. These variations may reflect management philosophy and culture; they may also be pragmatic responses to particular statutory, political, or financial requirements. Most agencies use a computerized tool, a bridge management system (BMS), to manage and process relevant data and to provide analytical support for bridge program decisions. Again, the particular BMS products agencies use can differ, and even the same product may vary in its details among agencies in how it is customized and applied. The familiarity of upper management with the assumptions, data, and conventions of bridge management, and with the capability of their agency's BMS, may also vary among agencies. DOTs would like to understand how their peers apply and benefit from their bridge management processes and systems when making resource allocation decisions.

MANAGEMENT PERSPECTIVES

A DOT's upper management and its bridge managers are involved in bridge program decisions. However, these two groups bring different responsibilities, perspectives, and criteria to their respective roles regarding resource allocation as it affects the bridge program. The DOT chief executive officer (CEO) and his or her senior management team provide executive leadership to the agency. They:

- Translate federal and state public policy and regulations into agency objectives, procedural requirements, and performance targets
- Set strategic priorities for the agency
- Understand and provide strategic direction regarding interactions among federal and local governments and the state DOT
- Provide guidance and oversee decisions on the department's long-range transportation plan, the Statewide Transportation Improvement Program (STIP), budget development, and resource allocation, including:
  - Meeting short-term and long-term projections of needs
  - Addressing uncertainties in the projections of economic and demographic shifts, traffic volume and composition, and revenue streams from different sources
  - Accounting for geographic equity considerations in the balancing of needs; that is, resource allocations among districts, regions, or other geographic subdivisions

  - Balancing needs versus funding sources, accounting for dollar levels required versus available, and funding eligibility of programs and projects
- Monitor agency and transportation system performance, document accomplishments, and track progress toward established targets
- Communicate with the governor, legislature, transportation board or commission, other stakeholders, and the general public regarding agency plans, programs, projects, and accomplishments.

Managers in the bridge unit at both central office and field levels (e.g., districts or regions) have responsibilities for the public highway bridge system within the state. Within the United States, state DOTs have certain responsibilities for bridges that are "on system"—that is, owned and maintained by the DOTs as part of the state highway network—and "off system"—that is, owned by local governments. Bridges on federal lands, privately owned bridges, and tribally owned bridges are excluded from state responsibility. Although bridge-related interactions between a DOT and local governments vary by state, at a minimum it is the state DOT's responsibility to ensure the conduct of federally required biennial inspections of local bridges as well as of state-owned structures, and report to the FHWA the results of these inspections. Refer to chapter two for additional information on this biennial inspection program. Within this context, managers in a DOT's bridge organizational unit:

- Conduct and assess biennial bridge inspections of on-system and off-system bridges in coordination with local governments
- Maintain and submit resulting inspection data to the FHWA, and compute and assess measures and trends of bridge condition and performance
- Identify and assess needs for work and their priorities that result from inspections and evaluations across several areas; for example, structural condition, functional performance, vulnerability to seismic damage and scour, potential security concerns, fracture-critical classification, and other circumstances
- Prioritize bridge projects according to agency criteria, which may include:
  - Bridge structural condition and functional performance
  - Other aspects of bridge health, safety, deficiency, and risk of failure
  - National Bridge Inventory ratings (refer to chapter two)
  - Funding availability and eligibility requirements
  - Long-term bridge needs and a strategy for addressing them as identified, for example, in the agency's long-term transportation plan or capital investment plan
- Design and manage bridge projects, including large, complex "major bridge projects"
- Recommend a bridge program, implement the approved bridge program, and conduct or manage delivery of required bridge work.

These management perspectives relate to each other through an agency's business processes, illustrated schematically in Figure 1. These business processes comprise top-down and bottom-up communications throughout the year in support of ongoing system management and performance monitoring, as well as for project selection, prioritization, and program trade-offs during the agency's budgeting cycle. Figure 1 is useful as an idealized illustration, recognizing that actual agency practices show considerable variability in, for example, centralized versus decentralized decision making, procedures and criteria for planning and programming, the sequence of top-down and bottom-up actions in proposing candidate bridge projects through final program recommendations, and resulting demands for information at various organizational levels.

Of primary concern to this study is the information that is transmitted from or by means of the bridge unit to the executive level as part of building the agency's programs and budget, as shown in Figure 1. The adequacy of this information certainly depends on ensuring that its descriptions of bridge status, needs, and costs are complete, current, accurate, and timely. Other attributes, however, are also important to upper management, such as the ability to compare this information with corresponding submittals on competing programs, and to understand the implications of funding all or part of bridge needs at a level, or with a schedule, that may be different from what is requested. These potential trade-offs between bridge and other programs are also indicated in Figure 1. All of these processes and information flows take place within the context of federal and state funding availability, governing regulations, agency procedural requirements, interagency coordination, and public and stakeholder demands on the quality and level of service of their transportation system.

STUDY OBJECTIVE AND FOCUS

The objective of this synthesis is to document how bridge management—its processes, analytic tools, and information—meets the needs of upper management regarding their planning, programming, and resource allocation decisions. Although Figure 1 represents many individual functions, flows of information, and decision points, it is important to realize that significant variations exist among agencies in how these are handled and with what information. An agency's management approach and culture, organizational roles and responsibilities, and strength in information technology are factors in these differences, and are discussed in the synthesis findings when they have a significant influence.

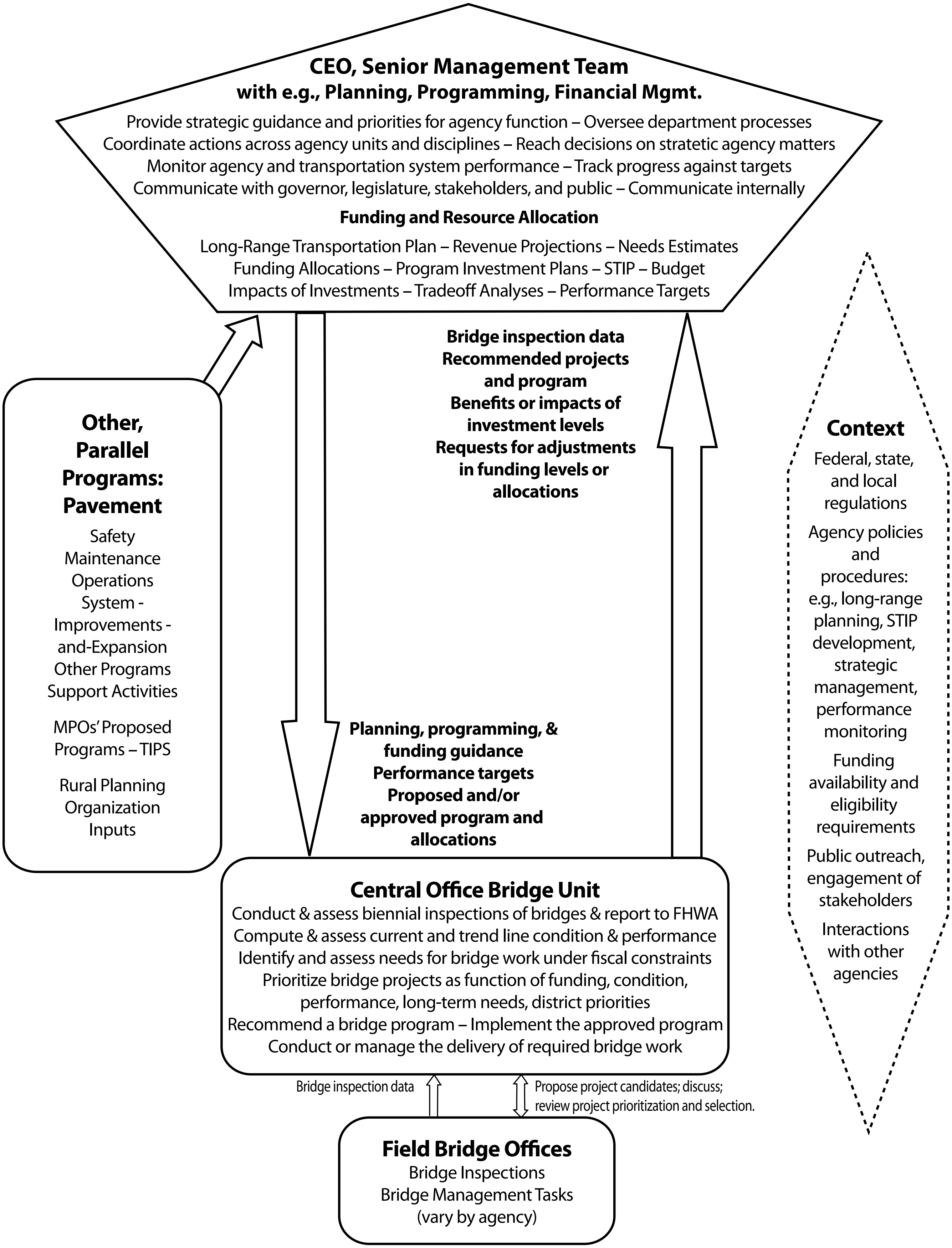

FIGURE 1 Interactions between the bridge unit and upper-management decision makers.
Note: CEO = chief executive officer; MPO = metropolitan planning organization; TIP = Transportation Improvement Program; STIP = Statewide Transportation Improvement Program.

In meeting its objective, this synthesis study has gathered information on current practices that agency CEOs and senior decision makers use to make network-level funding decisions for their bridges. It has asked how their bridge management processes are applied to these decisions. Information has also been collected on future plans for upgrading and better utilizing bridge management processes. The focus has been on both funding allocations for bridges in competition with other agency programs, and allocations within the bridge program for replacement, rehabilitation, and maintenance needs throughout the state. The information that has been gathered falls into a number of categories based on specific items called for in the project scope of work, among them:

- An agency's **overall approach** to decision making on infrastructure investments
- The current **state of practice** of bridge management, including what factors are considered in the process, ongoing improvements by DOTs, and additional capabilities that are desired
- The **organizational levels** at which bridge program decisions are made—that is, who typically makes decisions in the following areas: infrastructure funding allocations; selection of performance measures; funding splits among maintenance/repair, preservation/rehabilitation, and replacement; and project selection
- Comparison of the **information needed** by senior decision makers with that **actually provided** by the bridge management process/system
- Use of **economic methods** such as LCC and cost-benefit ratios by senior managers
- **Standard reports** provided to decision makers and other stakeholders, including the general public
- The extent to which senior decision makers rely on **BMS outputs or subjective judgment** from the bridge management process
- **Suggested enhancements** to existing bridge management processes and systems.

The collapse of the I-35W bridge in Minneapolis in August 2007 brought several issues related to bridge management and bridge funding into sharper relief. These issues include the need to understand better the current status of a bridge, the meaning of "structural deficiency" and its implications for public safety and structure preservation, and the adequacy of existing bridge program funding levels and eligibility requirements. Wider implications have been recognized regarding the accuracy and reliability of bridge inspections, potential needs for new inspection technology and wider adoption of existing nondestructive evaluation techniques, and a need to reexamine the nation's approach to assessing and reporting current bridge conditions. All of these issues have arisen in the context of more than 12% of the nation's bridges being classified as structurally deficient, and a lack of understanding of this concept among the public as well as concern as to what to do about it. This synthesis deals with these issues to the extent that they relate to study objectives.

This study is principally concerned with program- or network-level decision making. However, project-level concerns have not been ignored. For example, project prioritization and selection are critical steps in building a network-level program. Some agencies adopt an intermediate-level view of project definition and evaluation, in which bridge projects are considered and developed at a corridor or subnetwork level, consistent with the highway links they serve. Another example concerns budget allocations to major bridge projects, which can cost hundreds of millions of dollars and therefore have network-level ramifications. Also, if the scope of a conventional bridge project changes, the funding available for other projects within the program also adjusts, as may their schedules. Finally, a BMS may perform network-level calculations based on its project-level results.

STUDY METHODOLOGY

Information was gathered for this synthesis through a literature review, a survey of state transportation agencies, and interviews with chief engineers and bridge section engineers.

- The literature review contributed to the narrative describing the development of bridge management practice over the past four decades. It established much of the general BMS state of practice and related tools—for example, specialized applications to optimize bridge investments and perform trade-off analyses.
- Survey questionnaires were sent to all the states and Canadian provinces. The survey included three parts: Part A, broadly covering the bridge management process and BMS; Part B, a budgeting component; and Part C, a planning component. The surveys were sent to agency bridge engineers, who were requested to distribute the second and third parts to the heads of budgeting and planning, respectively. Alternately, a bridge engineer who had the knowledge to do so had the option to complete all parts of the survey. The survey results are discussed in chapter three and are a key source of information on current agency practice. The complete survey questionnaire is included in Appendix A.
- Ten chief engineers were interviewed to obtain an executive perspective on bridge management and provide insights on bridge program funding decisions as part of planning, programming, and budgeting. Five engineers in the bridge unit (e.g., state bridge engineers and bridge maintenance engineers) were interviewed to obtain specifics on how bridge management processes and BMS tools are used within their agencies, and how they saw these capabilities supporting upper-level managers in their decision making. Both

sets of interviews were critical in elaborating on general themes identified in the literature and the survey responses. Interview results are also discussed in chapter three and are another key source explaining current practice. The guides for both sets of interviews are included in Appendix B. Participants in these interviews as well as respondents to the survey are listed in Appendix C.

TABLE 1
TALLY OF QUESTIONNAIRES AND RESPONSES

Item Tallied	Total Number	Part B or C by Budgeting or Planning	Part B or C by Bridge Engineer
Number of questionnaires distributed	60		
Number of U.S. states responding	20		
Number of Canadian provinces responding	4		
Total responses: states plus provinces	24		
Part A: Bridge Engineer section returns with statistical data	24	—	—
Part B: Budget section returns with statistical data	22	7	15
Part C: Planning section returns with statistical data	17	6	11

Note: — = not available.

Table 1 tallies the questionnaires and responses in the study survey, in terms of both the number of overall questionnaires distributed and received and the specific numbers of results for each of the three parts of the questionnaire. Not all agencies completed all parts of the survey. The numbers of useable statistical results were therefore less than the total number of responses. For Parts B and C (the Budgeting and Planning components, respectively), Table 1 also identifies the organizational position of the respondents—that is, whether Part B or Part C was completed by the chief of budgeting or planning, respectively, or whether it was completed by the bridge engineer or a delegate. Chapter three presents the main survey results in graphic form as a series of charts. Numerical tallies of responses to these questions are included in Appendix D. Appendix E presents supporting survey results regarding factors that affect budgeting.

Because the survey response rate was less than desired, several efforts were made to strengthen findings on current agency practice. Additional information was gained from the 15 interviews noted previously and from several other sources—for example, comparison of Topic 37-07 survey findings with those of related NCHRP studies, proceedings of several recent peer exchanges, and congressional testimony regarding the condition of U.S. bridges, bridge safety, and funding adequacy. This supplementary information is reported in chapters three and four.

OUTLINE OF REPORT

Chapter two provides a brief history of the advancement of bridge management over the past four decades. It begins with the inception of the National Bridge Inspection Standards (NBIS) and progresses to today's general state of bridge management practice. Chapter three evaluates how agencies apply their bridge management processes and their BMS specifically to agency decision making, focusing on the several stages of planning and programming that deal with resource allocation and project prioritization and selection. Definition of bridge program objectives and performance tracking against targets are also covered. Chapter four considers emerging trends that will affect bridge management practice, and potential research that could strengthen the application of bridge management to funding decisions. This compilation of research needs draws from the literature review, interviews, and survey responses. Summaries of recent peer exchanges and of relevant items raised in recent congressional testimony are also included in this chapter. Chapter five concludes the report. The five appendixes are as follows: Appendix A, Survey Questionnaire; Appendix B, Interview Guides; Appendix C, Survey and Interviews Participants; Appendix D, Responses to Selected Survey Questions; and Appendix E, Survey Responses: Factors Affecting Budgeting.

CHAPTER TWO

STATE OF PRACTICE IN BRIDGE MANAGEMENT

NATIONAL BRIDGE INSPECTION STANDARDS

Overview

NBIS came about in the aftermath of the collapse of the Silver Bridge over the Ohio River between Ohio and West Virginia in 1967 (FHWA and FTA 2002, Chapter 11). This failure, and the concerns it raised about bridge conditions nationally and their implications for public safety, resulted in congressional mandates to the U.S.DOT in 1970 to develop and implement national bridge inspection standards and procedures (P.L. 91-605). Subsequent federal surface transportation legislation during the next 35 years expanded the inspection requirements and authorized federal funding to bridge programs (FHWA and FTA 2004, Exhibit 15-1). NBIS requirements are issued as federal regulations (23 CFR Subpart C §650.300) that are updated by the FHWA from time to time in a formal rulemaking process that is published in the *Federal Register*. The most recent NBIS update was in December 2004 (FHWA 2004).

A core requirement of the NBIS is the biennial inspection of all bridges and culverts greater than 20 ft in length on U.S. public roads. Bridges that have serious deficiencies are inspected more frequently, as required. Although select bridges that are in excellent condition and meet certain other criteria may be inspected at intervals longer than 2 years with prior FHWA approval, only a small percentage of bridges nationally, generally new bridges in excellent condition, meet these criteria. Most bridges in the United States are inspected at at least 2-year intervals, and the biennial inspection requirement of NBIS is widely understood throughout the U.S. highway community. NBIS regulations also include other provisions; for example, the required qualifications of inspection staff.

The practical guidelines for conducting NBIS-mandated bridge inspections are contained in a bridge recording and coding guide issued by the FHWA (1995). This guidebook includes instructions and examples for more than 125 entries to be recorded, together with coding forms. An overview of the items addressed in the inspection guidelines is as follows:

- Items 1–27: General description and administrative information
- Items 28–42: Functional or operational (capacity) information, design load
- Items 43–44: Structure/design/construction type and material of construction
- Items 45–56: Span information, geometric information, and clearance dimensions (no Item 57)
- Items 58–70: Structural condition and bridge loading information
- Items 71–72: Waterway and approach data (no Items 73–74)
- Items 75–97: Inspector's work recommendations and projected costs
- Items 98–116: Other information of various categories

Several items have multiple parts (A, B, C), which accounts for the more than 125 entries.

Items relating to structural components and operational characteristics must be observed, assessed, and rated by certified, trained inspectors. The FHWA *Recording and Coding Guide* describes the alphanumeric codes that inspectors must use to rate each item. Rating systems for bridge condition and structural and functional appraisals are recorded on a scale from 0 to 9 (summarized in the following sections). The results of inspection ratings for all bridges on a statewide network, plus local bridges within the state, are reported annually by each state DOT to the FHWA, where they are compiled and processed within the National Bridge Inventory (NBI) database. The NBI database is the source of reports on national bridge statistics, including numbers and percentages of bridges that are "structurally deficient" or "functionally obsolete," as explained later. The NBI database is also the source of data used by the FHWA in its biennial report on bridge conditions and performance to the Congress (e.g., FHWA and FTA 2006, chapter 3). NBI ratings are described in some detail here because they play a key role in federal bridge funding and state DOT tracking of bridge condition and performance. They are referred to repeatedly in subsequent chapters as a key component of bridge management information.

National Bridge Inventory Condition Ratings

The following scale is used to rate bridge condition (FHWA 1995):

- 9 = Excellent
- 8 = Very Good
- 7 = Good
- 6 = Satisfactory
- 5 = Fair
- 4 = Poor
- 3 = Serious
- 2 = Critical
- 1 = "Imminent" Failure
- 0 = Failure
- N = Not Applicable

For example, the condition of new, well-constructed bridges would be taken as 9. Ratings from 8 to 6 would characterize generally good performance, with only minor problems. Ratings from 5 to 3 are intended as warnings of growing problems that require action, whether (1) maintenance, rehabilitation, or replacement; (2) posting of load limits to prohibit heavy vehicles; or (3) increased frequency of inspection. Some agencies assign "flags" to these ratings to highlight these warnings for managers. Ratings of 2 or 1 are critical and call for immediate action, including possible bridge closure. A rating of 0 denotes a failed bridge that is out of service and cannot be repaired. N means that the particular item is not applicable to that bridge. These general descriptions introduce the rating scale; the actual inspection and rating process uses more specific definitions and explanations that are tailored to particular inspection items. For example, Table 2 gives rating definitions for Inspection items 58-Bridge Decks, 59-Superstructure, and 60-Substructure. For comparison, Table 3 lists rating definitions for item 62, Culverts.

National Bridge Inventory Appraisal Ratings

Appraisal ratings differ from the condition ratings. Appraisal items evaluate the level of service provided by a bridge to the highway it serves, as compared with that of a new bridge built to current design standards that are now applicable to that highway. Appraisals can apply to structural as well as functional items. Unlike condition ratings that are recorded by an inspector, appraisal items are computed by FHWA's NBI Edit/Update Program based on values of two or more other NBI rating items. The rating scale for appraisals is as follows (FHWA 1995):

- 9 = Superior to present desirable criteria
- 8 = Equal to present desirable criteria
- 7 = Better than present minimum criteria
- 6 = Equal to present minimum criteria
- 5 = Somewhat better than minimum adequacy to tolerate being left in place as is
- 4 = Meets basic minimum tolerable limits to be left in place as is
- 3 = Basically intolerable, requiring a high priority of corrective action
- 2 = Basically intolerable, requiring a high priority of replacement
- 1 = This value of rating not used in appraisals
- 0 = Bridge closed
- N = Not applicable

TABLE 2

NBI RATINGS FOR BRIDGE DECKS, SUPERSTRUCTURE, AND SUBSTRUCTURE

Rating	General Description of Condition
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION: no problems noted.
7	GOOD CONDITION: some minor problems.
6	SATISFACTORY CONDITION: structural elements show some minor deterioration.
5	FAIR CONDITION: all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
4	POOR CONDITION: advanced section loss, deterioration, spalling, scour.
3	SERIOUS CONDITION: loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION: advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION: major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structural stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION: out of service—beyond corrective action.
N	Not applicable.

Source: FHWA 1995.

Structural Deficiency and Functional Obsolescence

The NBI ratings are used to compute two measures of deficiency in bridge condition and performance: Structural Deficiency (SD) and Functional Obsolescence (FO). These designations are important because (1) they call attention to important bridge structural or functional needs; (2) they shape the public's and stakeholders' perceptions of bridge condition and performance that are obtained from annual statistical summaries of NBI data and the biennial bridge Conditions and Performance report to Congress; and (3) they are part of the discussions of bridge program funding at federal, state, and local levels.

TABLE 3
NBI RATINGS FOR CULVERTS

Rating	General Description of Condition
9	No deficiencies.
8	No noticeable or noteworthy deficiencies that affect the condition of the culvert. Insignificant scrape marks caused by drift.
7	Shrinkage cracks, light scaling, and insignificant spalling that does not expose reinforcing steel. Insignificant damage caused by drift with no misalignment and not requiring corrective action. Some minor scouring has occurred near curtain walls, wingwalls, or pipes. Metal culverts have a smooth symmetrical curvature with superficial corrosion and no pitting.
6	Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spalls on concrete or masonry walls and slabs. Local minor scouring at curtain walls, wingwalls, or pipes. Metal culverts have a smooth curvature, nonsymmetrical shape, significant corrosion, or moderate pitting.
5	Moderate to major deterioration or disintegration, extensive cracking and leaching, or spalls on concrete or masonry walls and slabs. Minor settlement or misalignment. Noticeable scouring or erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection in one section, significant corrosion, or deep pitting.
4	Large spalls, heavy scaling, wide cracks, considerable efflorescence, or opened construction joint permitting loss of backfill. Considerable settlement or misalignment. Considerable scouring or erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection throughout, extensive corrosion, or deep pitting.
3	Any condition described in Code 4 but which is excessive in scope. Severe movement or differential settlement of the segments, or loss of fill. Holes may exist in walls or slabs. Integral wingwalls nearly severed from culvert. Severe scour or erosion at curtain walls, wingwalls, or pipes. Metal culverts have extreme distortion and deflection in one section, extensive corrosion, or deep pitting with scattered perforations.
2	Integral wingwalls collapsed; severe settlement of roadway due to loss of fill. Section of culvert may have failed and can no longer support embankment. Complete undermining at curtain walls and pipes. Corrective action required to maintain traffic. Metal culverts have extreme distortion and deflection throughout with extensive perforations due to corrosion.
1	Bridge closed. Corrective action may put back in light service.
0	Bridge closed. Replacement necessary.
N	Not applicable—used if structure is not a culvert.

Source: FHWA 1995.

Structural Deficiency

An inspected bridge is *structurally deficient* if at least one structural rating item, whether condition or appraisal, is rated poor or worse. The structural rating items used to evaluate bridge deficiency are listed in Table 4. The conditions of bridge structures are rated using Items 58–60; the condition of culverts more than 20 ft in length are rated by Item 62. The criteria for poor or worse are also shown in Table 4 in terms of NBI rating values. The implications of this rating approach are that (1) a designation of SD may be triggered by any one of the items in Table 4, (2) a bridge rated as SD does not differentiate whether only one or many items in Table 4 were rated poor, and (3) an SD classification does not convey the causes of the poor ratings. Recent congressional testimony has described, for example, how poor ratings might result from deficiencies that do not reflect overall bridge structural integrity (Bizjak 2007; Kerley 2007, p. 7). SD is thus a coarse measure. SD signals a bridge problem requiring further attention, but in and of itself does not communicate details of the causes or implications of poor rating(s).

TABLE 4
STRUCTURAL DEFICIENCY CRITERIA

NBI Rating Item Number	Structural Item Rated	Type of Rating	Criterion for Poor or Worse
58	Deck rating	Condition	<5
59	Superstructure rating	Condition	<5
60	Substructure rating	Condition	<5
62	Culvert rating	Condition	<5
67	Structural evaluation	Appraisal	<3
71	Waterway adequacy	Appraisal	<3

Note: FHWA and FTA 2006.

The FHWA has observed that the primary reason to classify bridges as structurally deficient is a low condition rating. Eighty percent of structurally deficient bridges nationwide are so classified because of their condition ratings; 20%, because of their appraisals (FHWA and FTA 2006). The two are not mutually exclusive—that is, a bridge may be deficient in both its condition rating and its appraisal.

Functional Obsolescence

An inspected bridge is *functionally obsolete* if—

- it is *not* already structurally deficient; and
- it is deficient in terms of its geometry, clearance, or load capacity.

The NBI rating items that are considered when determining FO and the criteria used to determine whether an item is deficient are shown in Table 5. With one exception, these appraisal items are all computed from other NBI item ratings by the NBI Edit/Update Program.

TABLE 5
FUNCTIONAL OBSOLESCENCE CRITERIA

NBI Rating Item Number	Functional Item Rated	Criterion for Poor or Worse
67	Structural evaluation (function of load capacity)	=3
68	Deck geometry	<4
69	Underclearance (over highway)	<4
71	Waterway adequacy	=3
72	Approach roadway alignment	<4

Note: FHWA and FTA 2006.

Rating items 67 and 71 overlap the structural and functional evaluations (see Tables 4 and 5). If either of these ratings equals 3, then the bridge is not considered structurally deficient, because the problem can still be corrected (refer to the definition of the nine-point appraisal scale mentioned earlier). However, because a rating of 3 implies that bridge load capacity or waterway adequacy is too low to be tolerable, the bridge is characterized as functionally obsolete. If either of these ratings falls below 3, the bridge is considered structurally deficient (FHWA and FTA 2006).

Item 72, Approach Roadway Alignment, is an exception to the explanation of appraisal items described earlier. Rather than comparing this alignment with current design standards, the existing approach alignment is compared with the existing bridge alignment. Ratings are assigned based on the ability of the two alignments, functioning together, to permit traffic to enter the bridge without significant speed reduction.

If a bridge's ratings are such that it is both structurally deficient and functionally obsolete, it is reported in the NBI database as structurally deficient. SD takes precedence over FO in reporting bridge status. A bridge is listed as functionally obsolete *only* if it is not structurally deficient.

Sufficiency Rating

The Sufficiency Rating (SR) ranges from a value of 100 (best) to 0 (worst). It includes four rating components (FHWA 1995):

- Structural Adequacy and Safety, S_1 – maximum value = 55
- Serviceability and FO, S_2 – maximum value = 30
- Essentiality for Public Use, S_3 – maximum value = 15
- Special Reductions, S_4 – a deduction from SR, maximum absolute value = 13

Each of these rating components is defined here. Figure 2 provides a graphic representation of these SR components. Note that the structural and the functional components of SR, S_1, and S_2, respectively, are different from SD and FO in the preceding section.

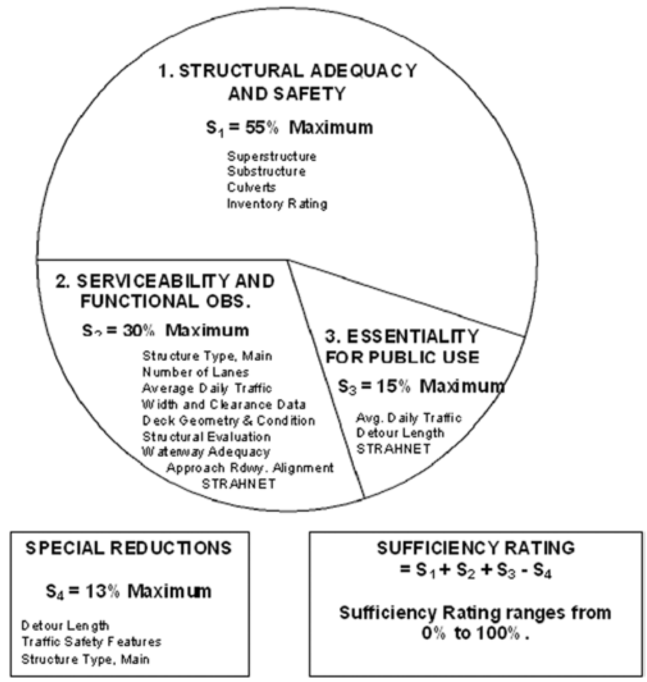

FIGURE 2 Sufficiency rating components (*Source:* FHWA 1995). *Note:* Obs. = Obsolescence; Rdwy. = Roadway; STRAHNET = Strategic Highway Network.

- **Structural Adequacy and Safety,** S_1, is a function of the following rating items:
  - Item 59, Superstructure;
  - Item 60, Substructure;
  - Item 62, Culverts; and
  - Item 66, Inventory rating (a measure of load capacity).
- **Serviceability and FO,** S_2, is a function of the following rating items:
  - Item 28, Number of lanes on the structure;
  - Item 29, Average daily traffic (ADT);
  - Item 32, Approach roadway width;
  - Item 43, Structure type, main;
  - Item 51, Bridge roadway width;
  - Item 53, Vertical clearance over deck;
  - Item 58, Deck condition;
  - Item 67, Structural evaluation (a function of load capacity);
  - Item 68, Deck geometry;
  - Item 69, Underclearance;
  - Item 71, Waterway adequacy;

  - Item 72, Approach roadway alignment; and
  - Item 100, STRAHNET (Strategic Highway Network) Designation (a network comprising about 61,000 miles, including the Interstate system, to serve national defense needs).
- **Essentiality for Public Use,** S_3, is a function of the ratings of the following bridge items:
  - Item 19, Detour length;
  - Item 29, ADT; and
  - Item 100, STRAHNET Highway Designation.
- **Special Reductions,** S_4, are a function of the ratings of items listed here. A Special Reduction is applied only when $S_1 + S_2 + S_3 \geq 50$; otherwise $S_4 = 0$. Relevant bridge items are:
  - Item 19, Detour length;
  - Item 36, Traffic safety features; and
  - Item 43, Structure type, main.

The rating components S_1 through S_4 are computed by a set of analytic procedures in the NBI database as a function of the respective NBI ratings listed earlier (FHWA 1995).

The SR is the total of S_1 through S_4: $SR = S_1 + S_2 + S_3 - S_4$, where S_4 represents a deduction. When all the NBI ratings listed earlier for S_1, S_2, and S_3 are at their maximum (best possible) value, $SR = S_1 + S_2 + S_3 = 100$, assuming $S_4 = 0$. As bridge structural, functional, or public use ratings decline, the values of S_1, S_2, and S_3 decline from their maximum values and $SR < 100$. By correcting structural problems, deficient geometry, or other problems represented in the rating items, bridge projects can restore SR to a higher value. Without any corrective measures, SR theoretically will continue to decline to its minimum (zero) value, at which point the bridge is no longer in service. If a bridge has an attribute that causes a Special Reduction—for example, a long detour route—its SR can never be at the theoretical maximum—that is, $SR < 100$ even when the bridge is new.

Implications for Bridge Management and Program Funding

The NBI measures of SD, FO, and SR are important to bridge management and to federal funding of bridge programs. The FHWA lists the number and percentage of SD and FO bridges on its website, and many agencies track these measures as key indicators of the success of their bridge programs. Table 6 gives these statistics for each state as of 2007, including bridges on National Highway System (NHS) as well as non-NHS highways.

NBI Ratings as Performance Indicators

The NBIS system of coding and recording bridge condition was designed to apply to the entire public highway bridge inventory in the United States. The NBI database currently includes almost 600,000 bridges of various designs, highway functional classes, traffic levels, and construction materials. The requirement for state DOTs, working with local governments, to inspect bridges periodically and submit NBI data to the FHWA annually ensures a nationwide consistency of method, a wide familiarity with NBI data and ratings, and a comprehensive, up-to-date database. NBI bridge ratings are specified at an aggregate level of structural component and are analytically simple. These characteristics are advantages in that they enable the NBIS to apply to a numerous and diverse nationwide bridge population. Because the approach depends on the skill and training of the certified bridge inspectors, this factor is addressed in detail in the federal regulations that govern the NBIS (23 CFR 650C). The FHWA has updated the NBIS rating items from time to time to address new problems—for example, the need for underwater inspections to protect bridges from scour, and the identification and need for inspection of fracture-critical members that, if degraded, could make the bridge vulnerable to further structural damage. Since its inception in the 1970s, the NBI database has compiled a detailed history of every bridge carrying a public highway in the United States, making it the most comprehensive and uniformly organized source of bridge condition data in the country. The NBI data are the basis of FHWA's identification of bridge needs, allocation of bridge program funding, and biennial reporting to Congress.

The NBI database and the computed SD, FO, and SR ratings have provided current and comprehensive data on bridge status and investment needs during the last 35 years. Today, however, the deficiency and sufficiency ratings are recognized to have shortcomings when applied to management or funding decisions. This chapter covers those shortcomings related to how the NBI ratings are formulated. Chapter three discusses how DOTs are working to compensate for shortcomings in NBI-rating decision support. Chapter four recaps key issues regarding NBI deficiency and sufficiency ratings that were presented in recent congressional testimony. These various concerns can be summarized as follows:

- The SD and FO ratings are coarse: Although they signal a potential problem, they do not distinguish between single versus multiple causes or their possible impacts, as discussed earlier.
- The SD, FO, and SR ratings are reactive; that is, they do not signal a bridge problem until it has already occurred. Moreover, they do not show an improved bridge condition unless *corrective* or *remedial* work is done. They are therefore unsuited to *preventive maintenance strategies* that could prevent or forestall bridge damage before it occurs and that could be more economical.
- The weights and formulas used to compute SRs are fixed and may be arbitrary as bridge designs, construction materials, vehicle loads, bridge investment strategies and priorities, and other factors continue to evolve.

TABLE 6
NBI STATISTICS ON BRIDGE DEFICIENCY, 2007

	No. of Bridges	No. of SD	No. of FO	No. SD or FO	Percent SD or FO
Alabama	15,881	1,899	2,158	4,057	25.5%
Alaska	1,229	155	179	334	27.2%
Arizona	7,348	181	600	781	10.6%
Arkansas	12,531	997	1,908	2,905	23.2%
California	24,184	3,140	3,837	6,977	28.8%
Colorado	8,366	580	824	1,404	16.8%
Connecticut	4,175	358	1,042	1,400	33.5%
Delaware	857	20	112	132	15.4%
Dist. of Columbia	245	24	128	152	62.0%
Florida	11,663	302	1,692	1,994	17.1%
Georgia	14,563	1,028	1,888	2,916	20.0%
Hawaii	1,115	142	358	500	44.8%
Idaho	4,104	349	452	801	19.5%
Illinois	25,998	2,501	1,840	4,341	16.7%
Indiana	18,494	2,030	2,004	4,034	21.8%
Iowa	24,776	5,153	1,455	6,608	26.7%
Kansas	25,461	2,991	2,372	5,363	21.1%
Kentucky	13,637	1,362	2,928	4,290	31.5%
Louisiana	13,342	1,780	2,180	3,960	29.7%
Maine	2,387	349	468	817	34.2%
Maryland	5,127	388	980	1,368	26.7%
Massachusetts	5,018	585	1,987	2,572	51.3%
Michigan	10,923	1,584	1,304	2,888	26.4%
Minnesota	13,067	1,156	423	1,579	12.1%
Mississippi	17,007	3,002	1,315	4,317	25.4%
Missouri	24,071	4,433	3,108	7,541	31.3%
Montana	4,980	473	541	1,014	20.4%
Nebraska	15,475	2,382	1,241	3,623	23.4%
Nevada	1,705	47	156	203	11.9%
New Hampshire	2,364	383	358	741	31.3%
New Jersey	6,448	750	1,501	2,251	34.9%
New Mexico	3,850	404	294	698	18.1%
New York	17,361	2,128	4,518	6,646	38.3%
North Carolina	17,783	2,272	2,787	5,059	28.4%
North Dakota	4,458	743	249	992	22.3%
Ohio	27,998	2,862	4,001	6,863	24.5%
Oklahoma	23,524	5,793	1,614	7,407	31.5%
Oregon	7,318	514	1,155	1,669	22.8%
Pennsylvania	22,325	5,802	3,934	9,736	43.6%

TABLE 6 (*Continued*)
NBI STATISTICS ON BRIDGE DEFICIENCY, 2007

	No. of Bridges	No. of SD	No. of FO	No. SD or FO	Percent SD or FO
Rhode Island	748	164	232	396	52.9%
South Carolina	9,221	1,260	808	2,068	22.4%
South Dakota	5,924	1,216	261	1,477	24.9%
Tennessee	19,838	1,325	2,776	4,101	20.7%
Texas	50,271	2,186	7,851	10,037	20.0%
Utah	2,851	233	254	487	17.1%
Vermont	2,712	500	467	967	35.7%
Virginia	13,417	1,208	2,234	3,442	25.7%
Washington	7,651	400	1,661	2,061	26.9%
West Virginia	7,001	1,058	1,515	2,573	36.8%
Wisconsin	13,798	1,302	789	2,091	15.2%
Wyoming	3,030	389	231	620	20.5%
Puerto Rico	2,146	241	822	1,063	49.5%
Totals	599,766	72,524	79,792	152,316	25.4%

Source: FHWA 2007b.
Note: Table for 2007. Data reflect bridges on NHS and non-NHS highways.
SD = structurally deficient; FO = functionally obsolete.

- The SD and SR ratings are somewhat inconsistent with respect to bridge decks. Although SD directly reflects a deck condition that is poor or worse, the SR is much less sensitive: A deduction for poor or worse deck condition in the Serviceability and FO calculation subtracts at most 3% to 5% from the SR value. Moreover, deck condition is not included in the Structural Adequacy and Safety component of SR.
- No generally accepted and used set of predictive models exists for SD, FO, and SR. The models that have been developed to date are for specific agencies and purposes as discussed later and are not in general use. Lacking such deterioration or performance models, agencies cannot forecast trends in deterioration of SD, FO, and SR. The lack of such models precludes using NBI ratings to predict future bridge needs; quantify the benefits of future bridge investments; analyze different scenarios regarding infrastructure policy, performance, and cost; and assess resource allocation trade-offs.

Chapter three provides examples of other technical measures of bridge condition and performance that DOTs have developed to overcome some of these drawbacks.

Funding Implications

> Utilization of the NBI as the primary data source for the disbursement of funds through HBRRP [Highway Bridge Replacement and Rehabilitation Program, now the Highway Bridge Program] and the Special Bridge Program has been the basis for bridge management decision making since the early 1970s (Small et al. 1999, A-1/2).

The FHWA specifies four criteria based on NBI data that must all be met for a bridge to qualify for federal Highway Bridge Program (HBP) funding (FHWA 2006):

- The bridge must be longer than 20 ft (NBI Item 49), be a highway bridge that carries a public road, and be included in the NBI database.
- The bridge must be classified as either structurally deficient or functionally obsolete.
- The bridge must have an SR of 80 or less to qualify for federally funded rehabilitation, or an SR of less than 50 to be eligible for federal funding of its replacement.
- The bridge cannot have been built or replaced (NBI Item 27) or rehabilitated or reconstructed (NBI Item 106) within the last 10 years, regardless of the source of funding (the "10-year rule").

The requirements for an SD or FO rating and the SR thresholds were an attempt to give greatest priority to those bridges that had greatest need for work (essentially a "worst-first" criterion) (23 CFR 650D). The FHWA imposed the 10-year rule "[to prevent] a bridge from remaining in a deficient classification after major reconstruction and thereby affecting the bridge fund apportionments to a State" (FHWA n.d.). Recently, the FHWA has clarified these provisions with respect to the eligibility of structurally deficient bridge decks for HBP funding (Lwin 2007). Structurally deficient bridge decks that require rehabilitation or replacement are eligible for federal funding regardless of the bridge's SR or requirements of the 10-year rule, consistent with the provisions of

SAFETEA-LU. Specific guidelines for decks include the following (Lwin 2007):

- Such bridge work is to be considered rehabilitation under the HBP regardless of the bridge's SR.
- Although the 10-year rule will not prevent federal funding of deck rehabilitation or replacement, once this work is performed, the 10-year rule will apply.
- Deck rehabilitation or replacement projects should be identified systematically, in conjunction with a comprehensive BMS, to use federal and other bridge funds wisely.
- This bridge-deck eligibility does not relieve the bridge owner of having to perform other work needed to restore bridge structural integrity or to correct safety deficiencies.

This clarification addressed several concerns expressed in 2007 congressional testimony regarding the eligibility of structurally deficient bridge decks for HBP funding. The key points that were presented in this testimony are discussed in Chapter 4.

Predictive Models for NBI Measures

The NBI condition and performance ratings are aggregate measures, sufficiently general to apply to the many combinations of bridge designs, materials, traffic loadings, and geographic locations throughout the country. It is therefore difficult to develop a general set of predictive models that could apply to the many different bridge configurations nationwide.

> This form of bridge management [based on NBI data] utilizes aggregated information and thus has limited applicability for analytical decision making. While the formula is convenient for funds allocation, it is not necessarily sufficient for analysis and needs prediction. … A new form of bridge management decision support to facilitate budgeting, policy analysis and project-programming [came to be] desired (Small et al. 1999, p. A-1/2).

Today's BMSs, which are alluded to at the end of the preceding quotation, employ more detailed descriptions of bridge elements and individual deterioration models for each group of elements. These systems are discussed in the next section.

A few DOTs have sought to take advantage of the wide coverage, ready availability, and rich content of their NBI database by formulating predictive models tailored to their own state practices and geographic conditions. In some cases, these models predict the change in NBI ratings on a scale of 0 to 9 (Michigan DOT, see Juntunen 2003) or the numbers of bridges in different SR intervals (Louisiana Department of Transportation and Development; see Sun et al. 2004). In other cases, yet newer models are being estimated for uniquely defined bridge indexes that individual DOTs are developing based on selected NBI rating items (see chapter three for examples of these indexes). Because a single agency deals with a smaller number of bridge designs and construction materials than those encountered nationwide, state DOTs are able to subdivide their bridge populations more easily into distinct groups for which modeling becomes more practical.

A needs forecasting model has been developed for use with the entire nationwide NBI database. The FHWA applies this predictive tool, NBIAS (National Bridge Investment Analysis System), when preparing its bridge-related needs estimates for submittal to Congress in the biennial Conditions and Performance reports. NBIAS draws on the information in the complete NBI database and on a set of unique analytic techniques based in part on the methodology and data in Pontis, a full-featured BMS used in more than 40 state DOTs (e.g., for element-level deterioration models and default values of required data such as unit costs). Users may specify key input parameters such as standards for bridge structural preservation and functional improvement. The predictive models for bridge deterioration require element-level data describing the bridge network, information much more detailed than that in the NBI database. For example, element-level data would require descriptions and condition information on each bridge girder rather than a single numerical rating for the entire superstructure as in the NBI database. NBIAS therefore incorporates a unique set of Synthesis, Quantity, and Condition (SQC) models that draw on current NBI data to estimate the quantity and condition of all the bridge elements in the NBI—that is, the element-level data are "synthesized" from the NBI data. SQC models were derived from a statistical study of more than 10,000 bridges representing structural and materials configurations from throughout the country. NBIAS has continued to be enhanced since its initial use in the 1999 Conditions and Performance report to permit greater user flexibility and to improve the reliability of its estimates (FHWA and FTA 2006).

BRIDGE MANAGEMENT SYSTEMS

Background

Development of new BMSs with more advanced decision-support capabilities began in the United States in the 1980s and continued through the 1990s. BMS designs and implementations were pursued independently by several DOTs, including North Carolina, Pennsylvania, Kansas, New York, Indiana, and Texas. The FHWA sponsored a demonstration project that led to the development of Pontis (Small et al. 1999). Today, Pontis is an AASHTOWare product maintained as part of AASHTO's BRIDGEWare suite, and is used by more than 40 state DOTs plus other transportation agencies. DOTs that are not Pontis licensees may employ state-specific systems. Agencies in other countries likewise have the option of licensing Pontis or developing their own BMS. Examples of two U.S. BMSs that illustrate two ends of the analytic spectrum at which these systems operate follow.

Alabama Bridge Information Management System

System Description

Some BMSs focus on database management—for example, input, quality checking, and processing of bridge data, and production of reports. The Alabama Bridge Information Management System (ABIMS) provides a series of bridge inventory and inspection menus by which users may input bridge descriptive information and inspection data. Another set of menus allows users to specify reports on, for example, bridges due for inspection, status of maintenance, bridge posting status, the rating history of a bridge structure, a variety of inventory listings, and priority ranking. The criterion for priority ranking may be specified as either the FHWA SR or the state's unique Deficiency Point calculation. The latter report may be tailored according to Deficiency category—for example, Total Deficiency, Load Deficiency, Vertical Clearance Deficiency, Width Deficiency, Condition Deficiency, and Statewide Deficiency (Alabama DOT 2006). This example illustrates one measure of value of a BMS: the ability to address unique aspects of bridge operation and customized features of bridge management. ABIMS is able not only to calculate Deficiency Points from NBI inspection data (together with SD, FO, and SR), but also to accommodate nonstandard legal loads in its bridge load rating calculations.

Reports

The ABIMS database is a repository of descriptive information on bridge structural characteristics, traffic loads, geographic and route location, functional class, and age, as well as current and historical records of inspection data. NBI data are included for annual reporting to the FHWA, and custom data defined by the agency are also included. Standard reports focus on breakouts of bridge characteristics, bridge condition, and information on related management tasks such as inspection and maintenance. Following are examples of the types of reports that are available:

- Separate reports presenting a complete **list of bridges** currently in the inventory, a list of structures categorized by **current operational status** (e.g., now in design or construction, in service, or out of service), and a list of bridges organized by **special categories** (e.g., those with underwater substructure, those with fracture-critical members, and those with certain NBI structural condition, waterway adequacy, and scour ratings of 3 or less). **Inventory cross-referencing** information is listed on another report.
- A list of **bridges by route**.
- A report of bridge **NBI ratings Structure, Inventory, and Appraisal (SI&A) and load testing** by structure. A supplementary report provides **historical trends in NBI ratings** for a structure.
- A report listing bridges by their **SR priority**.
- A list of bridges **scheduled for inspection**, with inspection due date.
- A list of bridges showing **current maintenance needed**.
- A list of bridges showing their **current posting status**.
- A list of bridges indicating those with **data errors** that have been identified in the FHWA edit report.
- A report relating **bridge projects to road projects** identified in the agency's construction project management system, identifying **bridge replacement projects** and **other types of projects** (e.g., bridge painting).
- Reports on **specific bridge characteristics**; for example, engineering and site conditions for scour-critical bridges.

If an agency has defined its own measure of condition and performance, an additional set of reports likely will be available to display this information. In this example for Alabama DOT, the ABIMS system provides a list of bridges by priority in terms of several categories of Deficiency Points: Total, Load, Vertical Clearance, Width, Condition, and Statewide.

A manager can tailor the ABIMS reports to focus on particular areas of interest. These may be geographic (district, city, or county); for certain reports, the particular bridges to be shown (e.g., identified by Bridge Identification Number or by route-milepost limits); for inspection and maintenance reports, the inspection responsibility code or the maintenance responsibility code for which records are to be displayed; the type of inspections to be displayed (e.g., those on 24-month intervals versus intervals less than 24 months); the specific maintenance activities to be displayed; for reports on historical records, the years to be displayed; and so forth.

All of these reports represent current or historical snapshots of bridge status. Some categories of reports, such as those related to identified bridge needs and actual maintenance work performed, or reports related to explanations of bridge engineering characteristics, may be available in both summary and detailed formats. Because the BMS has no predictive models, there are no forecasts, scenario analyses, or other future-oriented reports.

Pontis

System Overview

Pontis was developed for the FHWA in 1989 and is now supported through AASHTOWare as a product in AASHTO's BRIDGEWare suite. It is licensed as of 2008 to DOTs in more than 40 states and the District of Columbia, as shown in Figure 3 (Johnson 2008), plus several city, county, and international agencies. It is a full-featured BMS that provides a number of capabilities useful in supporting bridge program management and resource allocation (Cambridge Systematics, Inc. Jan. 2005b):

- Bridge Inventory: Establish and maintain an inventory of bridge and culvert information, and exchange data with other agency information systems.
- Managing Inspections: Schedule bridge inspections, enter or importing inspection data, produce SI&A and other inspection reports, and produce the NBI files that are required to be submitted to the FHWA annually.
- Needs Assessment and Strategy Development: Estimate and update bridge element deterioration and treatment cost models based on individual agency experience; develop long-range, network-level policies for both structure preservation and bridge improvement based on agency standards or guidelines and economic factors, including agency and road-user costs; assess current and future preservation and improvement needs; and evaluate alternative bridge program investment scenarios based on predicted structure condition and performance, accounting for the technical, economic, and policy-related factors described previously.
- Project and Program Development: Develop projects to respond to inspector work recommendations and agency policies and standards; evaluate the impacts of project alternatives on structure performance; rank projects; develop programs of projects subject to budget constraints; and track project status and completion.

Representation of Structural Elements

Pontis describes bridge and culvert structures in more detail than the NBI offers. Bridges are expressed in terms of their structural elements. Some examples for different types of bridges include girders, stringers, and beams; truss components; arches; pin and hanger assemblies; deck and deck slab; railings and traffic barriers; deck joints; bearings; piers and columns; abutments, approach slabs, and wing walls; and footings and pilings. These elements may be described for bridges as a whole, or within sections with varying characteristics termed "structure units," as illustrated in Figure 4 (Cambridge Systematics, Inc. 2005b). By contrast, the NBI would represent the bridge structure in Figure 4 by the more general components of superstructure, substructure, and deck.

Pontis' analytic approach is built around structural elements. A brief discussion helps to illustrate the difference between element-level descriptions of bridge condition versus the NBI ratings described earlier. Some examples are as follows:

- Bridge inspections are conducted at the element level. AASHTO has formalized these inspection procedures within its guide for "commonly recognized" (CoRe) elements (AASHTO 1997). Although this guide was based on the Pontis approach, it has been generalized to apply to other BMS in addition to Pontis. Agencies may also define their own elements within Pontis.

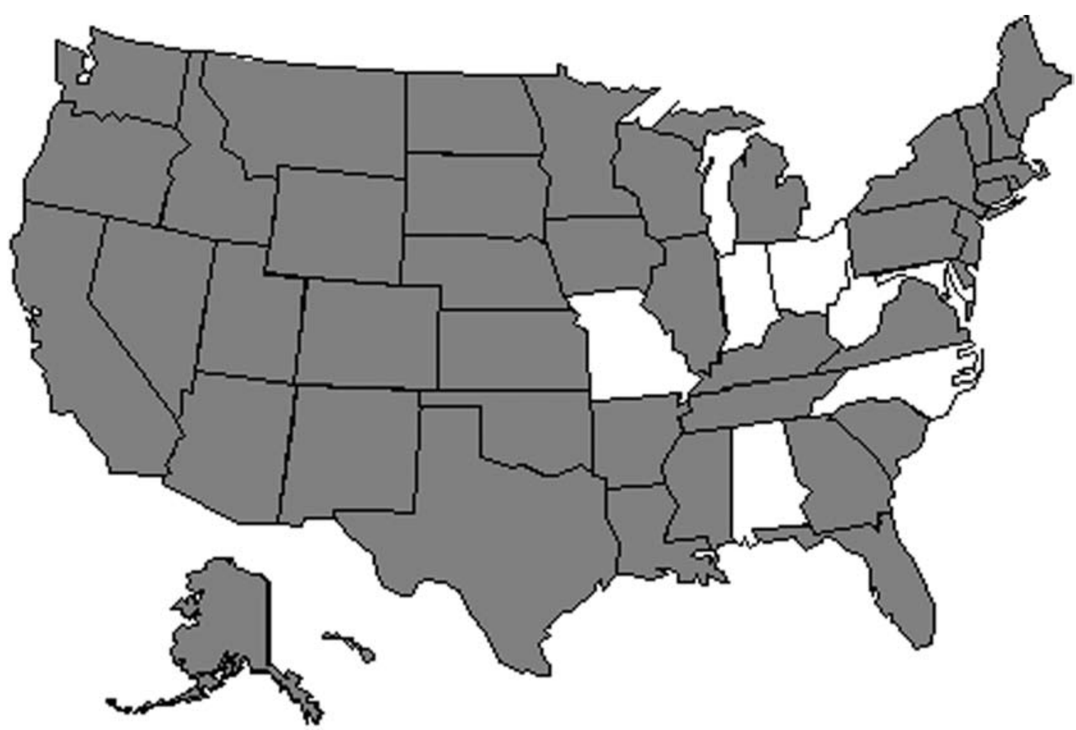

FIGURE 3 U.S. state agencies licensing Pontis as of 2008 (*Source:* Johnson 2008).

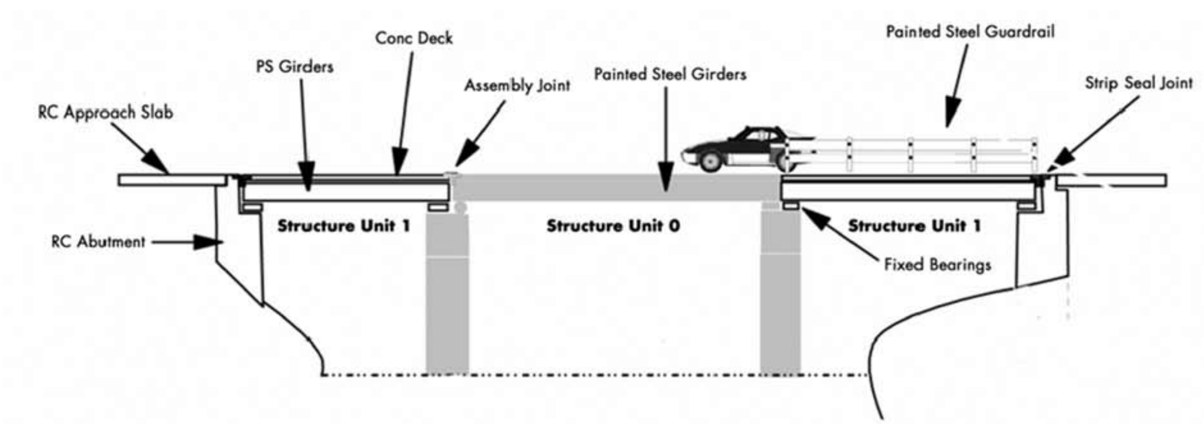

FIGURE 4 Structure units and elements in Pontis (*Source:* Cambridge Systematics, Inc. 2005b). *Note:* PS = painted steel; RC = reinforced concrete.

Some agencies inspect bridges at the element level and then apply a Translator program in Pontis (developed for the FHWA) to convert element-level data to the format required for NBI submittals. Other agencies conduct dual inspections, recording bridge conditions at both the element level and in NBI format. State DOTs also may develop supplementary inspection guides to accommodate state-specific bridge, traffic, or other data requirements.

- Structure condition is defined at the element level in terms of up to five discrete "condition states." The best condition is specified in condition state 1, and the worst condition in the last condition state (condition state 3, 4, or 5, depending on the element). The percentage of each element in each condition state is computed by Pontis in each time period and is available in a report. This breakdown describes the condition distribution of that element, allowing a manager to get a better perspective on the magnitude of network-level deficiency. CoRe elements have predefined condition state descriptors. For example, the condition states for element 152, Painted Steel Floor Beam, and element 313, Fixed Bearing, are as follows (condition states are identified using a CS number convention):
  – Painted Steel Floor Beam: CS-1, no corrosion; CS-2, paint distress; CS-3, rust formation; CS-4, active corrosion; CS-5, section loss
  – Fixed Bearing: CS-1, no deterioration; CS-2, minor deterioration; CS-3, advanced corrosion
- Up to 10 preservation treatments or actions may be defined at the condition state level for each element. Pontis users may apply default actions or define their own preservation treatments.
  – Actions may range across alternatives such as Do Nothing, Routine or Preventive Maintenance, Minor Element Repair, Major Element Repair, Element Rehabilitation, and Element Replacement.
  – A specific example by condition state for element 313, Fixed Bearing, is as follows: CS-1, no deterioration: Do Nothing; CS-2, minor deterioration: either Do Nothing, or Clean and Paint, or Reset Bearings, and/or Rehabilitate Supports; CS-3, advanced corrosion: either Do Nothing, or Rehabilitate Supports or Bearings, or Replace the Bearing Unit.
- Bridge deterioration models and cost models are defined by the Pontis user for each element. Deterioration models are expressed through transition probabilities that describe the likelihood of an element condition changing from one condition state to another in a simulated cycle. Pontis users may estimate these probabilities when first applying the BMS, and later update them when historical data on element deterioration are available. Preservation costs are expressed for each defined treatment or action by element and condition state. Pontis users may enter costs of bridge improvements—for example, for bridge widening, strengthening, or raising to improve vertical clearance.
- Bridge elements may be located in different environments, which might influence rates of deterioration. The following environmental regimes are defined in Pontis (Cambridge Systematics, Inc. 2005b):
  – Benign—No environmental conditions affecting deterioration
  – Low—Environmental conditions create no adverse impacts or are mitigated by past actions or highly effective protective systems
  – Moderate—Typical level of environmental influence on deterioration
  – Severe—Environmental factors contribute to rapid deterioration. Protective systems are not in place or are ineffective.

Analytic Processes

Pontis' analytic processes are extensive and address several aspects of bridge management. Their descriptions are contained in system documentation (Cambridge Systematics, Inc. 2005a, b; FHWA 2007d). An overview of the sets of procedures, which are organized in "modules," is shown in Figure 5.

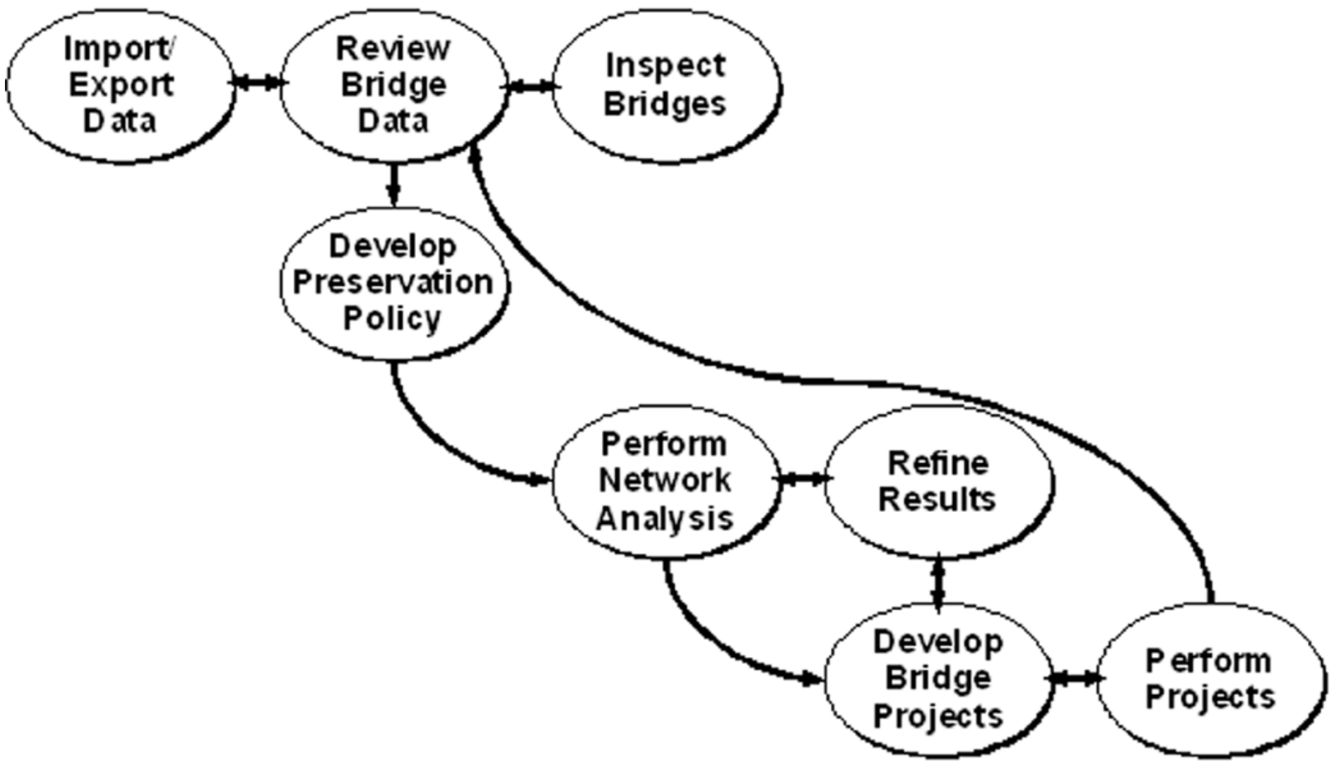

FIGURE 5 Overview of Pontis' analytic processes (*Source:* Cambridge Systematics, Inc. 2004).

The review and analysis of bridge data, including bridge inventory and inspection data, is handled through the Inspection module, which works with the database that is used in connection with Pontis. The data encompass the standard or default bridge elements and descriptors, the standard NBI data, and any custom data that the bridge manager has defined. The NBI Translator program may be applied to convert element-level data to the format required by the FHWA for NBI submittals. Other available processors include the SR program, which computes SR, SD, and FO status, and the Validation program, which conducts edit checks of the most recent NBI data.

Pontis conducts a comprehensive analysis of bridge preservation options to recommend a preferred strategy. This entails definition of a preservation policy for each combination of bridge element and environment. Other data items are also defined, including (1) treatments for each element and condition state, (2) corresponding unit costs, and (3) other technical and budgeting parameters. Similarly, specification of an improvement policy entails providing guidelines and costs for different types of bridge improvements; for example, widening and increasing clearances. Separate simulations and decision-support procedures are conducted for these two types of investments at the network level through the Pontis Program Simulation module. The network-level simulation accounts for the effect of budget constraints and supports estimates of bridge needs and decisions in programming, resource allocation, and budgeting. These analyses estimate impacts of future bridge investments in terms of benefits versus costs and the resulting condition of the bridge network.

The results of a Pontis simulation can be expressed in several ways (Cambridge Systematics, Inc. 2004):

- Condition distributions of structure elements
- Predictions of structure needs and work that is projected to have been accomplished
- The Pontis Health Index, which is the ratio of the current value of all structure elements (based on their current distribution of condition states) as compared with the total value of all elements (assuming all are in their best condition state)
- Benefits to both agency and road users as the result of preservation and improvement actions; for example, monetized benefits owing to improvements in the Health Index, and road-user benefits in terms of reduced travel time, vehicle operating, and accident-related costs as the result of bridge improvements
- NBI condition ratings for deck, superstructure, substructure, and culvert; deficiency status (SD, FO); NBI appraisal ratings; and calculation of the NBI SR
- Other measures, including the Health Index of subsets of elements, eligibility for HBP funding, and detail information for individual structures.

The Project Planning module focuses on projects for individual bridges. Projects are developed from results of the network-level analyses and from work candidates recommended by bridge inspectors. Projects can be assembled into programs. Once programs are defined, further network-level analyses can be run to refine results—for example, by varying the characteristics of scenarios, running what-if analyses, and adjusting policy specifications and costs to match agency business processes more closely.

Results can be viewed in reports as described here.

Customization Options

The ability to customize BMS features will be shown in chapter three to be an important aspect of BMS usefulness and acceptability. Pontis has features dedicated to incorporating user-defined additions or revisions within its analytic framework and graphical user display. A number of items may be customized, including the definition and classification of bridge elements, the definition and classification of bridge actions, the cost index that is used, internal formulas for data processing, and organization of the desktop and assignment of user privileges. Features such as data input forms and reports may be customized to accommodate the analytic revisions.

Reports

Pontis presents a broad selection of standard reports, reflecting its extensive features and functionality. The reports are organized by system modules and include the examples listed here. Reports are available in metric or English measurement units. If a report pertains to a given structure (as opposed, for example, to summaries for a bridge network), the bridge(s) may be selected using Pontis' Select Structure screen, which selects bridges by district, county, owner agency, custodian agency, function class, NHS or non-NHS, defined administrative area, defined bridge grouping, or inspector responsibility. These descriptions are adapted from the *Pontis Release 4.4 User Manual* (Cambridge Systematics, Inc. 2005b).

Inspection Reports present information on the bridge inventory, current and historical information on bridge condition and performance, and inspection schedules. Example reports include the following:

- The **SI&A sheet** lists for each bridge the NBI SI&A information, element-level condition data, and past inspection comments.
- The **Expanded SI&A** report includes notes recorded by the inspector regarding a bridge, bridge element, and inspection; work candidates specified by the inspector; and summary information on past inspections.
- The **Inspection Schedule** gives inspection planning and scheduling information, including the frequency of regular and special inspections, the date and inspector of the most recent regular and special inspections, and planned dates for the next inspections.
- The **Inspection Resource Requirements** report provides the dates of the last and the next scheduled inspections and planned resources needed in terms of estimated hours for the inspection crew, flaggers, helpers, snoopers (trucks with inspector baskets on articulated, telescoping arms that can reach overhead or under a bridge), special crews, and other special equipment.
- The **Bridge Health Index** displays the current Pontis Health Index for selected bridges plus detailed information about the condition distributions of bridge elements that are used to calculate the Index.
- The **Bridge Condition Summary** shows, for each selected facility, the most recent inspection date, the SD and FO rating, the SR, and NBI ratings for the deck, superstructure, substructure, culvert, and channel rating items.
- The **Network Element Summary** shows the network-wide distribution of bridge elements by environment and condition state.

Two reports present the results of the network-level modeling of **Bridge Preservation**:

- The **Unconstrained Needs** report displays the costs and benefits of the optimal preservation policy as applied to the bridge network when unconstrained by budget limits. The effect of the budget constraint is shown, however, in the distinction between those recommended projects that are "programmed" by Pontis (i.e., allowed by the budget limit) versus those that are not.
- The **Preservation Details** report identifies the recommended actions for each element in each type of environment and condition state, and compares the current distribution of bridge elements versus the distribution that would result from the optimal preservation policy applied over the long term. The report also provides the details on unit cost of each action, and the transition probabilities that were used in the deterioration model to determine the optimal policy.

In addition to the bridge preservation results cited previously, several standard reports provide information on **Bridge Needs and Projected Work**:

- The **Bridge Management Summary** reports the current requirements of the bridge inventory in terms of estimated future needs and programmed work by year. It helps managers to determine whether current investment levels can meet the optimal long-term investment policy recommended by Pontis.
- The **Backlog Summary** displays the annual budgeted amounts versus the backlog of unmet needs by year and work category: preservation, replacement, and improvement/other work.

- A **series of reports** displays the **costs and benefits of needed work and programmed work** for the bridge network by year in different formats—for example, for each element or set of selected elements; for each element, grouped by element category; for different combinations of element category and material type; for each district, functional class, on/off NHS, and on/off system classification; for each district and each scenario; for all combinations of values of district, functional class, on/off NHS, and on/off system classification; and overall costs and benefits by year.
- Two reports on performance measures: a **Bridge Performance Measures** report that displays performance measures by structure and year, and a **Network Performance Measures** report that displays performance measures for all combinations of values of district, functional class, on/off NHS, and on/off system classification.
- A **Scenario Report** displays the specifications for the currently selected scenario.

Project Reports produce information related to individual bridge structures:

- The **Preservation Needs** report displays preservation needs for individual structures that Pontis has generated for the currently selected scenario, and an indication of whether or not they have been programmed by the simulation. By selecting a particular year to display, a manager can identify whether needs for specific bridge(s) have been programmed (i.e., recommended as work candidates when budget constraints are considered).
- The **Work Candidates and Projects** report displays the proposed projects, inspector-specified work candidates, and Pontis-generated work candidates for all scenarios for a selected set of bridges. This report is useful to determine which work candidates have been addressed by projects.
- The **Project Priority List** displays projects sorted by program, year, and Pontis Program Rank. Managers may select a single year, a single *project status* (i.e., Initiated, Programmed, Deferred, In Progress, Completed), or an individual program to be displayed. If these fields are left blank, all projects will be selected. The Pontis Program Rank may be based on project benefits, costs, benefit-cost ratio, average Health Index, SR, or Agency Rank (e.g., a numerical score computed by the agency or a district-provided ranking).
- The **Pontis Priority List** displays Pontis-generated work candidates for a selected scenario and one or more selected years.
- The **Pontis Candidate List** displays Pontis-generated needs or work candidates for a selected set of bridges. Managers may select the groups of work to be included based on year, costs and benefits, whether work was programmed by the selected scenario, whether the work was assigned to a project, and other items available in the Pontis work-related data.
- The **Project Details** report is a one-page-per-project display of all information provided on the project data entry forms, including a list of work items. Projects may be selected for this report based on project ID, primary action type for the project (e.g., Replace Element, Overlay Deck, Replace Paint, or Replace Structure), the year for which the project is programmed, the project status, the program ID, and the district, route, and milepost/kilometer-post.
- The **Actual versus Budget** report compares the dollar value of programmed work by year to the annual budget that has been established for that program. The manager can specify the projects to be included in the programmed work totals in terms of project status criteria (i.e., one or more of the project status designations listed previously).
- The **Program Funding** report displays the funding sources and amounts by year for each active program.

CHAPTER THREE

APPLYING BRIDGE MANAGEMENT TO AGENCY DECISION MAKING

OVERVIEW

This chapter presents findings on bridge management and agency decision making that were gained through the study survey, literature review, and interviews. There is considerable material regarding past and current bridge management practices and how these processes and systems are applied to agency decision making. The chapter is organized as follows:

- The historical perspective outlines past bridge management practices and their applications to agency decision making based on several previous studies. This background provides a context for the current study findings.
- The section on current practices describes today's bridge management processes relating to condition and performance measures and targets, analysis of bridge needs in the context of available funding, resource allocation and prioritization, use of economic methods, and accountability and public communication.
- The next section on BMSs and their application to decision making presents additional information on current practices, focusing on the application of current BMS capabilities and information to planning, programming, and resource allocation.
- A final section on organizational responsibilities summarizes survey findings on those DOT units or other agencies that play material roles in various categories of bridge program and project decisions.

Additional survey-related information supporting the findings in this chapter is contained in Appendixes D and E.

HISTORICAL PERSPECTIVE

Synthesis Topic 27-09

NCHRP Synthesis Topic 27-09 (*Synthesis of Highway Practice 243* 1997) examined how state DOTs had responded to the planning and programming provisions of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and other factors that at that time were influencing capital programming and project selection. The passage of ISTEA contributed to a more dynamic decision-making environment characterized by a stronger linkage between public policy and transportation system planning and programming; a greater interest in quantitative measures and criteria of performance and accountability; increased roles of actors other than the state DOTs in planning, programming, and shaping the nature of selected projects; greater funding flexibility, prompting a need to investigate trade-offs in resource allocation among programs and projects; and innovative financing mechanisms involving the private as well as the public sector. Adding to this dynamic management environment were continuing trends in broad, sometimes conflicting policy directions; competition among agency programs for scarce resources; increasing emphasis on system preservation and more efficient system operation; and uncertainties in several pertinent management areas, including funding, project budgets and schedules, and policy shifts following new state administrations and DOT executive turnover. *NCHRP Synthesis 243* thus addressed methods used by DOTs for priority setting, and the types of quantifiable measures of policy objectives and system performance that they applied, among other topics (Neumann 1997).

The *NCHRP Synthesis 243* survey was structured to elicit information comprehensively and flexibly. Survey design incorporated open-ended responses that were not limited to particular types of assets or programs, allowing agencies to describe their methods and management systems exactly as they perceived them. Agency responses were therefore broadly cast; for example, encompassing pavement, bridge, safety, congestion, maintenance, drainage, and highway management; public transit and rail system management; major projects; program management and value engineering; economic development impacts; environmental impacts; and a number of state-specific management systems or priority methods. The results cited here include only those subsets of information that are relevant to this bridge management study.

The *NCHRP Synthesis 243* results established useful background and context for this current study. Conducted more than 10 years ago, the results of this synthesis can be compared with the current results to see where changes in practice and perspective, if any, have occurred. Overall, 39 state DOTs submitted responses to the *NCHRP Synthesis 243* survey, although the numbers responding to any specific question sometimes varied from this total. The sections here focus on bridge-related findings, with corresponding data for pavement management systems (PMS) and safety management systems (SMS) included for comparison.

Quantifiable Objectives and Performance Measures

Participants in the *NCHRP Synthesis 243* survey were asked whether they used quantifiable measures of program objectives or system performance—that is, measures of a program's impact on facility condition or service. Thirty-two DOTs (86% of respondents to this question) indicated that they used such measures or had them under development. These agencies were asked further to identify the types of measures they employ. Figure 6 shows selected measures and the percentages of the 32 affirmative respondents that identified each as one that they either used or were developing.

sis on asset condition and performance exceeded results for other program areas, which are not shown in Figure 6, such as capacity and safety measures. The importance of condition and performance of bridges and other assets as intended guidance for capital programming decision making was clear. These results also implied the importance of periodic inspections of assets in keeping condition and performance information current and accurate.

Only a handful of agencies cited measures involving benefit-cost, value-for-cost, and needs prioritization (e.g., relational evaluation of state needs). These measures were described generally and not identified with any particular asset. The implication is that economic or needs-related measures were not widely used in establishing objectives or performance measures.

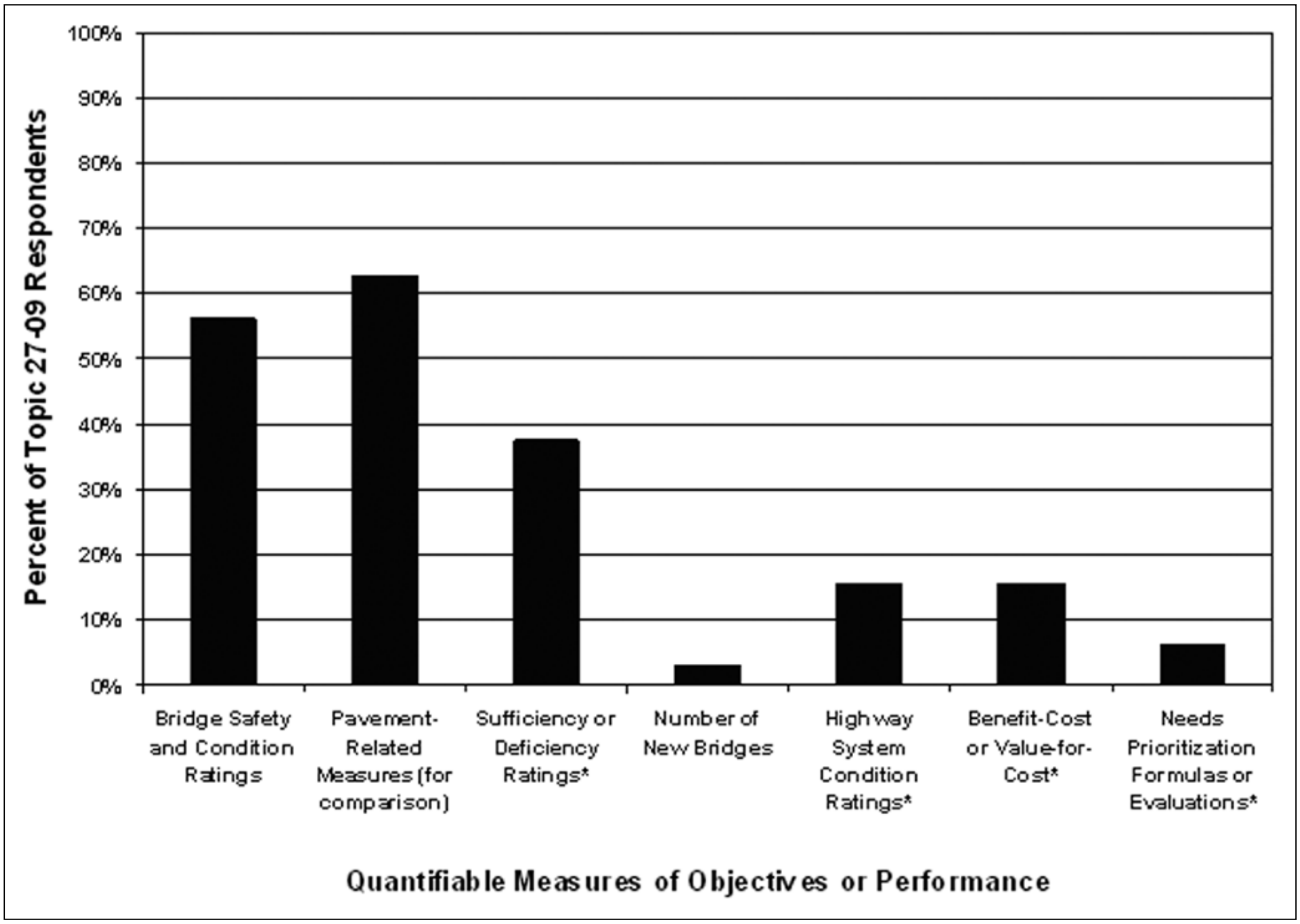

FIGURE 6 Measures of program objectives and system performance (*Source:* Neumann 1997).
Note: Because respondents could name more than one type of measure, data do not sum to 100%.
*No specific asset specified.

The results in Figure 6 demonstrate a strong leaning toward condition ratings for bridges and other assets. Bridge safety and condition ratings were identified by 56% of the agencies; pavement-related measures, by 63%; and sufficiency or deficiency ratings (pavements or bridges), by 38%. Five agencies also mentioned general highway system condition ratings, with no particular asset specified. This empha-

One agency identified the number of new bridges as a measure of objectives or performance. This agency also cited a corresponding measure of pavement output in kilometers built or resurfaced. *NCHRP Synthesis 243* noted that whereas only a few states volunteered productivity or program-delivery measures such as these, such measures historically have been an important component of tracking program accomplishments, and they likely will continue in that role. Although not discussed in *NCHRP Synthesis 243*, the few examples of delivery-based measures may also have been the result, in part, of increased attention to results-based rather than output-based measures, and in the bridge case specifically, to a growing emphasis on preservation and maintenance.

Use of Bridge Management Systems for Decision Making

A specific objective of *NCHRP Synthesis 243* was to investigate how agencies met post-ISTEA planning and programming requirements by applying management systems and related data. For example, pavement and BMSs were already in use by a number of agencies and, in some cases with PMS, for many years before the passage of ISTEA. Although the *NCHRP Synthesis 243* study was conducted after the use of these and other management systems was once again made voluntary, the study found that 87% and 79% of responding states had PMS and BMS, respectively, already available or under development. Much lower percentages of agencies (in all cases less than 40%) reported developing or using other management systems such as safety (SMS), intermodal, and congestion management. The key question that the *NCHRP Synthesis 243* study wanted to address, however, was the extent to which these systems were *actually being used* in capital programming and project selection. The survey for the 1997 report therefore asked DOTs which management systems they had and, of these, which were used in the following programming decisions:

- Developing goals; that is, desired system condition or service levels
- Establishing program funding levels
- Identifying specific projects and setting project priorities
- Evaluating capital maintenance allocations.

Of the 39 survey respondents, 38 reported having at least one management system operational or under development. Responses for selected systems are shown in Figure 7. In addition to the BMS, selected other systems have been included that may address bridge projects; only a handful of states reported these types of highway network or project management applications. Figure 7 shows that PMS, BMS, and SMS were the most widely implemented systems at the time of this survey. These three systems were evaluated in terms of their use in the four program management functions described earlier.

Figure 8 shows the rates of application of each of the three systems to the four programming functions at the time of the *NCHRP Synthesis 243* survey. In each case, the percentage using the system for decision support is computed on the basis of those states that already had, or were developing, the particular system; that is, the percentages of BMS use are based on 31 agencies (see Figure 7); for PMS, 33 agencies; and for SMS, 14 agencies. Roughly 55% to 75% of state DOTs were using these management systems to develop goals (likely based on current and projected condition and performance) and to identify projects and support project prioritization. Although the application for these two uses was greater than those for program funding levels or capital maintenance trade-offs (for BMS, less than 25% and 15%, respectively), the results nevertheless indicate that 25% to 45% of DOTs were not using their systems even for program goals or for prioritization. *NCHRP Synthesis 243* explains this lack of use for decision support in the following ways:

> It appears that many DOTs are using management systems primarily to record and monitor infrastructure conditions or are experimenting with different potential applications but have not determined what, if any, role the systems may play as decision support tools. [When compared to the number of agencies reporting that they have management systems, far] fewer agencies report the use of management systems for management decision making on a program level (Neumann 1997, p. 22).
>
> Some of this lack of use of the PMS or BMS to examine capital/maintenance funding tradeoffs reflects the varying approaches that transportation agencies have to the management of capital and maintenance funds. Eight DOTs report that their budgets for the two activities are completely segregated. Fifteen DOTs … [fully fund] a specified level of preventive maintenance/preservation … and then apply the remainder to capital expenditures. In contrast, six DOTs reported … [that they fully match] available federal aid, and then allocate remaining state resources to maintenance. While not specifically reported by any survey respondents, some agencies' management systems may not have the technical capability to look at both capital and maintenance actions (Neumann 1997, p. 23).

Survey respondents were asked about their perceptions on limits and barriers to management system use for decision making. Comments highlighted four general problem areas (Neumann 1997, pp. 23–24):

- **Problems with data collection**, including the need for more timely data acquisition and analysis and the difficulty of data integration.
- **Incomplete system development or implementation**, thus limiting functionality and requiring continuing service needs.
- **Limited usefulness of management systems to the programming process**, which reflected issues in a number of areas; for example, statutory requirements for infrastructure and the use of funds; the need to incorporate judgment regarding policy, liability, and financial capability with the technical data; the need for more subjective or qualitative judgments and decision factors that management systems did not provide; the adequacy of the then-current programming process; and a judgment that the benefits of management systems were not worth the additional expense.

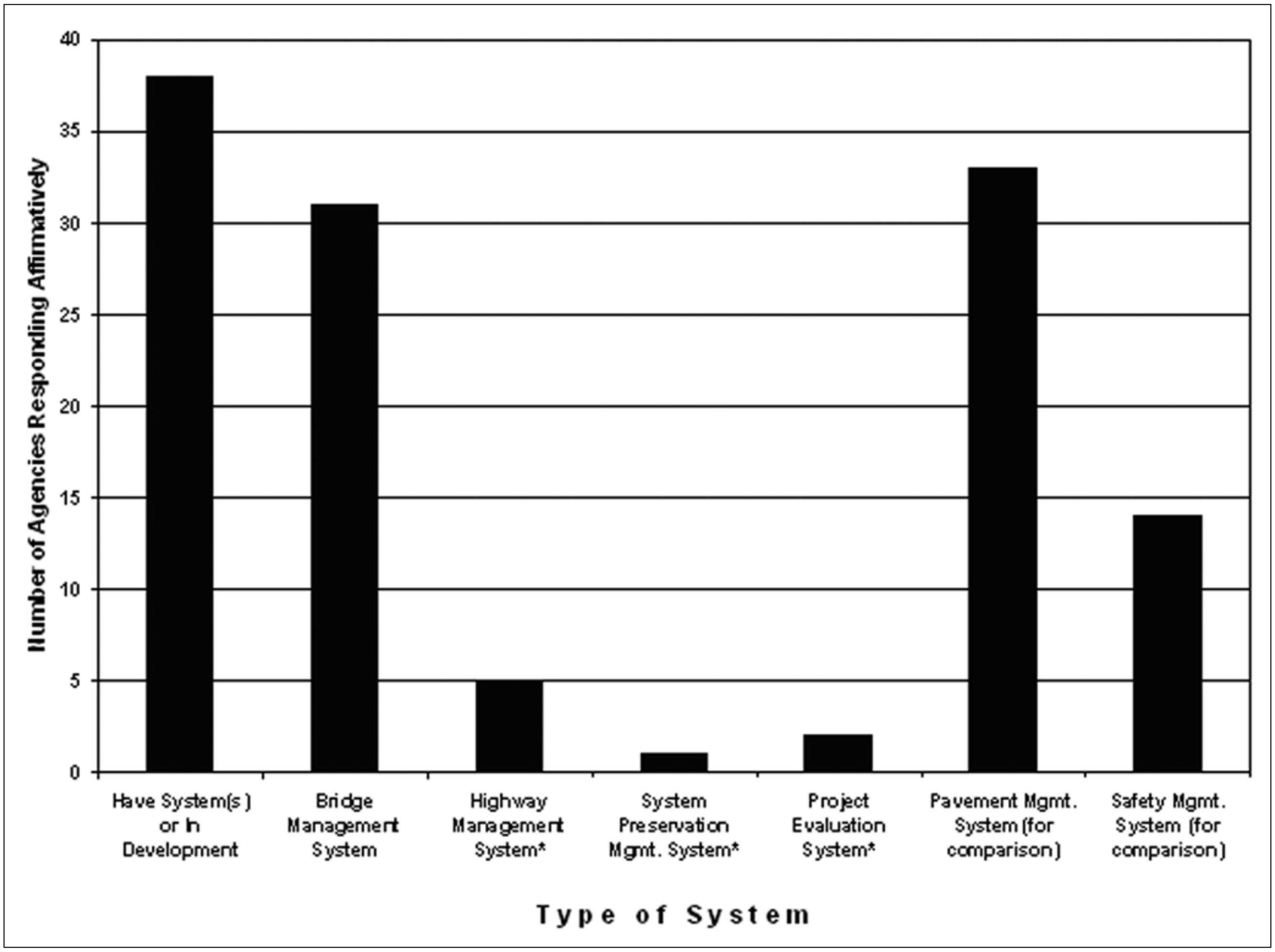

FIGURE 7 Agencies having management systems (*Source:* Neumann 1997).
Note: *No specific asset specified.

- **Resource limitations** on developing and implementing these management systems.

Priority Methods

The *NCHRP Synthesis 243* survey gathered additional details on a specific management function: prioritization. State DOTs were asked about their quantitative methods of priority-setting and to which programs or projects these applied. Methods potentially relevant to the current bridge management study included sufficiency or deficiency ratings, benefit-cost analysis, priority given to particular programs or their economic benefit (among other factors), and cost-effectiveness measures. Survey results are shown in Figure 9.

The first response under each method in Figure 9 shows the percentage of the 39 responding agencies that reported using that method. For example, 74% (29 agencies) used sufficiency or deficiency ratings for prioritization. The additional responses show the extent to which that method was used for specific programs or projects. In the case of sufficiency or deficiency ratings, bridge and pavement programs/projects were the predominant applications. It is likely that PMS and BMS assisted many agencies in this process. Other programs or projects (e.g., for safety, traffic, or major projects) were each prioritized by this method in only one or two states in the survey respondent pool.

The other prioritization methods in Figure 9 were likewise used by a significant percentage of responding DOTs: almost 70% applied benefit-cost analysis and more than 50% reported using the other methods shown. However, the program or project categories to which these methods were applied were quite different and did not include significant bridge-related use. *NCHRP Synthesis 243* made the following observations:

> Benefit-cost analysis is most frequently used to evaluate safety projects or highway improvement projects. Four [reporting] states use cost-benefit primarily for major highway capacity improvements or high-cost projects. … Cost-effectiveness approaches and other priority ratings [in Figure 9] are used across a broad range of categories with no one type of project being the primary focus (Neumann 1997, p. 20).

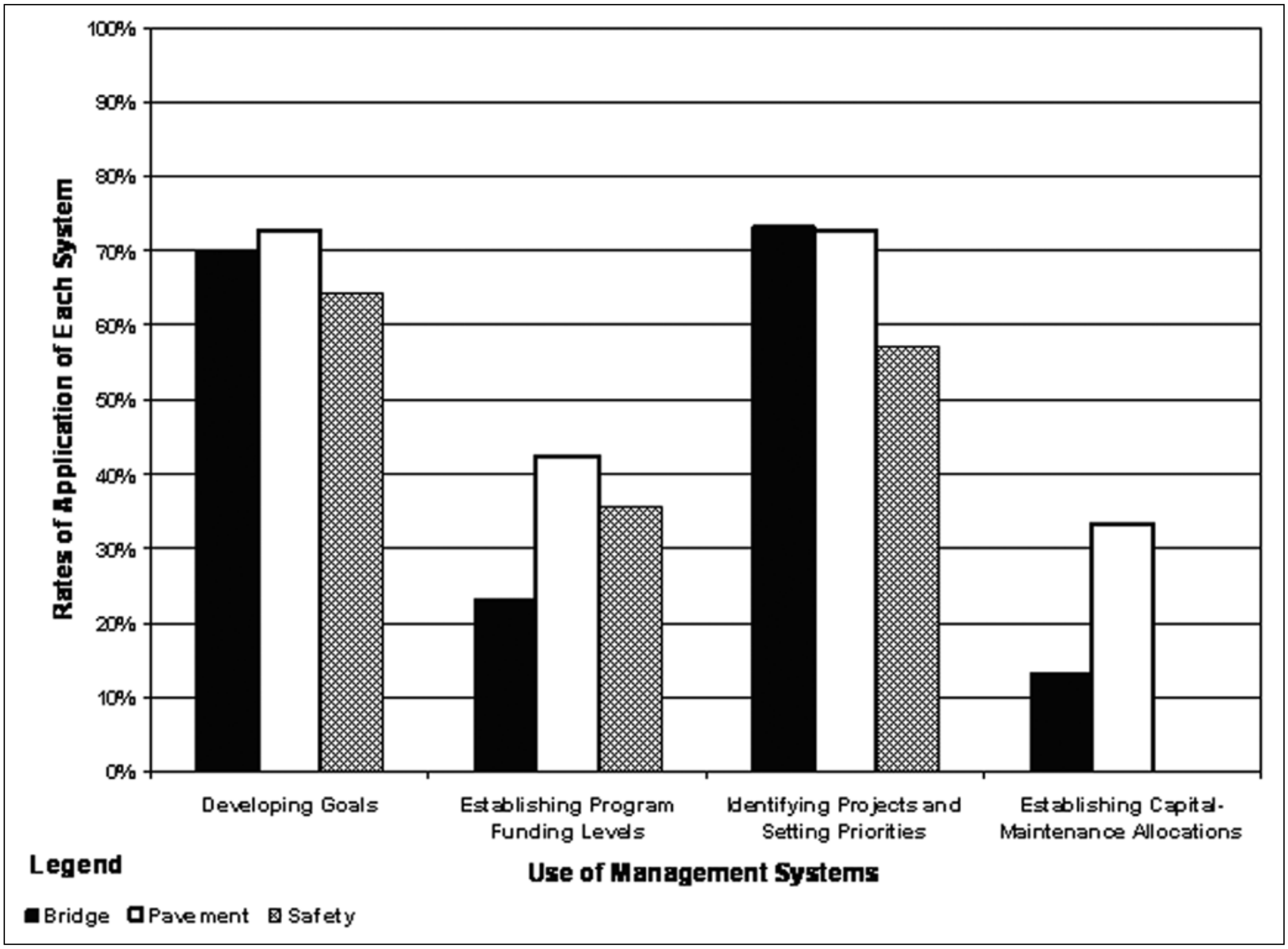

FIGURE 8 Use of management systems (*Source:* Neumann 1997).

Additional Comments

Throughout its discussion of the programming process, *NCHRP Synthesis 243* observed that capital programming ultimately reflects a mix of technical, policy, and financial considerations. Whereas the previous findings have presented policy objectives, performance measures, and prioritization primarily in technical terms, these functions operate in a much broader context in actual decision making on projects and programs. Perceived transportation needs; funding sources and constraints; transportation implications of statewide public policy; engineering philosophies regarding design, construction, maintenance, and replacement; the technical rigor desired in planning and programming; and a host of other factors all contribute to differences in state practice. *NCHRP Synthesis 243* also noted that state DOTs differ in their degree of centralization of capital programming decisions. Although program priority decisions are often made centrally, some agencies adopt a hybrid approach, with some program decisions being made in the central office, others by regions or districts. *NCHRP Synthesis 243* also observed that some agencies were moving toward a more decentralized approach to capital programming generally throughout their states.

FHWA Survey of Bridge Management System Practices

In 1999, Small and colleagues presented preliminary results of an FHWA survey of agency use of BMSs. The survey focused on activities including strategic and long-range planning, STIP and Transition Improvement Program (TIP) development, and project-level planning. It was supplemented by in-depth follow-up discussions with state DOT personnel. In all, 40 survey responses had been processed at the time of paper preparation, and 26 had been finalized with the follow-up interviews. The paper by Small and colleagues discussed these 26 results, comprising 24 Pontis states and two non-Pontis states that used their own agency-specific BMS. Key findings of this review follow (Small et al. 1999).

Custodians of BMS Data and Users of BMS Information

NBI and BMS data were universally maintained within DOTs by the central office. Bridge management activities were either concentrated in a single organizational unit or dispersed across several DOT offices. The primary users of BMS information were bridge engineers and bridge maintenance engineers. The two non-Pontis states reported the use of their systems by agency bridge managers and metropolitan planning organizations (MPOs) for STIP and TIP development. Among the 24 Pontis states:

- Seven reported using the system as part of the bridge management process.
- Four reported using the system solely within the bridge or maintenance section.

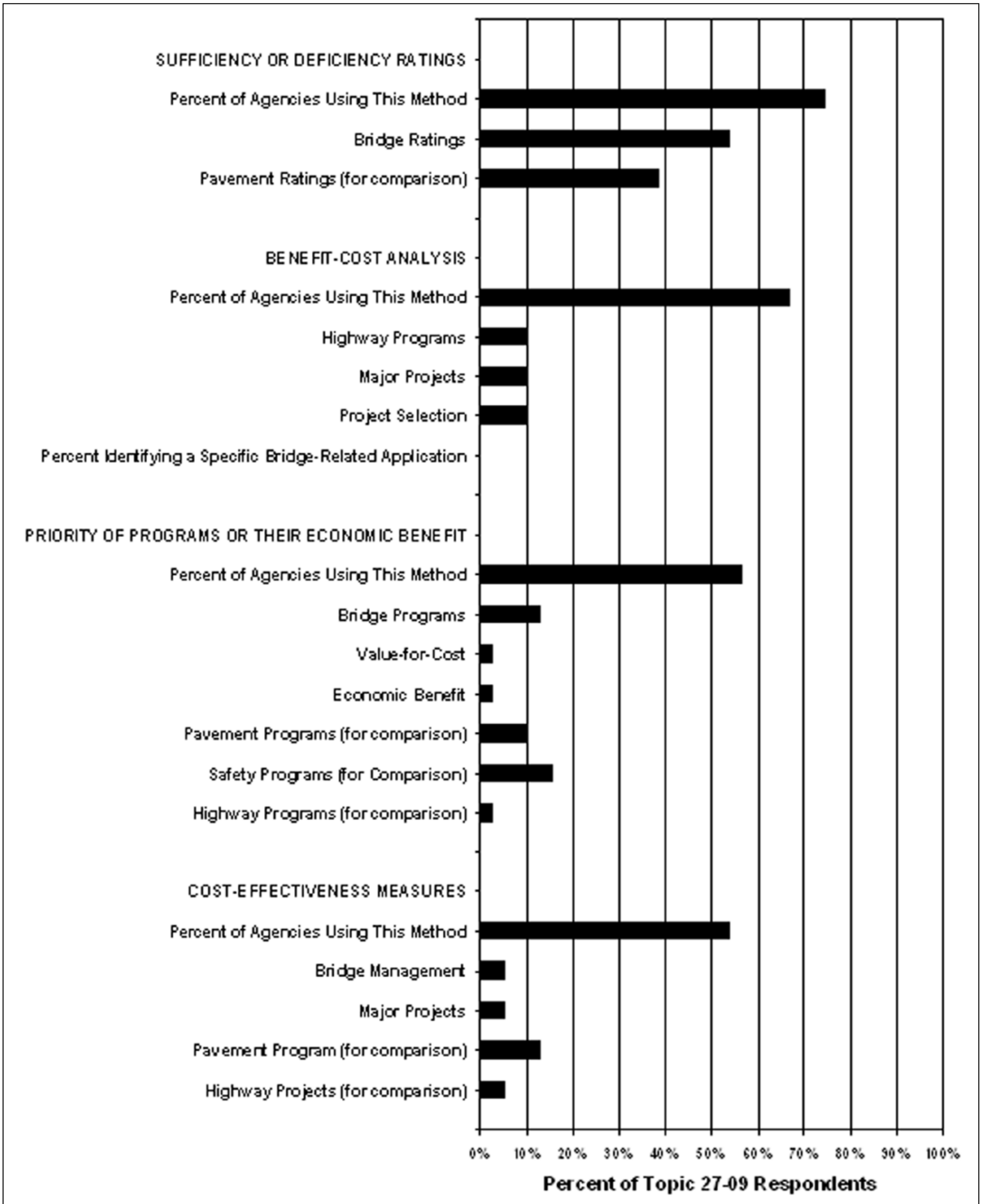

FIGURE 9 Priority methods reported by state DOTs (*Source:* Neumann 1997).

- Three reported using the system to produce results at the request of planners, district or regional personnel, county engineers, MPOs, and others.
- Fifteen agencies (including some listed earlier) reported that no one outside the bridge or maintenance sections had requested results from the BMS to date.

Long-Range and Strategic Planning: System Users and Goals

Modern, full-featured BMSs are well suited to strategic and long-term planning. These systems can deal with strategic goals, targets, and investment levels; identification of system-level problems and trends; and suggestions of long-term strategies and optimal actions to achieve the stated goals. Key findings among the 26 completed states were as follows:

- Agencies using a strategic planning process. Fifteen of the 26 agencies, or more than half, had a strategic planning process with a bridge component. In 9 of these 15 agencies, the strategic plan was developed by the bridge or maintenance section or by the chief engineer. In 5 of the 15, the strategic planning process involved high-level, external bodies; for example, transportation boards or commissions, or committees encompassing DOT as well as outside personnel.
- Eleven of these 15 agencies expressed goals quantitatively, but they varied in their practice. Examples of goals included the following:
  - Reduce the number of bridges with health index below a minimum level.
  - Reduce the number of deficient bridges by 5% per year.
  - Have no more than a defined percentage of structures with SRs less than 50.
  - Improve a specified number of bridges each year.
  - Impose specific goals to reflect legislative proposals.
- Four of these 15 agencies did not use quantitative goals in their planning process, but rather relied on generally understood priorities; for example, to reduce or eliminate structural and functional deficiencies, reduce the number of load-restricted bridges, and so forth.
- The 11 agencies without formally defined planning goals followed FHWA's suggested bridge network targets as guidelines for reducing bridge deficiencies. These FHWA targets recommend minimum percentages of acceptable (i.e., nondeficient) bridges on NHS and non-NHS systems. Several of these reporting states had bridge populations that met or exceeded the FHWA acceptability levels.

Long-Range and Strategic Planning: Performance Measures and Data

The performance measures used by responding states were concerned primarily with bridge condition and structural or functional performance. Nineteen of the 26 agencies reported using only the SR or number of deficient bridges as performance measures, singly or in combination with each other. Other agencies reported using a variety of measures, such as the following:

- Number of Bridges Needing Work
- The Pontis Health Index
- SD, SR, and other measures such as Number of Bridge Postings
- Number of Deficiencies plus Load Carrying Capacity
- Bridges in "Safe" condition as determined by agency formula.

Use of BMS for STIP/TIP Development

State DOTs develop STIPs that provide intermediate-range (typically 3 to 7 years) plans and program cost estimates that support long-term goals and are the basis for near-term programs and budgets. The survey results indicated that the bridge component of these documents is prepared in several ways; for example, by planning or intermodal programs offices (7 of 26 agencies), bridge or BMS offices (9 agencies), districts or regions (2 agencies), and in the remaining agencies by committees comprising representatives of several offices. Proposed projects and estimated costs in the STIP are developed using prioritization procedures plus engineering judgment among all agencies surveyed. However, only four agencies reported using their BMS for STIP development. Three of these agencies applied their BMS to develop lists of bridge replacement projects, although one agency used its BMS to estimate costs and budget levels for various bridge actions. The other agencies did not apply their BMS to STIP development, but five planned to do so in the future.

Project-Level Planning and Programming

Project-level planning and programming moves proposed bridge work into design, construction, maintenance, or operation. Based on projected annual or biennial budget levels and bridge projects and actions in the STIP, bridge program managers prioritize and implement bridge work. For many agencies, the STIP itself defines the annual or biennial program. Agencies that do not obtain prioritized programs directly from the STIP rely on either the SR or agency-specific prioritization procedures together with engineering judgment and inspectors' recommendations to build their programs. The four agencies that use their BMS for STIP development also use their systems for project programming. Almost all agencies reported that they intended to use their BMS for project-level programming in the future.

Status of Pontis Implementation

A paper describing the status of Pontis BMS implementation as of 2002 provided further insight into how agencies were using BMSs more than 10 years after the passage of ISTEA

(Robert et al. 2003). Licensees of the Pontis BMS were evaluated to identify U.S.DOTs that (1) used Pontis primarily to manage a network of bridges (as opposed to other primary uses such as training and research) and (2) had a confirmed production database already implemented. Of the 46 domestic licensees, 34 met these two criteria and were profiled in this study. Characteristics of Pontis usage in each of these agencies was gathered through telephone interviews, supplemented by information gathered at the 2002 Pontis User Training Meeting and from the Pontis Support Center.

Survey Findings

The 34 selected agencies used Pontis regularly, but for different purposes. This variety in usage is shown in Figure 10 in terms of particular Pontis modules (Inspection Data Management or "Inspection," Programming Simulation or "Programming," and "Project Planning"). All but four of the agencies (approximately 88%) used Pontis to manage their bridge inspection data. Among these, 17 agencies (50% of the 34 total) used Pontis solely to input and manage bridge inspection data through the Inspection module. These 17 agencies thus did not apply the advanced functionality of the system to simulate and optimize network-level programs or conduct project planning. The breakdown of Pontis module usage among the other 17 agencies that did use its advanced functions is given in Figure 10 as follows:

- Six agencies (17.6%) used only the Programming module for network analysis of bridge needs and systemwide optimization of bridge investment strategy.
- Three agencies (8.8%) used only the Project Planning module.
- Eight agencies (23.6%) used both the Programming and Project Planning modules.

Robert and colleagues observed that the use of the Project Planning module reported in this survey had increased since the previous survey of Pontis customers in 2000.

Four of the 26 agencies did not use Pontis to manage their bridge inspection data, as mentioned earlier. Two of these agencies collected and processed bridge inspection data using systems that were integrated with the Pontis database. The other two agencies used external systems that included procedures to export needed data into Pontis.

System Customization

Customization played a key role in enabling agencies to incorporate Pontis effectively within their business processes (Robert et al. 2003). This ability to customize the default features and functions within Pontis was important, because agency bridge management philosophies, business processes, and decision criteria could vary considerably.

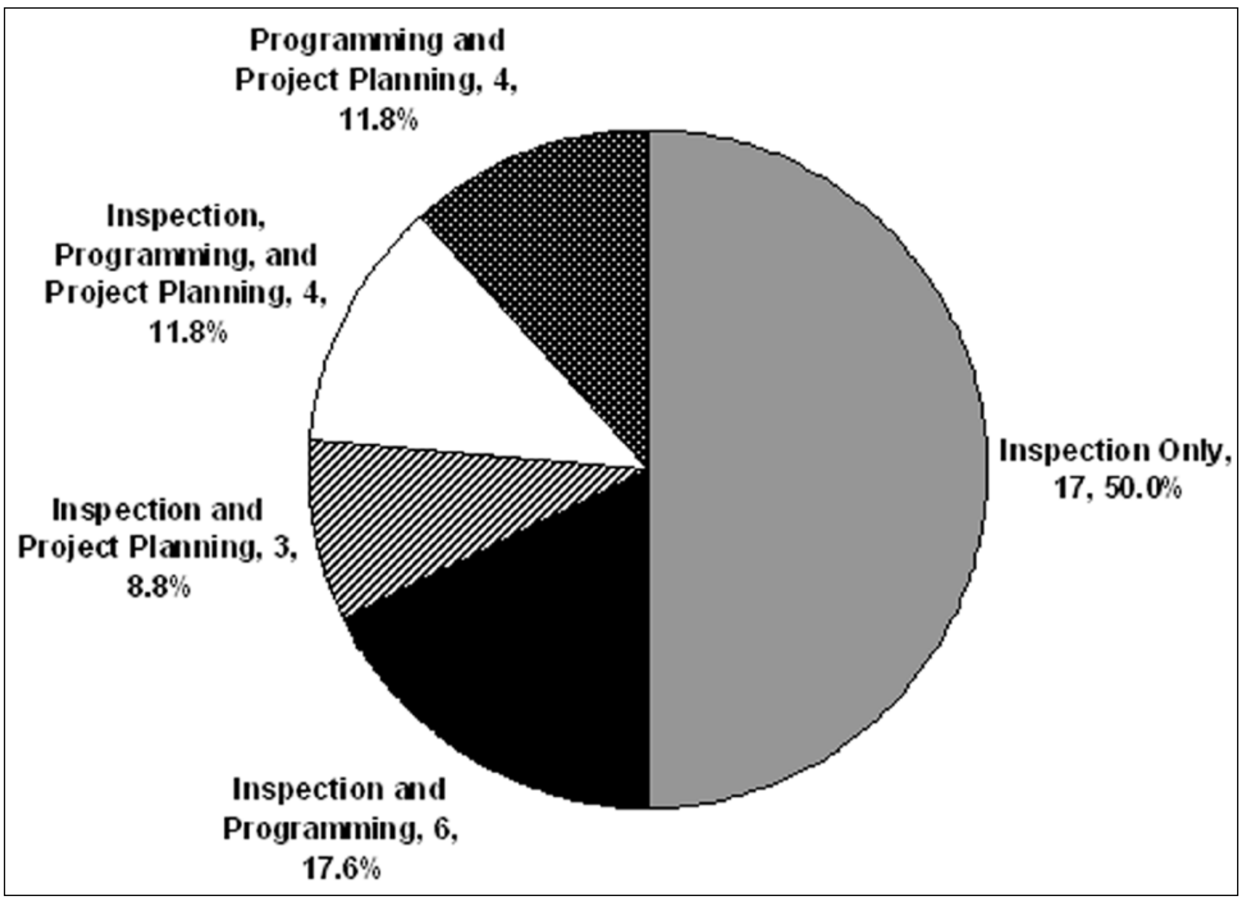

FIGURE 10 Pontis functionality used by licensing agencies (*Source:* Robert et al. 2003).

The reported degree of customization among licensees was significant, as shown in Figure 11, with most agencies performing moderate to extensive customization. Forty-seven percent (16 agencies) made moderate customizations; that is, enhancements that could be accomplished using built-in Pontis features or through Infomaker, a product used to create reports. Thirty-five percent (12 agencies) completed extensive customization, including developing applets or external applications to work with the Pontis database. As of the time of this survey, more than one-third of the agencies had used all of the available basic approaches to customizing Pontis, including reports, desktop layouts, forms, system adjustments, and additional applets or applications. Eighteen percent (six agencies) had performed either no customization or minor customization; for example, adjusting bridge element definitions.

Examples of how agencies were relating customized enhancements to their specific business-process needs were as follows (Robert et al. 2003):

- The South Dakota DOT made a number of enhancements to accommodate state-specific bridge data that were not included in the NBI database or the Pontis default data. These changes included six new tables in the Pontis database and new forms for entering and editing these data. Other enhancements included customized database security, a custom desktop layout, and several new procedures to facilitate and manage data exchanges between the Pontis database and the DOT's mainframe system, and between central office and field office bridge databases.

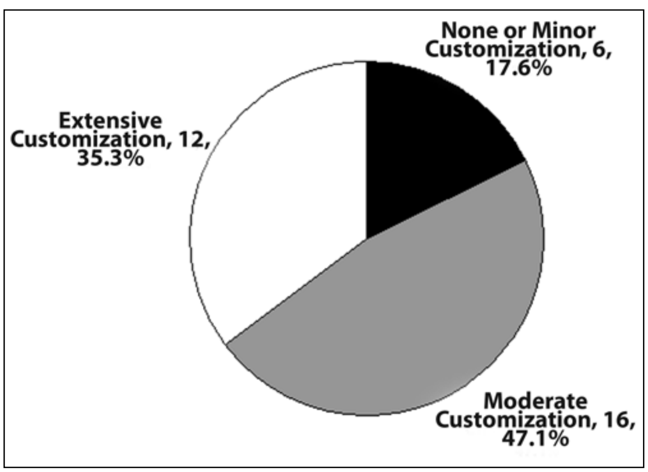

FIGURE 11 Degree of Pontis customization (*Source:* Robert et al. 2003).

- The Kansas DOT (KDOT) added more than 100 agency-specific bridge data items—essentially NBI-like items that are collected at a more detailed structural level or with a greater number of codes. It accomplished this by customizing the Pontis database, data entry forms, and reports. It created an applet to perform batch entry of inspection data, and added functionality to the Pontis database to automatically convert the KDOT specialized inspection data to the required NBI formats. KDOT also developed an interface between the Pontis database and the agency's centralized system that stores information on bridges, pavements, and other transportation assets.
- The Illinois DOT (IDOT) customized Pontis behavior to support bridge programming and project planning. The agency defined its own bridge elements in lieu of the standard CoRe elements discussed in chapter two to match its procedures for bridge inspection and recording of costs and quantities. It customized the Pontis desktop layouts and database to incorporate additional data for network programming. IDOT also developed an extensive set of program simulation rules to ensure that the project recommendations by Pontis were consistent with agency practice.
- Virginia DOT likewise enhanced Pontis program simulation rules to produce results that better reflected agency practices and preferences.
- Florida DOT added new elements to be able to manage other assets through Pontis, such as tunnels and sign structures. It has provided additional functionality in Pontis through agency-specific analytic modeling for programming and budgeting (Sobanjo and Thompson 2007).

Many of these advances promoted exemplary asset management practices. Agencies also undertook database and information technology (IT) enhancements that likewise promoted better asset management. These efforts included data integration between Pontis and other applications as implemented by Michigan, Mississippi, and Kansas DOTs, and moves toward applying Pontis as a thin-client application by California DOT, Montana DOT, and Florida DOT (Robert et al. 2003).

NCHRP Project 20-57

As part of its development of new analytic tools to support asset management, NCHRP Project 20-57 (*NCHRP Report 545* 2005) researched existing IT capabilities and perceived needs and requirements for new systems. Broad-based information was gathered from the DOT user community through literature reviews and discussions with potential system users at two asset management forums in the summer of 2002. More focused, detailed information was obtained through structured interviews with representatives of 10 state DOTs (California, Florida, Maryland, Massachusetts, Michigan, Montana, New York, Ohio, South Carolina, and Wisconsin) in the summer and fall of 2002. The information gathered in these early stages of Project 20-57 led to the development of AssetManager NT, now an AASHTOWare product, which assists agencies in conducting program trade-offs using the results of their own management systems for individual assets (e.g., pavements, bridges, signs, and drainage) or programs (e.g., safety, new capacity/congestion, and maintenance). Results of this study were published in *NCHRP Report 545* (Cambridge Systematics, Inc. et al. 2005c).

The interviews of 10 DOTs were not detailed case studies, and perspectives among the states varied (as did those of different interviewees within individual states). Nevertheless, a number of insights were obtained regarding existing analytic capabilities, needs for new capabilities, receptivity to different types of new analytic tools, and specific features desired. BMSs were part of this overall review. The following major findings relate to the current study (Cambridge Systematics, Inc. et al. 2005c):

- Most of the 10 states had pavement and BMSs. Many of these agencies used these systems (albeit to varying degrees) to support project prioritization and analyses of the relationship between investment levels and system performance within individual program categories; for example, bridges or pavements.
- Only one agency reported looking at performance trade-offs for different budget allocations across multiple program categories: Michigan DOT used a spreadsheet analysis for this purpose.
- Many of the 10 agencies reported use of LCC analyses, but most of these examples related to pavements or to major projects above a certain estimated cost that varied from $1 million to $20 million. Only South Carolina DOT explicitly mentioned using LCC for bridges. In terms of potential new tools, a number of agencies gave high priority to LCC for bridges or for "important assets."
- The reported level of interest in new analytic tools generated varying responses among agencies, but appeared to reflect an awareness of the capabilities of existing BMS. For example, queries about potential new tools to relate investment levels to predicted performance, or to support project prioritization, generally gave higher priority to assets and programs other than bridges. These responses were consistent with the concept that such capabilities were available in current BMSs.
- The level of interest in new tools for trade-off analyses across program categories was uniformly high (with the exception of one DOT that already had a multi-program analysis tool). The interest in a new tool to predict the impacts of a set of projects on system condition, safety, mobility, economic growth, and so on was generally high, but varied somewhat with respect to bridges: One state ranked bridges the highest priority, whereas another gave bridges the highest priority only if the tool included "more than roads and bridges."
- A proposed new tool to monitor actual project costs and effectiveness to provide feedback into management systems also received high priority from 9 of the 10 agencies.

CURRENT BRIDGE MANAGEMENT AND AGENCY DECISION-MAKING PRACTICES

Introduction

Current information on how bridge management processes relate to agencies' decision making was gathered through structured telephone interviews with chief engineers and bridge managers from 15 state DOTs, and through state DOT and provincial MOT responses to a comprehensive survey. The survey questionnaire is reproduced in Appendix A. The two interview guides that were used are included in Appendix B. The agencies that participated in the survey and interviews are listed in Appendix C.

This section describes the bridge component of current planning, programming, resource allocation, and supporting processes as described by agency personnel in the interviews. Five agencies have been profiled to describe the several management steps involved in bridge investment analysis and resource allocation, and to contrast differences in practices among agencies. These profiles are presented in two tables. Table 7 describes processes for two non-Pontis states, each of which employs its own, agency-specific BMS. Table 8 describes equivalent processes for three Pontis states. The specific business processes documented in these tables include the following:

- General introduction
- Condition and performance measures and targets, which are used to track and monitor system performance, set management guidelines and decision criteria for bridge work, and (potentially) to express policy goals and objectives
- Procedures to identify funding levels available for bridge work
- Procedures to determine bridge investment needs
- Methods of resource allocation and prioritization, considering (as applicable) allocations between the bridge program and other programs, allocations to districts (or regions or divisions), and prioritization of projects
- Use of economic methods to support the previously described processes
- Formal programs to establish and monitor organizational accountability for bridge program management, program accomplishment, and system performance, and to communicate information about bridge programs to stakeholders and the public.

TABLE 7
BRIDGE DECISION PROCESSES IN TWO NON-PONTIS STATES

Item or Process	State A	State B
Interview With	Assistant State Maintenance Engineer—Bridges	State Bridge Engineer; Head of the Agency's Division of Transportation Investment Management (DTIM, responsible for planning, programming, and multimodal investment decisions)
General	The agency-specific BMS applies to all state and local bridges (i.e., bridges with nonfederal, nonprivate owners). The system is used by central office and divisions (districts) to process, manage, and report bridge condition and performance data. The BMS does not have predictive models. Bridge information encompasses and goes beyond NBI data to include (a) a customized Deficiency Point calculation and (b) a customized load rating calculation to reflect particular classes of heavy vehicles (above AASHTO HS-20) that are legal in the state. Data are based on district NBI inspections that also report state-specific data items. Bridge decisions are centralized for rehabilitation and replacement, and decentralized for preservation and repair. In addition to input from the bridge office, the DOT's office engineer plays a key role in reviewing the proposed bridge program and making recommendations to the chief engineer. There is also a Bridge Replacement Prioritization Committee comprising agency managers from several offices plus a nonvoting FHWA Division Office representative to advise upper management on bridge investment decisions. Bridge decisions are based primarily on Deficiency Points. The process is vertically integrated, maintaining communication up and down DOT organizational levels.	The Central Office Transportation Investment Management Division uses an agency-specific management system to help allocate resources among pavement, bridge, and safety programs. Based on these allocations, regional bridge maintenance engineers decide bridge projects and treatments, applying their knowledge of their bridge condition and professional judgment. They may use custom management tools. Regions handle most bridge management functions; the Central Office manages only major bridge projects and bridges on the statewide "backbone" or trunkline system (network of multilane, high-volume freeways). The bridge management process is not formally documented, but is vertically integrated from the executive level to the regional offices. Decisions on bridge rehabilitation and replacement projects are reached collaboratively between the chief bridge maintenance engineer and regional directors. Decisions on preservation and maintenance are made primarily by regional bridge maintenance engineers. Bridge decisions consider NBI data and a Rate Score that is based on NBI structural and functional information, but computed differently from the Sufficiency Rating.
Condition and Performance Measures and Targets	NBI measures of SD, FO, and SR are used, together with the agency's Deficiency Point calculation, for bridge program management. A separate, state-specific, weighted average index of NBI condition ratings is used exclusively for GASB 34 reporting. The Deficiency Points measure is based on bridge physical condition, allowable load, deck width, vertical clearance, and special deductions. Different threshold levels of deficiency apply to bridges based on ownership and traffic use. While there are no quantitative bridge program targets or target years, an understood program objective is to work toward eliminating posted bridges. Percent deficient bridges are also tracked. Implicit targets are also built into the Deficiency Point methodology (e.g., a Special Deficiency assignment of 30 points for posted bridges, and the fact that the bridge load Deficiency Points depend on the degree of load restriction).	SD and FO are monitored and considered by regions in their bridge work recommendations. There are no documented, quantitative bridge program targets or target years. There is a general understanding, though, that the percentage of SD and FO bridges should be declining. In addition to NBI ratings, the agency uses a Rate Score, which is an index based on NBI data but computed using weights that are different from those applied for SR. The Rate Score is a function of the structural items in the SR plus ADT, functional class, and inventory rating.
Funding Level	Rehabilitation and replacement needs are very large and are met through federal HBP funding plus state funding at a level recommended by the agency's Finance Advisory Committee, with final decisions by the director and chief engineer. Repair funds (state money) are allocated to divisions based on relative bridge inventory.	There is a large appropriation for bridge rehabilitation, replacement, and preservation as compared with new or expanded capacity. The bridge program is well funded; state funding is considerably higher than is needed for a federal match. State funding to meet bridge needs is taken off the top; remaining funds are then applied to roadway, safety, minor capacity, and other needs.

TABLE 7 (*Continued*)
BRIDGE DECISION PROCESSES IN TWO NON-PONTIS STATES

Item or Process	State A	State B
Bridge Needs	For bridge rehabilitation and replacement: Replacement and rehabilitation needs are very large (see Funding Level above) and are identified based on Deficiency Point ratings. Bridges with high deficiency ratings are evaluated by the office engineer, who adjusts the list to account for bridges already programmed, fiscal year targets for work performance, posted bridges, and timber bridges (which the agency is trying to eliminate). For bridge repair: The Central Office proposes candidates; division directors comment. Final recommendations are made by the office engineer, state bridge engineer, and bridge maintenance engineer; these recommendations are forwarded to the Front Office for approval. Future needs are anticipated in terms of the "bulge" in bridges built during the interstate era that will soon be approaching the end of their service lives.	Needs are estimated within a 10-year horizon by applying agency-specific models of deterioration in Rate Score. This projected deterioration is then addressed in the analysis by a standard set of sequential activities (i.e., defined treatments that are scheduled at determined times during the bridge's service life) and associated unit costs to compute total estimated bridge needs. These deterioration and cost models vary with bridge configuration.
Resource Allocation and Prioritization	A Bridge Replacement Prioritization Committee assists the Front Office in high-level decisions on transportation program funding. The role of this committee is still evolving. Committee membership comprises the chief engineer, assistant chief engineer for operations, state bridge engineer, assistant state maintenance engineer–bridges, the office engineer, planning and multimodal systems, and a structural engineer from the FHWA Division Office (nonvoting). The office engineer addresses financial aspects of the discussions. Statewide competition among bridge projects for rehabilitation or replacement is decided based on Deficiency Points. Ties are broken by consultations between the Bridge Office and the agency office engineer. For bridge repairs and maintenance, allocations to divisions are based on the respective centerline lengths of bridges as maintained in the MMS inventory. Each division has a bridge maintenance or operations engineer who tracks bridge condition and needs and is able to determine appropriate priorities and treatments.	The DOT's Transportation Investment Management Division handles resource allocation across programs and regions with the help of its management system. The legislature does not interfere in these decisions. While the Central Office recommends a regional allocation, it consults with the regions to identify any special requests requiring adjustments in the allocations. The regions manage their respective road networks and select projects to be included in the STIP. The Central Office does not get involved much in these decisions with one exception—the Central Office manages bridge projects on the "backbone" or trunk-line highway network, a statewide network of high-volume freeways of statewide importance—and major bridge projects. The database with bridge condition data is provided to regions, which exercise discretion within limits in determining projects, programs, and costs. Prioritization methods may vary by region and are not documented. Regional personnel apply their knowledge, judgment, and possibly their own customized tools in prioritizing and selecting projects. The FHWA Division Office has recommended that the department adopt more uniform, better documented decision processes.
Economic Methods	Economic methods are not yet generally used, but the agency's bridge management system will be enhanced to include such procedures. Economic factors are incorporated in agency standard practice to some degree. For example, precast concrete bridge designs that are in conventional use have demonstrated cost and performance advantages. However, methods like life-cycle cost analysis are not used formally.	Benefit-cost analysis is used sparingly (e.g., to evaluate rehabilitation versus replacement), but is not in general use. In its process improvement recommendations, the FHWA Division Office has also recommend use of economic analysis methods.
Accountability and Public Communication	While the agency tracks the percentage of bridges that are deficient, there are no formal performance targets. While there is no formal public communication program on bridges, there is a Legislative Infrastructure Committee comprising representatives of the agency and industry to publicize infrastructure needs. For example, it may produce color-coded maps of the planned bridge program and permits and postings. This information is important given the growth in heavy trucks spurred by recent construction of automobile manufacturing plants in the state.	A performance monitoring and accountability program has been discussed, but none has been developed to date. Normally there is no formal communication on the bridge program. Occasionally bridge information is provided to the public (e.g., following an incident).

Note: ADT = average daily traffic; BMS = bridge management system; FO = functionally obsolete; GASB 34 = Governmental Accounting Standards Board Statement 34; HBP = Highway Bridge Program; MMS = maintenance management system; NBI = National Bridge Inventory; SD = structurally deficient; SR = sufficiency rating; STIP = Statewide Transportation Improvement Program.

TABLE 8
BRIDGE DECISION PROCESSES IN THREE PONTIS STATES

Item or Process	State C	State D	State E
Interview With	State Bridge Engineer	State Bridge Maintenance Engineer	Bridge Management System Coordinator
GENERAL	Pontis contains all bridge data for state and local bridges. Database includes standard Pontis items plus customized data. Bridge management functions are centralized; districts are involved in data collection on the state-owned network. Central Office manages inspection of local bridges. District inspections are at the element level. Agency uses Pontis's NBI Translator program to produce NBI measures.	Pontis helped the bridge maintenance unit become much more involved in bridge program decision making, also involving the districts more in bridge replacement decisions. Pontis is applied at the Central Office. Districts inspect bridges using dual inspections (element level and NBI). A joint approach, bottom-up and top-down, is used in bridge management and program development. See text for details.	The Central Office conducts bridge management using Pontis, supplemented by customized analytic functions that operate on data in the Pontis database. Districts perform element-level inspections only. Bridge management is part of the state's overall asset management, and is included with other programs that are considered within a corridor.
Condition and Performance Measures and Targets	Agency computes NBI ratings via the NBI Translator program within Pontis; it uses the Pontis Health Index occasionally. Bridges eligible for federal HBP funding are tracked via the Select List, based on SR. The Bridge Office is developing its own Bridge Index that will provide more granular descriptions of bridge condition and address problems with SR and the Select List. See text for details. **Current practice:** Bridges in "acceptable" condition are those that are NOT on the Select List. Targets: 83 percent NHS, 80 percent non-NHS bridges in acceptable condition (developed for GASB). **Future practice:** Targets will be expressed in terms of Bridge Index values of Good, Fair, Poor, etc.; meeting these target values will be reflected in projects included in the STIP, and will also be used in trade-off analyses with other programs. Top management supports these efforts and the move toward trade-off analysis.	Dual inspections are conducted to obtain element-level and NBI data. The Pontis NBI Translator program is used to check district NBI data, with generally good agreement. Tracking of condition and performance is mainly by considering trends in basic measures, including SD and FO. FHWA thresholds for NHS highways (specifying allowable percentages of SD and FO) are also considered. This agency is looking to eliminate SD bridges in 10 years, and replace FO bridges in 10–20 years. The bridge unit provides input to Commission reports and submits bridge needs to executive management, the commission, and the governor. Upper management generally accepts the recommendations of the bridge maintenance office.	NBI ratings for SD and FO are used in a trend analysis for the bridge capacity program only (new bridges, expanded capacity, bridge replacement based on strength considerations), not bridge preservation. For preservation (preventive maintenance), only decks, joints, and bearings are considered. Decisions are informed by a modified health index. There are separate priority indexes for specific details on steel bridges and for off-system bridges, for which posting is an issue.
Funding Level	Construction program is relatively small ($200 million annually, total for all projects); bridges and other structures are about 10 percent of total. State dollars ($15–$25 million annually) go to bridge repairs.	Federal HBP money is dedicated to bridges and constitutes most of the agency's bridge funding (>$100 million). State funding ($10 million) is competitive.	Planning provides revenue projections by highway system. There is strong federal bridge funding, and state funding is used on road corridor preservation projects. Bridge Management runs scenarios in Pontis to obtain performance trends for different budget levels.

TABLE 8 (*Continued*)
BRIDGE DECISION PROCESSES IN THREE PONTIS STATES

Item or Process	State C	State D	State E
Bridge Needs	A Needs Analysis across all major program categories is conducted as part of STIP development. **Current practice:** Needs identification is generally by road segment, driven by deficient pavement condition. Bridge unit identifies bridges on the Select List, the top 10 needs in deck condition, and the top 10 needs in expansion devices, and provides this information to key players. Districts make decisions on meeting bridge needs. **Future practice:** Needs will be based on Bridge Index values; focus will be more bridge-oriented (by individual structure) rather than by road segment. An integrated management system is proposed for development, which will allow trade-offs across different program needs. Again, upper management supports these efforts. Current metrics show the number of deficient bridges (based on the Select List) to be declining. This trend may change in the future with (a) introduction of the Bridge Index, which is more granular and may flag additional bridges as deficient; and (b) aging of bridges built a half-century ago, now approaching design or economic service lives. Targets may need to be revised in the future.	The bridge maintenance office has conducted about eight needs studies with Pontis assistance since the 1990s, the most recent in 2004. The bridge maintenance office also keeps track of progress in meeting needs (e.g., through deck replacement) and updates trend lines monthly. Before Pontis implementation, bridge investment decisions were not made systematically. There was no formal process, and decisions were based on ad hoc considerations such as projects that were "easy to do." The policy now is that bridge managers need to understand the operations aspects of their decisions (i.e., where are bridge needs, what are the causes of these needs, and how can the road system operation benefit from bridge investment?). This requires understanding how the bridge relates to its surrounding locations in the road network. This implies a management perspective of how the route or corridor is used when considering bridge investments. The element-level data drive the program analyses and recommendations in Pontis. Scenarios are run for unlimited and constrained budget cases.	Based on Pontis scenario projections, trends are developed for numbers of state-owned bridges that are SD or FO (for capacity projects), for use by Planning in its trade-off analyses. For preventive maintenance, the deck health index is the primary measure that is tracked. Preservation work is developed on a corridor basis to gain economies of scale. Bridge posting is an issue primarily for local (off-system) bridges. The agency informs local governments when bridge posting is needed. Posting status is also part of the prioritization for federal aid to counties. Other factors that are considered include bridge age, whether a bridge is of timber construction, traffic (ADT), bridge length (counties do not have the expertise to design bridges longer than a certain length), and internal county preferences.
Resource Allocation and Prioritization	Allocations between bridge and other programs are made at the Needs Analysis meeting. Districts comment on the timing of bridge projects in the STIP in relation to overall needs and funding. Bridge projects (except an occasional bridge replacement project) are typically not a major topic in the Needs Analysis meeting, and the state does not have many major bridge projects. In the future, trade-off analyses will consider the impacts of different funding levels and allocations among programs. The $200 million in construction funding is divided equally among five districts, $40 million per district. However, bridge funding may not be proportional. The districts prioritize bridge projects.	Allocations of state funds are decided in a meeting among program/office managers. One potential area of improvement is for other functional areas to estimate needs in their programs on an equivalent long-term basis (20 years), as is done for bridges. Another is to consider the type and criticality of needs more explicitly rather than allocating by, for example, formulas or prorated percentages. District allocations of federal bridge funds in the past were based upon a roughly uniform distribution of projects (e.g., five or more bridges in each district each program year). The trend now is to think more in terms of statewide needs; any one district may therefore see its number of federally funded projects vary from year to year. The Central Office allocates federal funding. State bridge funds are prorated to districts based on their relative shares of bridge lane miles. Pontis data are used for this allocation formula. Project prioritization is done statewide and discussed with the districts.	Allocations between bridge and other programs are analyzed by the trade-off process conducted by Planning. The agency has experimented with the AASHTOWare product AssetManager NT to conduct trade-off analyses. Regarding allocations among districts: Bridge projects on the NHS are evaluated statewide. The first cut at prioritization is obtained using Pontis and the supplementary, customized calculations that operate on data in the Pontis database. A second pass considers the political dimension in district allocations. Allocations for secondary system and off-system bridge projects are consistent with the state's redistricting law, which is updated every legislative session (2-year intervals), and are prorated by bridge deck area. Project prioritization maintains conformance to the district allocations required by state code, consistency between functional class and color of money, and Pontis database computations of deck health index.

TABLE 8 (*Continued*)

BRIDGE DECISION PROCESSES IN THREE PONTIS STATES

Item or Process	State C	State D	State E
Economic Methods	Formal economic analyses are not really used now (other than in the Pontis algorithm). The future integrated management system will, however, have a benefit-cost analysis.	The state applies the benefit-cost analysis and user cost algorithms in Pontis.	The state applies the benefit-cost analysis in Pontis. The bridge management office has tried life-cycle cost analysis, but estimates of road user costs for work-related delays have problems.
Accountability and Public Communication	The GASB 34 targets above provide some degree of accountability, but no other accountable targets exist for bridges at present. The implementation of the Bridge Index will change this and provide increased accountability. Communication of bridge information to the public is provided through the state's Transportation Fact Book (annually in November), which summarizes state and local bridge conditions and numbers of deficient bridges by functional class. Additional information on the STIP is on the bridge unit's webpage.	This agency issues an Accountability Report annually. It includes updates on the bridge deck area that is rated SD. The Bridge Maintenance Office formerly issued an annual State of Bridge Infrastructure Report to DOT management and the Transportation Commission. The recent collapse of the I-35W bridge has renewed interest in reviving this report.	There is a performance measurement program related to budgeting. Scenario analyses are used to estimate performance trends for different budget levels, to identify a recommended budget and performance target. Performance is expressed primarily in terms of the deck health index. Information on bridge status and investment programs and projects is communicated to the public through the department's bridge website.

Note: ADT = average daily traffic; BMS = bridge management system; FO = functionally obsolete; GASB 34 = Governmental Accounting Standards Board Statement 34; HBP = Highway Bridge Program; MMS = maintenance management system; NBI = National Bridge Inventory; NHS = National Highway System; SD = structurally deficient; SR = sufficiency rating; STIP = Statewide Transportation Improvement Program.

The tabular organization of bridge management processes helps in two ways. First, describing these processes by agency illustrates important linkages among process steps. For example, particular condition and performance measures may be used to guide resource allocation and prioritization, as well as to communicate agency accountability. As another example, understanding how an agency estimates bridge needs and accounts for funding availability may help in understanding its methods and criteria for resource allocation and prioritization. Second, because they are described in parallel for each agency, the processes of one agency can be compared with the others to observe similarities and differences.

Supplementary information on the resource allocation and performance accountability business processes was obtained from the interviews with the 10 additional agencies (15 agencies interviewed in total). These additional examples round out the various practices in bridge management used by state DOTs. Collectively, these descriptions establish a picture of how agencies today relate their bridge management capabilities and information to their procedures for analyzing program investments and resource allocations. These results will be amplified by later discussions of the survey responses. The survey data will provide a broader agency coverage of several relevant topics; for example, the use of BMSs, organizational responsibility for various processes in bridge management and resource allocation, and applications of bridge management specifically to planning and budgeting.

When current practices are compared with the historical findings that were discussed in the preceding section, one can identify advances that have taken place in bridge management and its application to agency decisions. This comparison can crystallize long-standing issues that continue to affect bridge program management, analyses of bridge investment needs versus funding availability, resource allocation within and among programs, and bridge project prioritization. Trends in BMS implementation can likewise be revealed, indicating what advances agencies have made, or what impediments they continue to face, in applying their management system, data collection, and database processing capabilities to actual business decisions. Finally, an historical perspective provides a framework for understanding how current practice reflects principles of good asset management that have emerged in the U.S. transportation sector in the last 10 years.

General

The five DOTs represented in Tables 7 and 8 were selected by the Topic 37-07 Panel as having exemplary bridge management practices that extended into planning, programming, and resource allocation. The interviews described business processes that are well integrated among technical, middle management, and executive levels, and that are consistent with the broader financial, policy, and programming environment in which the agency operates. Offices involved in bridge management are able to produce the information upper management needs. Executives and managers appear to be satisfied with this input to their decision making. These agencies have created various mechanisms to advise upper management in their decisions and to resolve differences among organizational units in their respective assessments of needs and priorities. These will be described further later, with the understanding that some of these organizational roles and business processes are still evolving. Although all of these DOTs incorporate professional judgment as an element of their bridge investment and resource allocation decision making, agency practices vary in who exercises this judgment, as well as how, when, and with what effect.

Although bridge management is well integrated into agency decision making among the DOTs represented in Tables 7 and 8, this is not to imply that policies and procedures are perfect. Aspects of the agencies' management system capabilities, performance measures, and executive advisory committee roles that were described in the interviews are still evolving. In some cases, the objectives for further improvement of these internal processes have been spurred by suggestions from the respective FHWA Division Office; for example, the desirability of more standardized, documented project selection procedures, and encouragement in the greater use of economic methods. These agencies are working continually to influence the external factors that affect their bridge program management as well as their broader planning and programming processes—for example, to promote more stable and predictable short- and long-term funding streams, and to match available funding to bridge and other program needs. These pragmatic steps, including defining alternative bridge decision criteria to supplement the SR, using various internal mechanisms to decide bridge funding allocations, and transferring funds among programs, are described in later sections of this chapter as well as in chapter four.

Underlying the current practices described in the remaining sections of this chapter are each agencies' applications of different BMSs and approaches. These differences can be modest or substantial. The two non-Pontis states in Table 7 use agency-specific BMSs: One consists of a database with management and reporting tools that build on those used for NBI data; the other is an overarching system encompassing bridges, pavements, and safety projects that assists in planning, capital programming, and resource allocation. Both systems use customized data and performance measures. The three Pontis states likewise differ in how their systems are customized and applied, whether with additional, state-specific elements, unique analytic tools to compute custom performance measures, or the degree to which Pontis' economic modeling is employed.

The influence of BMSs can extend beyond their analytic results. State D reported that its implementation of Pontis coincided with a strengthening of its bridge maintenance office's role in formulating the state's bridge investment program. The bridge maintenance office of this state had little influence on bridge programs before the late 1990s. In 1993, however, the state began preparing to use Pontis by beginning collection of element-level data and developing cost data and element deterioration estimates. The bridge maintenance office began formulating agency bridge programming policy across the board, including replacement or rehabilitation and preservation (maintenance and repair). The state began using Pontis fully in 1998.

The experience of State D is an example of how a strengthened bridge management approach can result from an informed bridge program initiative coupled with the effective use of BMS information. State D's approach is now one that, as shown by the framework of Figure 1, includes both top-down and bottom-up aspects. For bridge replacement and rehabilitation projects, a joint program development approach between central office and districts is used. The bridge maintenance office asks the districts for their top 20 to 25 project candidates, while it concurrently runs Pontis to obtain corresponding BMS recommendations. The two lists usually show more than 80% agreement, and they are compared and discussed in a meeting between the bridge maintenance office and district representatives. The final list of recommended bridge replacement projects is prepared by the bridge maintenance engineer for one final district review, and is then submitted as a 5-year plan. Each year the bridge maintenance office (1) adjusts project priorities if needed, (2) conducts statewide audits to ensure that work to date conforms with the recommended program, and (3) checks with districts to ensure that they are still in agreement with the program. To date this process has worked well.

Preservation work—for example, for bridge painting and deck replacement—is handled by the bridge maintenance office with the help of Pontis recommendations, subject to funding constraints. Pontis is used to review local bridge proposals; for example, if a locality wishes to widen a bridge, the bridge maintenance office checks to see whether a replacement would be preferred. Districts generally do not adjust these decisions unless there is a major change in the field.

This is but one example; others are described in Tables 7 and 8. Comments on the remaining items in these tables follow, along with further information gained from the 10 additional agencies that were interviewed.

Condition and Performance Data and Guidance

The policy objectives and performance targets that agencies use to guide bridge program development include several types of measures that are described here, but underlying them are themes that cut across the various practices among agencies—for example, the widespread use of NBI deficiency ratings. These themes are countered by a desire in many agencies to overcome the limitations of these ratings; the development of customized measures of bridge condition and performance; the preference of many agencies to track progress toward objectives and targets somewhat informally, especially by looking at general trends rather than firm thresholds and schedules of accomplishment; and, where explicit policy objectives and performance targets are not available for strategic guidance, the use of other mechanisms to guide resource allocation. Moreover, the field is in flux: a number of agencies that were interviewed in this study described new, improved measures of system condition and performance that were under development and could be used to express better their program objectives and performance targets. These new quantities, they believed, would help them to understand better the condition of their bridge inventory, the implied bridge investment needs, and the potential benefits of funding these bridge needs. A caveat noted by even those states that had well-developed approaches to policy guidance and performance measurement, however, was that meeting transportation objectives and performance targets in a consistent manner required a stable, sustained, long-term trend in their program funding.

Five DOTs Represented in Tables 7 and 8

The measures used to define bridge program goals and targets and to monitor system condition and performance over time are shown in the second row of Tables 7 and 8.

- All five states monitor NBI ratings: SD, FO, and SR. SD is often considered in terms of a desired downward trend rather than as a fixed numerical target.
- Four of the five states have also defined custom measures. Although these new measures may draw on NBI data, they may differ from NBI database computations in terms of the particular data items that are included, the numerical rating scale that is used, and the weights assigned to respective items.
- Agencies have defined these custom measures to serve several purposes that they believe are not being met by the current NBI or default BMS approaches: to provide more detailed or granular information on bridge condition and performance, to supplement the SR as a decision criterion, to give a more comprehensive and transparent picture of the impacts of bridge investments, to focus on particular state issues and priorities, and to serve as dependent variables in agency-developed predictive models (i.e., bridge deterioration models) that are used, for example, in needs estimates.
- State A, which employs a Deficiency Point approach, notes that bridge program objectives are essentially "built into" this process in terms of how Deficiency Points and bridge load definitions are defined (certain

legal truck loads in this state differ from AASHTO standard loads). A Special Conditions deficiency category allows managers to reflect implicit objectives by essentially raising the priority of a bridge with particular problems.
- None of the five agencies now employs strict numerical targets for bridge condition and performance, or for the allowable time to meet condition and performance targets. Rather, the agencies monitor general trends in key indicators, particularly NBI ratings such as SD and, where relevant, the number of posted bridges. Declining trends in deficiency measures are generally understood agencywide to be desirable goals of the bridge program.
- Two of the five states explicitly mentioned program goals defined exclusively for use in Governmental Accounting Standards Board (GASB) 34 reporting.

Additional information is provided here as indicated for two of the agencies in Table 8.

State C

State C is developing a new Bridge Index for use with Pontis that will provide a more granular description of its bridge condition and performance than the NBI rating approach now used, which involves the Select List (bridges eligible for federal HBP funding for rehabilitation or replacement) based on SR criteria (SR between 80 and 50 for rehabilitation, less than 50 for reconstruction). State C identifies two problems with SR and the Select List: (1) a bridge may be structurally deficient or functionally obsolete, but not meet the criteria for the Select List (this case would typically represent a bridge with deficient deck condition, but no other deficiencies); and (2) changes in the Select List do not fully reflect improvements owing to all bridge investments (i.e., the impacts of investments on non-federal aid bridges are not picked up).

The proposed Bridge Index is founded on a number of NBI items: deck, superstructure, and substructure condition; channel and waterway adequacy; inventory load rating; bridge railing and approach-guardrail-to-railing transition; approach guardrail and guardrail ends (comparison to state standards); bridge width; vertical clearance over a road; vertical underclearance; lateral underclearance; and functional class. Measures of traffic (e.g., average annual daily traffic) are excluded from the Bridge Index because they are not strict measures of bridge condition. They are accounted for, rather, in the programming process and should manifest themselves in bridge deterioration trends. The weights used in the Bridge Index computation are different from those used in the NBI ratings, and they are still being tested and adjusted for reasonableness with respect to how they yield (1) the relative Index values of bridges in different conditions, (2) the improvement in the Bridge Index value that results from work performance, and (3) the relationship of this improvement to cost. The DOT intends to define three to five intervals of bridge criticality in terms of the weighted Bridge Index computation on the 0 to 4 scale—for example, Index values less than 1.75 might be judged Critical, and values greater than 3.5 might be judged Good, but these are still subject to further development and sensitivity analyses. The DOT is analyzing what level of investment is needed to address bridges at given Index values, and what improvement in Index value results from a certain level of investment. The Bridge Index is expected to provide more accurate and helpful indications of bridge condition and performance, as well as a more specific measure by which to communicate objectives and performance targets.

The NBI data that contribute to the Index are derived from element-level inspections. NBI ratings for bridge structure elements are computed from the element-level data by the NBI Translator program, which is developed and maintained by the FHWA and incorporated within Pontis.

State D

NBI ratings in this state's view were established for safety and are not really management tools. In the opinion of this agency's state bridge maintenance engineer, SR should not be used to prioritize projects because it does not encompass all of the factors needed to make wise bridge program decisions. For example, a bridge may have an SR value somewhat above 50 (e.g., 54 to 56), but replacement may be the preferred long-term option. This agency has discussed this point with the FHWA Division Office and has obtained its understanding of their position. This agency would prefer that a level of service-type measure be used instead of the SR.

10 Additional Agencies That Were Interviewed

Some states reported only that their current strategic documents (e.g., mission statement, departmental strategic management guide, or long-range state transportation plan) were the source of transportation system goals and objectives, with no further elaboration. Several DOTs that did not now have a performance measurement program for their transportation system reported that they are planning or now undertaking efforts to develop and apply such measures and targets. Other agencies already have fairly detailed goal-setting and review procedures and tools. For example, one DOT issues an extensive quarterly report on system performance and the status of its programs. A biennial update on progress toward attaining five legislatively set, overarching goals is attached to this DOT report. The secretary of another DOT reports annually to its transportation commission with a report card on system performance that is transmitted to the governor and legislature. The agency's executive management team reviews performance measures with the commission in detail, using dashboards. Although agency staff makes recommendations on targets based on departmental data, analyses, and professional judgment, the commission makes the final decision on updated targets. A couple of states pointed out that their current approaches are corridor based. The two apparently separate and distinct motivations are as follows: (1) to base programming decisions primarily on roadway pavement condition and to identify needed bridge work (apart from critical situations) primarily on corridors slated for pavement investment; and (2) to gain economies of scale in all bridge work identified within the corridor. Bridge managers within an agency driven by the first motivation are hoping that a more refined Bridge Index will shift the focus more toward individual bridge conditions and performance, irrespective of overall corridor condition. Placing greater importance on bridge conditions specifically is particularly important in maritime regions. The harsh environmental conditions in these locations expose bridges to corrosion that causes bridge elements to deteriorate faster than other components of the highway corridor.

Several agencies do not have explicit measures of objectives and targets, relying instead on general, often qualitative, goals in mission statements and strategic plans. For example, one state reports that its top priority is preservation and maintenance; this goal is embodied in the 25-year vision in its long-range plan, which guides the 10-year investment plan, 3-year program, and 1-year work program. Another DOT notes that an overriding objective is to use all available federal aid. Funding set-asides are used to allocate resources to bridges, particularly for state bridge needs not covered by federal funding and for local bridges. Another agency relies on its senior management team to relate revenue projections to recommendations from central office and district managers, supported by management system outputs, to devise goals and objectives for the long-range plan.

Some agencies that do not have explicit statements of goals, objectives, and performance targets contend that their budget, program structure, or funding formulas have implicit goals and objectives. A bridge manager in another agency believes that condition and performance objectives and targets represent idealized, ambitious vision statements. Because future improvement in bridge condition is not now realistic in light of current funding, the real objective (and a challenging one at that) is to maintain the status quo.

A DOT using the Pontis BMS employs a computer-based dashboard with performance measures and targets for bridges. The Pontis Health Index provides a network-level view of bridge condition. This agency looks at bridge condition relative to available dollars for different types of needs. The legislature agrees with and supports this approach.

Another DOT uses program-output performance measures such as the number of bridges requiring rehabilitation that go to contract, the number of bridges requiring replacement that go to contract, and the percentage of weight-restricted bridges. The target in this state is that no more than 1% of bridges should have weight restrictions. There are separate safety and weight-restricted goals concerning structurally deficient and functionally obsolete bridges. The agency's bridge management unit develops these measures and targets as part of the update of the state transportation plan.

Funding Availability and Needs Estimation

Five DOTs Represented in Tables 7 and 8

The five agencies included in Tables 7 and 8 all acknowledge the important role of federal HBP funding to meet bridge replacement and rehabilitation needs, and the use of state funding to meet preservation needs—bridge repairs and corrective and preventive maintenance—as well as to provide the required federal match. These agencies differ, however, in the magnitude of their federal HBP apportionments, the ratio of their bridge replacement and rehabilitation needs to preservation needs, and the relative split between federal versus state dollars in their bridge programs. These differences reflect the varying physical and transportation environments among states (degree of urbanization, traffic volumes and compositions, terrain, climate, and so on) as well as the composition, age, and condition of their respective bridge inventories. Transfer of HBP funds to other programs has not been an issue among these five agencies in recent years, and therefore was not discussed in the interviews. Bridge funding transfers are now an issue nationally, however, and are covered further in chapter four.

Approaches to needs estimates also vary. Agencies with access to the analytic features in Pontis are more likely to consider budget scenarios and to conduct trade-offs of different budget levels versus expected system condition and performance. Methods to estimate bridge needs are evolving in some agencies concurrently with more sophisticated use of their BMS and the introduction of custom performance measures that better reflect individual state perceptions of needed work. In one case, an agency is departing from past practice by focusing more on bridge needs specifically, rather than considering them as part of overall conditions within the roadway segment to which the bridge belongs. In a second case, the agency is encouraging its managers to understand bridge investment needs in an operational context. In other cases, agencies are looking to improved performance measures to provide a more explicit way of expressing needs and the consequences of different investment levels. By contrast, those agencies that do not analyze budget scenarios estimate needs based strictly on a single forecast of the deterioration in bridge condition and performance.

Two agencies mentioned that projected needs likely will increase in the future owing to the "bulge" in bridge replacement and rehabilitation work expected for bridges built during system expansion in the mid-twentieth century.

10 Additional Agencies That Were Interviewed

Several agencies reported that maximizing federal aid is an important objective, although secondary to more fundamental bridge-related goals and objectives. One DOT begins with the amount of federal bridge program funds for replacement and rehabilitation. This is matched at the appropriate percentage by projected state dollars, which this agency forecasts quite accurately. Bridge program managers and upper management compare the sum of these resources with the needs. Supplemental funds sometimes come from general revenues or other occasional sources, but an effort is made not to distort the overall program. Another DOT reported that a significant change from historical funding patterns could invalidate the strategic plan. The agency might then need to revise its current highway program, implicitly changing its goals, objectives, and priorities.

One state DOT has separate sources of state money to fund bridge needs, based on a history of successive revenue packages passed by its legislature. Although some funding sources allow flexibility, other sources are more restrictive, with budget line items that dictate individual projects, scope, and schedule. Furthermore, existing needs for bridge replacement and seismic retrofit reduce flexibility further. As a result, even with some line items dedicated to bridge preservation, work is lagging behind needs in areas such as bridge painting, repairs, and maintenance of movable spans.

When DOTs have encountered institutional impediments to setting what they perceive as appropriate objectives and priority for the bridge program, and when procedural improvements have appeared to be impractical, some of them have created work-around mechanisms to attain the desired ends. For example, in one state, the bridge program formulation has been stripped from STIP development. The DOT's head of asset management under the chief of operations now turns to bridge experts under the chief engineer for information on deficiencies, needs, recommendations, and program coordination. A formula remains for distributing funds to the primary and secondary systems, but the total level of bridge funding comes off the top, so it does not have to compete with other projects. The agency's chief financial officer has played a major role in taking the bridge program out of the normal STIP development process. The DOT commissioner has likewise supported this procedural approach. Other DOTs have reported that their state funding for bridge programs is taken "off the top" or from set-asides for bridge use.

A common way to assess needs is by having staff and upper management examine bridge condition, performance, and age distributions of bridges or of key components, such as decks. One state DOT shares this information with the legislature in articulating investment needs. The CEO and top decision makers in another state DOT annually review bridge recommendations based on inspections and other data. Representatives of each funding area make presentations, as do districts. Top management informs the districts of the proposed funding policy. The districts examine the funding policy and request changes or accept the proposal. The current bridge performance level, information on scour problems, and bridge needs in coastal areas are part of the funding analysis.

Bridge program managers and top decision makers in this state also look at trade-offs. The criteria for making trade-offs in order of importance is as follows: data, analysis, engineering judgment, and political considerations. Top management tries to ensure that political considerations do not trump other factors. This process is meeting top management's needs for good information they can use to establish funding levels and make good bridge decisions. At present, 90% of all bridges on this state highway system have condition ratings of good or excellent. Further research seeks to improve decision support for bridge programming and budgeting to make the bridge management process even more seamless.

Another state starts with district input based on inspections. Needs are organized by Interstate system, regional corridor system, and so on. The program delivery personnel in each district meet to establish priorities and discuss the scope and timing of bridge work. This information then comes to the chief engineer's office for review.

Another DOT discussed its federal- and state-funded programs for bridge replacement, bridge repair, and so on. For bridge replacement, the agency uses a method in which it applies SRs, priorities according to an internal priority formula, and traffic volumes to produce a list of priority bridge replacement projects. This list is distributed to districts and headquarters. The list, adjusted for comments, results in a federal aid bridge replacement program. The level of state funding has remained constant for many years. In trying to complete the defined program, the agency has had to take money from the set-aside programs for bridges, safety projects, pavement overlays, and so on. Funding for the bridge repair program has therefore declined in the last 4 to 5 years. The agency is starting to slip behind in funding pavement preservation needs, and pavement condition is beginning to decline as well.

Some DOTs that have BMSs with predictive capabilities apply them to needs estimates. They assess future bridge deterioration under different scenarios to see what the needs are at various time periods. However, another DOT, although a Pontis state, uses its BMS software mainly to store inspection results, foregoing use of the system's predictive capabilities. This inspection information is used to identify candidate projects. Agency personnel go to the field to corroborate identified project needs and prepare a priority list. This list is revised if needed. The highest priority projects are identified from both inspection data and designers' judgments in reviewing the proposed projects. Agency personnel characterize this process essentially as triage: to deal first with serious problems, then with remaining problems. The agency tries to perform preventive maintenance to keep existing conditions from getting worse.

Agencies also discussed their handling of special bridge program needs: particular problems on individual bridges that require ongoing attention—for example, susceptibility to scour, seismic damage, and terrorist attack. Approaches differ on identifying special bridge needs and allocating resources to address them. In one state, monitoring devices are placed on bridges that have been identified as scour critical to understand what is happening. The DOT devotes resources as necessary to address identified problems. This agency has had internal discussions regarding bridges that might be subject to terrorist attacks, but other states are believed to have much more extensive and serious vulnerability problems. An emergency repair fund exists to help with identified special bridge needs. Another state notes that homeland security is not a source of funding, although management does pay attention to the security issue. States apply different approaches in program funding structure to address special needs. Some states have separate subprograms or funding for scour or seismic needs. Other states fund all needs from the same pot of money, with no special bridge subprograms.

Several agencies mentioned coming bulges in needs that will arise from the waves of bridges constructed during the Depression and the Interstate construction era that have exceeded or will soon exceed their service lives. Other age-dependent needs may emerge as a result of individual problems with materials, workmanship, or other causes.

Resource Allocation and Prioritization

Five DOTs Represented in Tables 7 and 8

Resource allocation and prioritization are at the heart of infrastructure investment decision making. The entries in Tables 7 and 8 illustrate the differences arising from centralized versus decentralized bridge management philosophies. Several common themes, however, appear in all five agencies. These similarities and contrasts at three stages of the decision-making process are summarized here:

- **Resource allocation among programs.** Fundamental decisions on funding allocations among an agency's programs are made at a high level within all of the interviewed organizations. These decisions, although informed by technical and financial analyses, involve executive and senior management judgment in all cases. Two of the five agencies rely on a single organizational unit to make these decisions; the other three employ a senior-level meeting or an advisory committee assisting agency executives. Decision making tends to be centralized, although State B reports that its central office unit consults with regional managers on its decisions. State E performs trade-off analyses across programs in support of its decisions.
- **Fund allocations to districts, regions, or divisions.** Allocations of bridge monies among districts encompass a mix of procedures within and among agencies. For example, two agencies distinguish between types of proposed work (e.g., replacement vs. preservation) or highway classes to be addressed (NHS vs. non-NHS) and employ a statewide competition using BMS analyses for one category (e.g., bridge replacement or NHS projects), but a formula-based allocation for the other (e.g., preservation or non-NHS). These formulas account for the relative share of bridge inventory in each district based on bridge length or deck area. The remaining agencies adopt other methods: a uniform distribution of funds across all districts (driven by state law), statewide competition among all bridge projects (supported by Pontis analyses), and a centrally mandated allocation.
- **Project prioritization.** Prioritization methods reflect a mix of centralized and decentralized techniques. Several states rely on decentralized project prioritization, which may entail professional judgment among district bridge managers. Other agencies prioritize projects centrally with the assistance of their management systems, applying their own bridge condition and performance measures. One agency reports computing priorities centrally, but consulting with districts on the results.

10 Additional Agencies That Were Interviewed

The interviews with chief engineers of 10 additional state DOTs echoed many of the themes identified in Tables 7 and 8.

- **Resource allocation among programs.** Decisions on bridge program funding in competition with other transportation programs are made in most of the interviewed agencies by high-level committees formally charged with this function, or by groups of high-level agency managers. For example, in one agency, these senior managers include the director, chief engineer, heads of design, the bridge office, and other offices. Another agency includes district as well as functional managers. The specific decision processes and analyses these agencies use vary, however. Whereas one agency applies its BMS specifically to analyze critical bridge needs and conformance with technical standards and requirements, at least two other agencies base decisions on a highway corridor approach in which bridge needs are accounted for only within the broader context of roadway (particularly pavement) needs, with the roadways receiving greater priority. Other agencies depend on managerial or committee recommendations to senior managers, who make the final decisions on program funding. Some agencies perform trade-off analyses on different funding allocations, whereas others do not; one agency reported that its Transportation Commission is interested in the potential of AssetManager NT, a new AASHTOWare product, to assist in cross-program trade-off analyses. Another agency mentioned that bridge program proposals tend to be data-rich compared with those for other programs, making it difficult to provide evenhanded comparisons of needs across programs. Three of the agencies referred to dedicated funding mechanisms affecting bridges as a consideration in their program allocations: one state's constitutional protection of highway-related funding against modal competition; the dedicated bridge funding provided by the federal HBP; and a desire by an agency to take all bridge funding "off the top," asserting a priority for bridge needs and avoiding competition with other programs. None of the agencies discussed transfers of federal bridge funds. (Again, this topic will be covered in chapter four.)

- **Fund allocations to districts, regions, or divisions.** Allocations to districts by the 10 additional states that were interviewed represent a mix of methods similar to those reported by the agencies in Tables 7 and 8. Many of the reported methods involve centralized decisions (or a shift toward an increasingly centralized approach), often retaining input from the districts. Allocations may be based on analytic results (percentage distributions of needs) or criteria such as worst-first project candidates. One agency reported a more decentralized, data-driven approach involving district recommendation of funding needs with central office response. Two of the agencies referred to differences in allocation methods based on the type of bridge work (replacement or rehabilitation versus maintenance and repair), with decisions on the former work categories more centralized, and on the latter, more decentralized.
- **Project prioritization.** All of the reported prioritization methods involved collaboration between central office and districts, regardless of whether priorities are set centrally or by individual districts. In one example, the central office produces a list of priority projects, but districts can adjust the timing of projects. In another set of examples, the districts submit a recommended prioritization to the central office, but the final decision rests with the state bridge engineer or the chief engineer. One agency has a Feasible Action Review Committee to prioritize work needs and urgency. The committee meets monthly and determines whether the bridge work represents routine maintenance or periodic repair. Although this decision is based on the magnitude of the projected work scope, it also has funding implications because the two categories of work are funded from different programs.

Economic Methods

The five agencies in Tables 7 and 8 employ economic methods to varying degrees, but overall, their practices do not represent wide use. Two of the Pontis states use its benefit-cost analysis, and both are familiar with its user-cost component. One agency routinely applies user costs in its analyses; the second reports some issues with the calculation of road-user delay costs. Two other agencies plan to use economic methods in the future, following enhancements to their management systems. The fifth agency uses economic analyses infrequently in specific cases (e.g., to compare a rehabilitation versus a replacement project), but not on a regular basis. The FHWA Division Office has recommended greater use of economic methods to this agency.

Economic methods were not discussed in the 10 additional DOT interviews. Additional information on the application of economic methods is given, however, in the survey results discussed in the next section.

Accountability and Public Communication

Five DOTs Represented in Tables 7 and 8

A formal program of performance monitoring and accountability reporting does not yet exist among the five agencies interviewed, although several reported having considered the idea. Individual efforts have been undertaken in several specific areas. All agencies track NBI deficiencies in condition and performance ratings. Current reporting methods include providing bridge condition and performance information on an agency's website, issuing an annual accountability report, including bridge data in an agency's Transportation Fact Book, applying performance management as part of an agency's budgeting process, and communicating with the public when needed following bridge-related incidents. GASB 34 reporting also provides a measure of accountability. State C reported that when its new Bridge Index performance measure is implemented, it will provide a clearer picture to the public regarding the overall condition of the state's bridge inventory.

10 Additional Agencies That Were Interviewed

Several of the additional agencies that were interviewed have defined performance measures within a structured program of accountability, but the detail and level of sophistication vary. For example, one agency provides regular information on the status of bridge preservation as well as progress in delivering the bridge construction program. Another has developed a report card for distribution to the Transportation Commission, legislature, and governor, and discusses performance targets with the Transportation Commission. A third provides information on bridge structural integrity and impact on mobility using information based on the NBI data. Others base performance reporting on the physical condition of bridges as established through their inspection programs.

BRIDGE MANAGEMENT SYSTEM APPLICATIONS TO AGENCY DECISION MAKING

The preceding sections have described agencies' bridge management and decision-making processes in general. More focused information was also obtained regarding specific uses of their respective BMSs.

Support of Planning Process

The planning component of the survey asked whether particular features of the agency's BMS were used to support the planning process. A total of 17 agencies responded to this question, with the distribution of responses as shown in Figure 12. More than half of the respondents reported using their BMS for planning-related information in the following areas:

- The bridge inventory and condition and performance in several categories: structural and functional deficiency; susceptibility to catastrophic damage from scour, fracture critical elements that require attention, and seismic events; other safety problems; measures of statewide and district condition or health; and comparison of performance measures to targets
- Past and planned work by organizational or geographic unit
- Reporting in accordance with GASB Statement 34.

About 30% to 40% of respondents reported using their BMS for higher-level management functions, including budgeting, scenario testing, trade-off analyses, generating quantifiable parameters to provide guidance in project selection, and documenting past and planned bridge projects by political jurisdiction. Fewer than 10% of the respondents used their BMS for economic analyses—that is, for LCC analysis or computation of avoidable user costs as a function of alternative budget scenarios.

These results have implications similar to those documented in the *NCHRP Synthesis 243* (the Topic 27-09 survey) 10 years ago and the other historical reviews of BMS implementation summarized earlier: a strong use of bridge and other asset

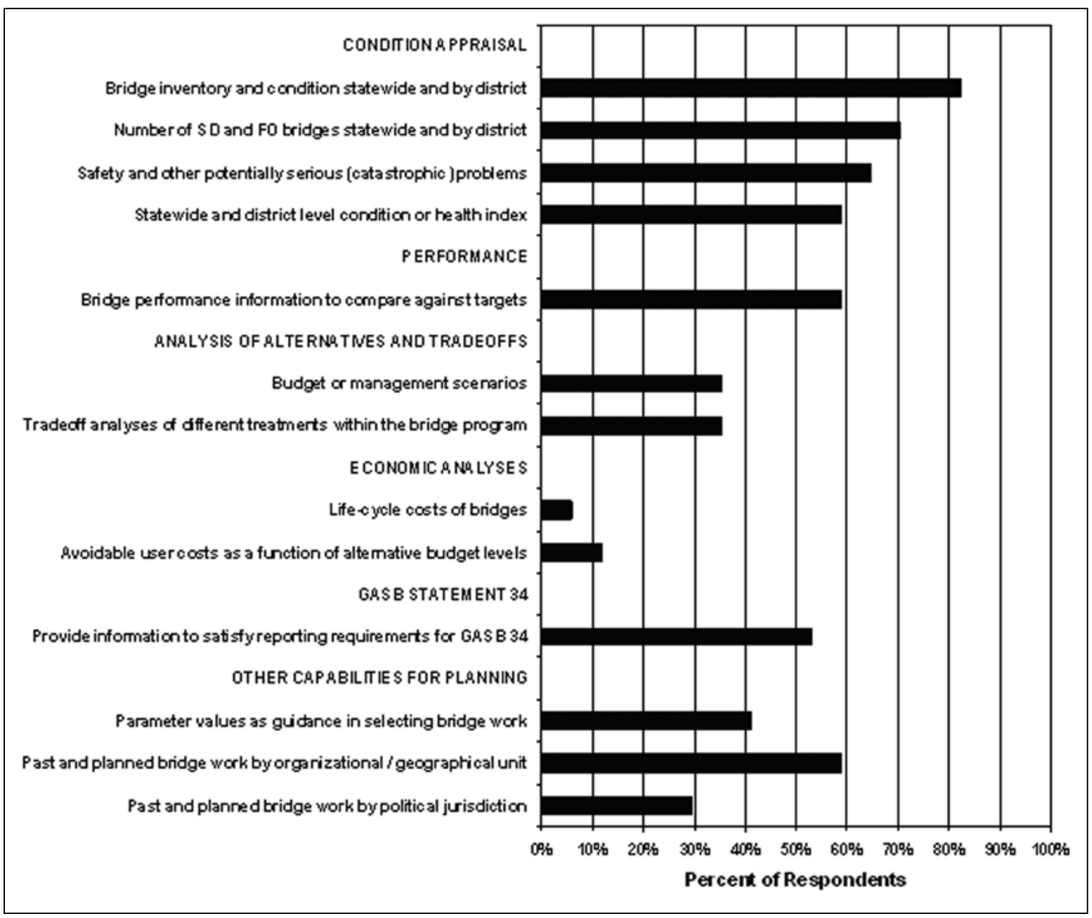

FIGURE 12 BMS support of agency planning processes. *Note:* FO = Functional Obsolescence; GASB = Governmental Accounting Standards Board; SD = Structural Deficiency.

management systems to track inventory and asset condition and performance, but less use for more advanced tasks in management, budgeting, and predictive analyses. Although economic methods are recognized as important techniques in good asset management practice, they reportedly receive little attention in BMS applications to planning. Similar findings will be seen in the discussion of programming processes and senior management uses of BMS information in the following sections.

Support of Programming Process

Survey participants were queried regarding the application of their computerized BMS to three analyses that are part of project programming: (1) quantifying performance measures; (2) needs analyses; and (3) resource allocation and trade-off analyses. Each question required one of the following ratings as a response:

- The analysis is accomplished primarily through use of the BMS.
- The analysis makes use of the BMS plus additional processing of BMS information (external to the BMS) or professional judgment.
- The BMS is seldom or never used for this analysis.

The survey results for these three stages of programming analyses are shown in graphics similar to Figure 13. These graphics apply stacked 100% horizontal bars to illustrate the distribution of responses according to the three ratings cited previously; they also give a visual cue as to whether or not the BMS is used at all in each type of analysis. This is done by using a positive and negative scale that extends to 100% of responses in each direction. For example, a bar that extended to +100% would indicate that all respondents used the BMS in some capacity, whether to complete the analysis fully (the first rating cited previously) or partially, supplemented by additional analyses outside of the BMS (the second rating cited previously). A bar that extended to −100% (i.e., to the left of the zero origin) would mean that none of the respondents used their BMS regularly for the particular analysis (i.e., all would have selected the third option cited previously). More typically, the bars will lie between intermediate values: say, 70% of respondents using the BMS, but 30% that do not. There are, of course, many other possible combinations, but the sum of those using the BMS plus those not using the BMS by definition will always total 100%. Graphics similar to Figure 13 display the survey results; the actual numerical response data are in Appendix D (see Questions 34–50).

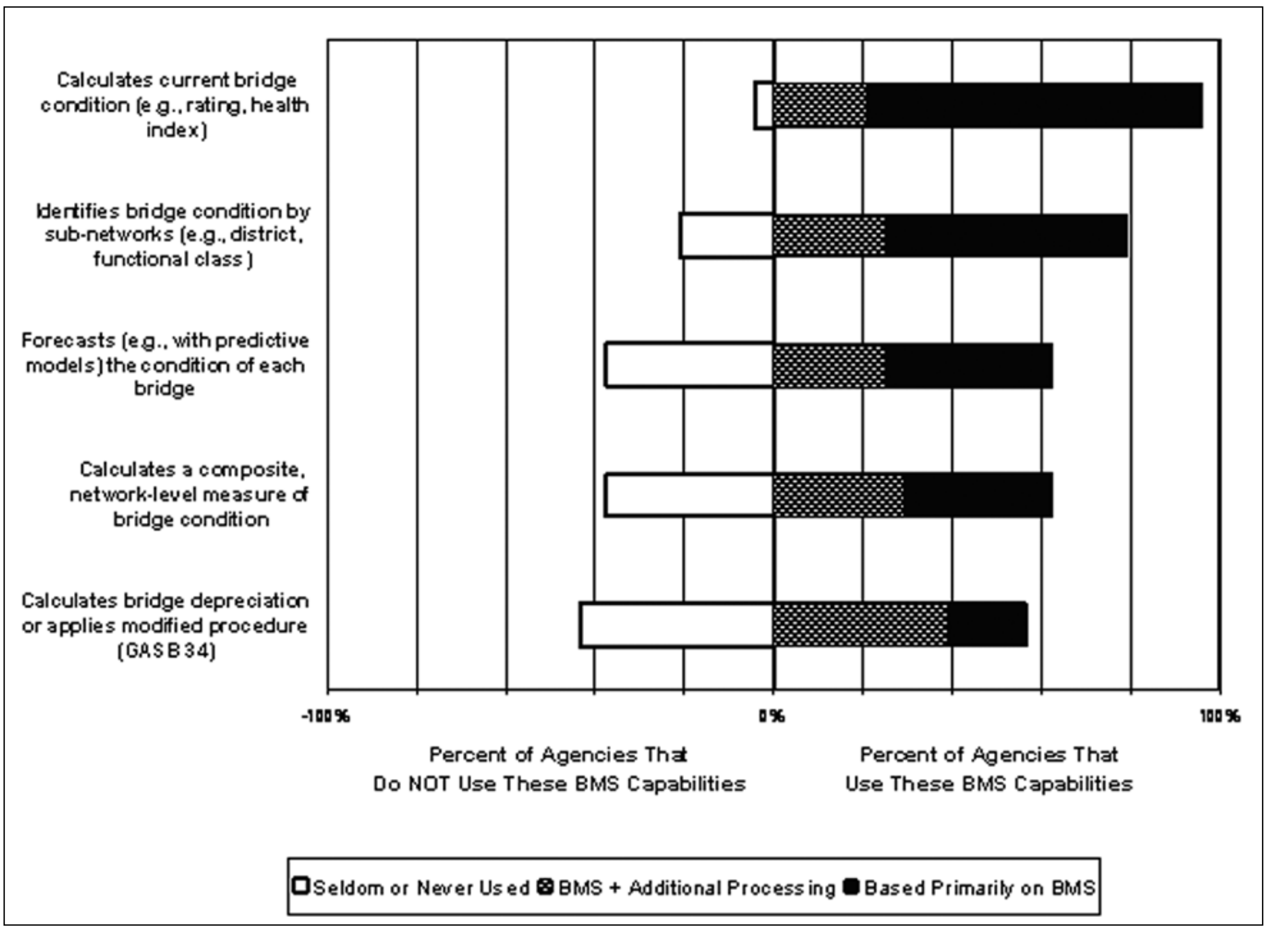

FIGURE 13 Agency use of BMS to quantify performance measures. *Note:* BMS = bridge management system; GASB = Governmental Accounting Standards Board.

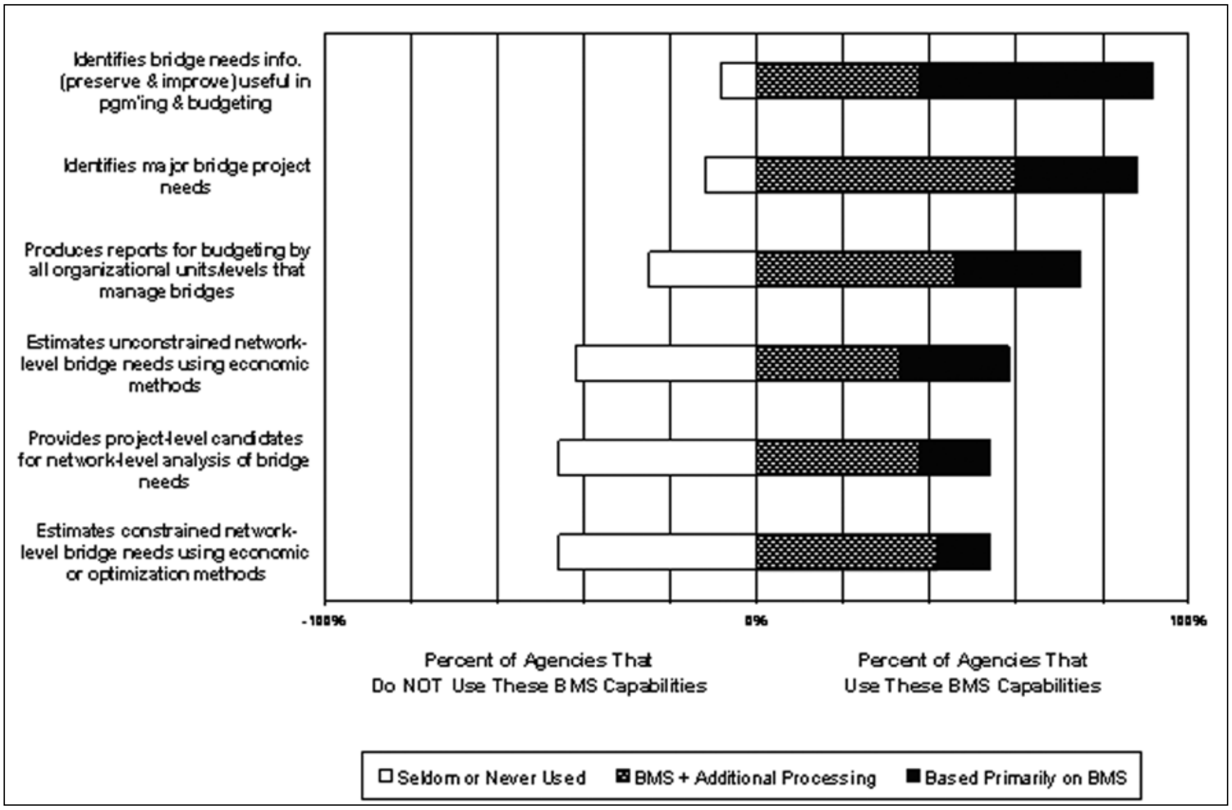

FIGURE 14 Agency use of BMS for needs analyses. *Note:* BMS = bridge management system.

Quantifying Performance Measures

The use of BMSs to quantify performance measures is one of two programming-support analyses that received strong positive survey responses, as shown in Figure 13. Almost all respondents indicated that their BMS is used to calculate current bridge condition or performance directly, with relatively little need for additional input from supplementary analyses or professional judgment (first response in Figure 13). Eighty percent of respondents reported obtaining corresponding condition-performance information for particular subsets of the bridge network. For the other options in Figure 13, the BMS was reportedly used by a smaller share of respondents (roughly 60% in each case), with additional analytic support particularly noted for GASB 34 reporting.

Needs Analysis

Needs analysis was a second area in which survey respondents strongly indicated a key role for BMS in programming, as shown in Figure 14. More than 90% of survey respondents use a BMS to support needs analysis, and almost 90% use BMS information in connection with identifying major-bridge needs (first and second entries in Figure 14). The frequent use of other information in addition to that from a computerized system in addressing major projects is not surprising, given the high visibility of these projects and the extent of input provided by agency executives, political leaders, and stakeholders. BMSs are applied when preparing reports for use in budgeting by subordinate levels. To a lesser degree, BMSs are used to develop network-level estimates of needs by applying technical inputs in terms of project-level candidates and economic analyses of unconstrained and constrained needs. Supplementary analyses and professional judgment are relatively important in these network-level needs calculations. One interview described an example of such a situation. This particular DOT uses Pontis, which already has built-in predictive models for analyzing future bridge conditions and estimating needs. Nevertheless, the agency applies the NBI Translator program to convert Pontis element-level bridge ratings to NBI ratings. The agency then uses these NBI ratings to estimate its coming bridge needs, even though the NBI data are less detailed and represent current rather than future bridge condition.

Resource Allocation and Trade-offs

BMSs are used less frequently for resource allocation and trade-off analyses than for the previous two analytical aspects of programming, as demonstrated by survey results in Figure 15. BMS applications to resource allocations statewide, by functional class or subnetwork and by organizational unit, and budgeting support to central office and field personnel that manage bridges, were reported by 60% to 70% of survey respondents. In many of these cases the BMS information is supplemented by additional analytic or subjective considerations. Interviews indicated that this often occurs regarding decisions on funding allocation. Use of BMS information to produce project-level or network-level summaries of the impacts of different proposed budgets, as might be used by bridge personnel and upper management to justify particular levels of investment, was reported much less frequently, and where it is performed, it rarely is accomplished using the BMS alone. The reasons for these results may include one or more of the following: (1) preferences by different managers vary on what categories or formats of information to display; (2) models and data that are needed to compute these impacts are not now part of the agency's BMS; (3) data or analytic models that are needed to calculate the desired impacts may not be available or credible in the opinion of potential users; and (4) agency personnel do not believe that predictions of the impacts of different budget levels are needed or useful.

Budgeting

Responding to the budgeting component of the survey, two-thirds of participating agencies reported that their agency's BMS is used to support their budgeting process. The extent of use of particular BMS information was identified as shown in Figure 16.

The most widely applied uses were as follows, with the percentage of respondents:

- To generate summary information about the inventory, condition, SD, and FO at the network and district levels (67%)
- To produce information that can be compared with performance targets set by management (48%)
- To identify safety or other serious problems such as scour, presence of fracture critical elements, or seismic vulnerability (43%)
- To provide information to satisfy public reporting requirements of GASB 34 (43%).

Additional Information on Budgeting

A separate component of the budgeting portion of the survey asked about factors that influence the budgeting process for the bridge program. The results generally reinforce the findings described earlier and provide additional details. These additional results are included in Appendix E.

System Information Used by Management Team

A related set of survey questions inquired about the use of BMS-produced information generally by the CEO and

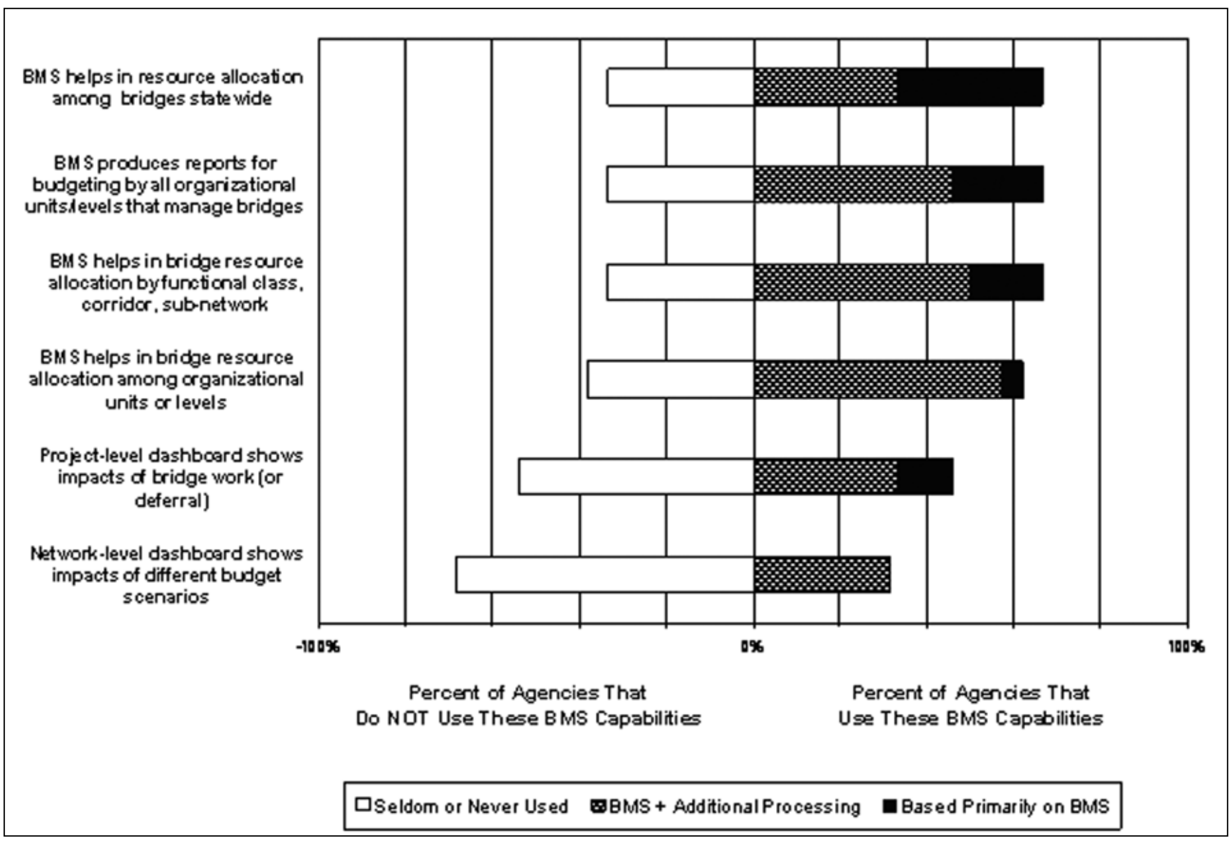

FIGURE 15 Agency use of BMS for resource allocation and trade-off analyses. *Note:* BMS = bridge management system.

upper-level managers. The three categories of information that were posed were bridge condition and performance, programming and budgeting, and economic analysis. Findings are presented graphically in the sections that follow. The numerical survey tallies are in Appendix D (see Bridge Engineer Questions 1–25 and 64).

Bridge Condition and Performance

Reported use of different types of bridge condition and performance information by senior managers is shown in Figure 17. More than 80% of the respondents use BMS reports on bridge condition and performance, including NBI ratings,

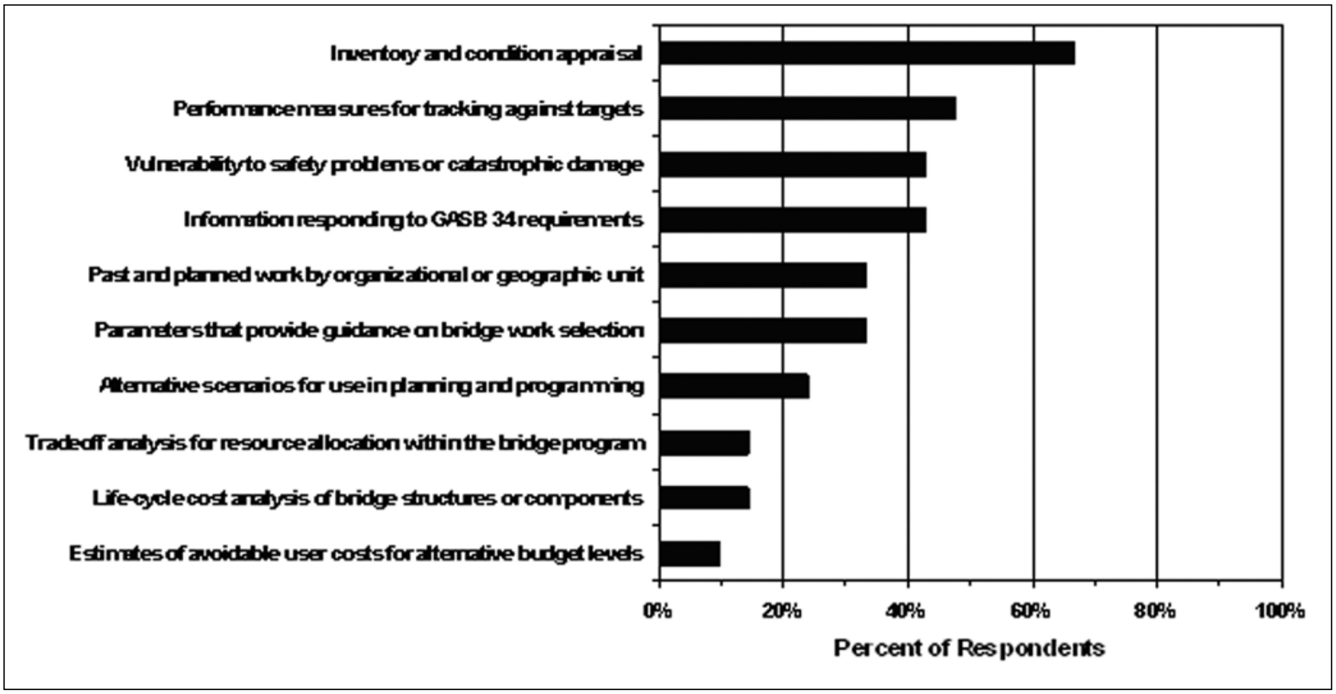

FIGURE 16 Agency use of BMS information for budgeting. *Note:* GASB = Governmental Accounting Standards Board.

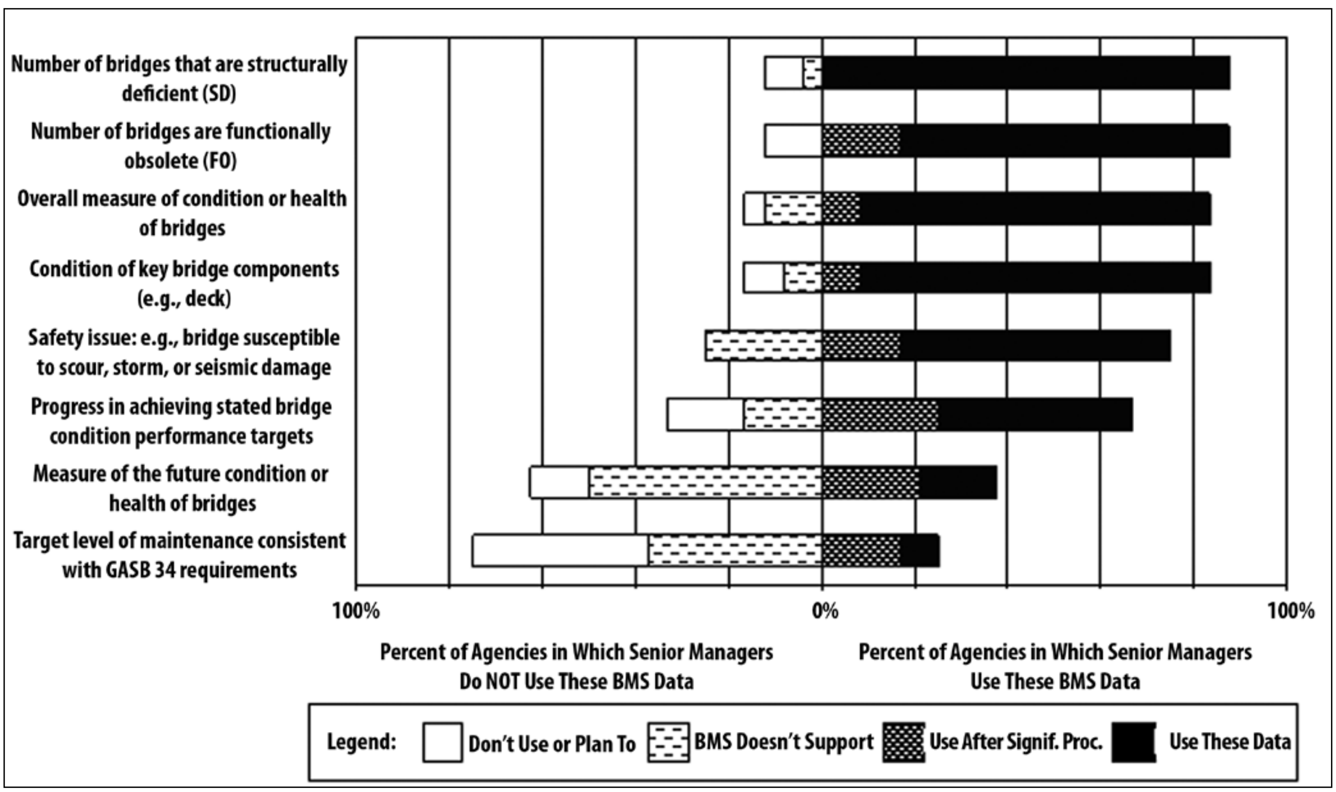

FIGURE 17 Senior manager use of information on bridge condition and performance. *Note:* BMS = bridge management system; GASB = Governmental Accounting Standards Board.

other measures and health indexes, and specific ratings of key bridge components. Respondents expressed strong interest in other information on bridge safety, including susceptibility to catastrophic events, and tracking the success in meeting stated condition targets. All of these examples relate to the current status of the bridge inventory. Reported use of information that is produced by the predictive capabilities of BMS is substantially lower. A perhaps surprising result is that half of the respondents attributed this lack of use to the inability of their agencies' BMS to predict the future condition or health of their bridges. The survey results did not reveal the reasons for this limited use of BMS prediction models, which might be the result of a number of reasons:

- An agency's BMS may lack predictive models.
- The BMS has predictive models, but agency staff do not use them or are not familiar with how to use them.
- Available models may employ condition or performance measures that are different from the ones the agency uses.
- The BMS has predictive capability, but the agency has not yet analyzed the data needed to develop appropriate models.
- The BMS itself may be difficult to use in terms of its user interface, navigation controls, access to the bridge database, lack of integration with other systems and data, and so forth.
- The available predictive models do not enjoy credibility within the agency.

The low reported use of the BMS for GASB-related information may reflect some of these issues or may stem from the agency's choice of method for GASB 34 reporting.

Programming and Budgeting Information

Senior management use of various categories of programming and budgeting information is shown in Figure 18. The greatest reported use is for items that are of immediate interest and most direct and unambiguous in their scope—for example, a single recommended bridge program budget, estimates of short-term needs for different funding scenarios, and information on major bridge projects. Use of BMS results declines as the focus of this information extends to longer planning horizons, more predictive types of analyses such as trade-offs and impacts of different resource allocations, and various ways of breaking down the information. (It is possible that agencies organize their information differently from the ways suggested in the survey.) Two interesting aspects of agency responses were the following:

- Many responses, including those for widely used budgeting capabilities, indicated that additional processing is needed beyond that provided by the BMS before

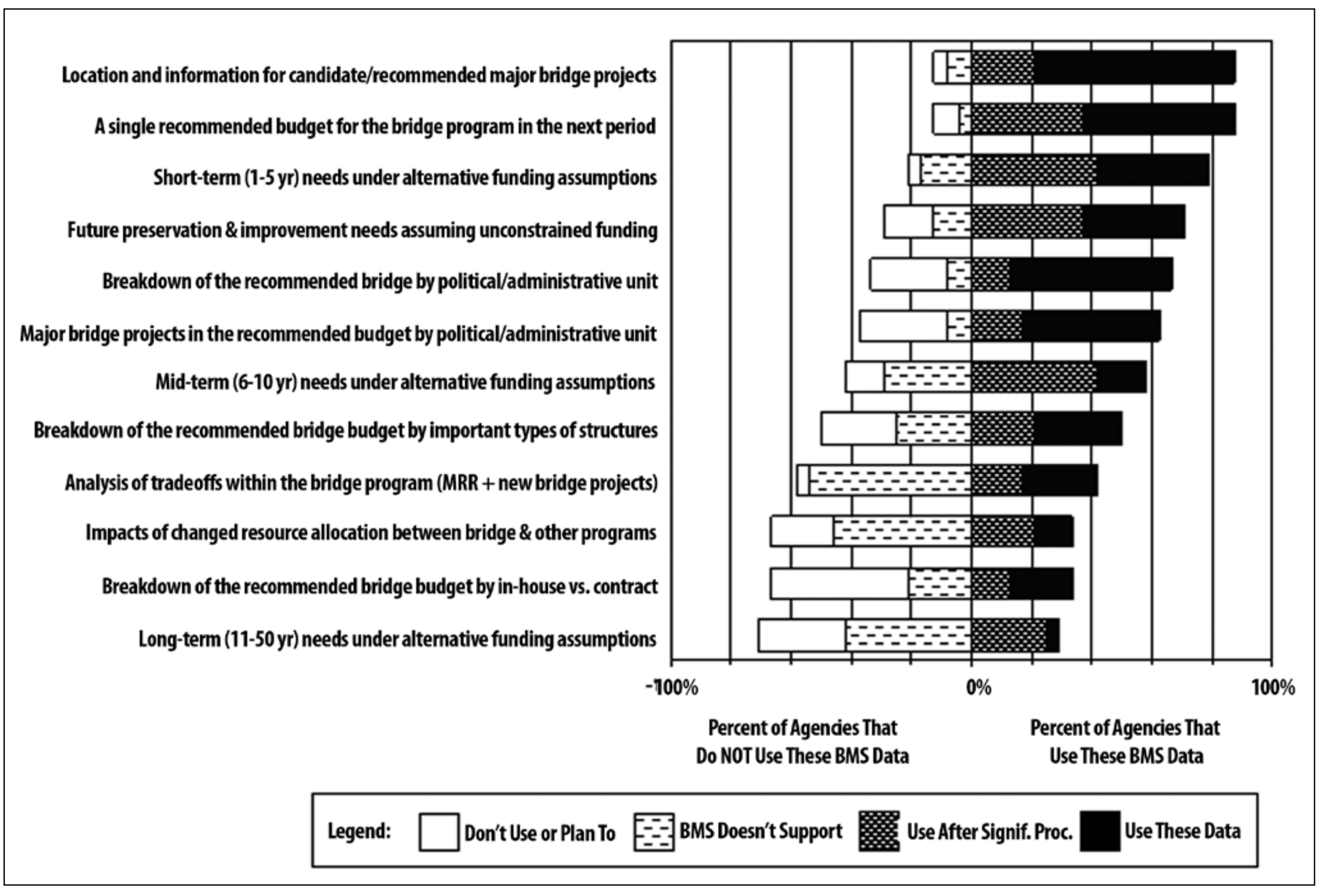

FIGURE 18 Senior manager use of information for programming and budgeting. *Note:* BMS = bridge management system; MRR = maintenance, rehabilitation, and replacement.

the information is in a form useable by agency executives. Supplementary comments suggested that additional information and analyses may relate to things such as district and local priorities, more comprehensive project information, socioeconomic and political considerations, and information for other, nonbridge programs, such as roadway pavements, safety, and operations.

- Many responses referred to the programming and budgeting information that is reportedly less widely supported by a BMS (the results in the lower part of Figure 18). With the exception of information on in-house versus contracted program delivery, a majority of the respondents who do not use their BMSs to obtain this information cited a lack of capability within their BMS as the reason. These results are again somewhat surprising given that features built into modern BMSs appear to support most of the categories of information listed in Figure 18, including mid- and long-term needs projections and analyses of scenarios and trade-offs. The survey results did not state reasons or explanations for the agencies' perceptions, but a number of possibilities exist similar to those proposed in the preceding section. Regarding in-house versus contract program delivery, the lack of use of the BMS to produce this information appears to relate more to a lack of desire for this information than to any issue with the capability of the BMS.

Economic Analysis Information

Figure 19 displays the reported use by DOT top managers of economic analysis for bridges. Overall, the use is relatively small for all of the cases listed in the survey. Relatively, the greatest application is for benefit-cost analyses of major bridge project alternatives, an occasionally used capability that was confirmed in the interviews. The other economic analyses shown in Figure 19 were each reported by fewer than 20% of the respondents. The implication is that the leadership of a relatively small number of agencies is able to use their BMS to gain a network-level perspective of the economic issues relating to their bridge program. These issues include, for example, network-level benefit-cost ratios for alternative bridge program investments, network-level estimates of LCCs, and network-level estimates of avoidable road-user costs (accident, travel time, and vehicle operating costs). Once more, most of the respondents who do not use their BMS for economic analyses claim that the BMS does not support these methods, a claim that is difficult to reconcile with the existing features of Pontis and other modern bridge management tools.

Overcoming Obstacles to Achieve More Effective Bridge Management System Use

Agencies that reported *not* using many of the BMS capabilities discussed earlier (specifically the features listed

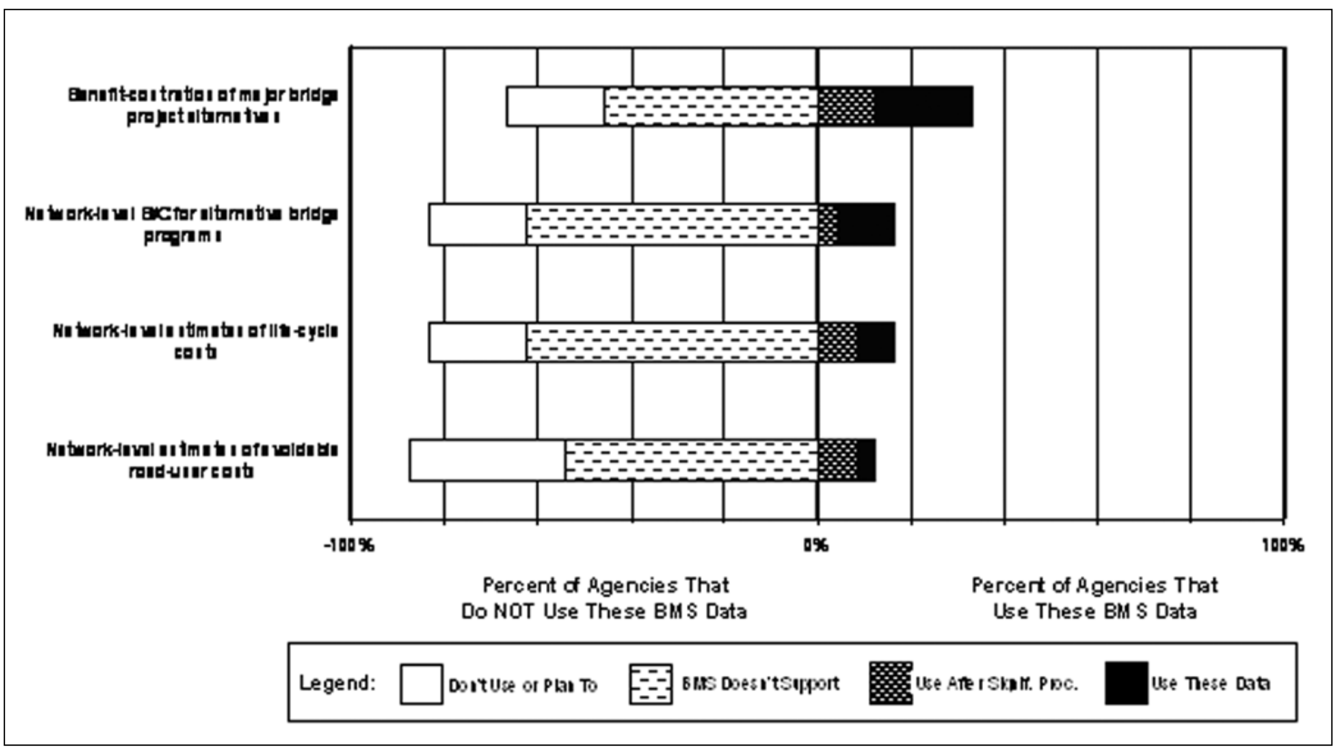

FIGURE 19 Senior manager use of economic analysis information. *Note:* B/C = benefit-cost; BMS = bridge management system.

in Figures 13 through 15) were asked to identify barriers or impediments to greater BMS use for investment and resource allocation decisions. Responses are listed here as paraphrased from the survey questionnaire, followed by the number of respondents in parentheses. The reasons are wide-ranging with no particular dominant theme, although a few responses do reflect some common agency reactions in terms of (1) reservations about the economic analyses within their BMS and (2) a lack of confidence in, or familiarity with, their BMS's technical analyses.

- The recommended actions from the BMS are too different from the actions that agency bridge inspectors and engineers recommend (2).
- The BMS gives too much emphasis to economic considerations relative to other considerations, especially conditions observed in the field (1).
- The economic assumptions are not accurate (2).
- Too many managers perceive the BMS as a black box—it uses analytic procedures that are not well understood by agency personnel (1).
- Management's capabilities include the ability to assess current and future needs. A BMS detracts from the bridge manager's prerogatives (1).
- We have found it difficult to implement a BMS, train personnel, and obtain buy-in from managers who must depend on it (2).
- We have had problems with reliability; for example, in software, data, and/or analysis (1).

Additional survey responses that discuss recommended new BMS capabilities to strengthen the support of programming and budgeting are presented in chapter four.

RESPONSIBLE ORGANIZATIONAL UNITS FOR DECISION MAKING

Table 9 organizes the bridge engineer survey responses according to where program decisions are made; that is, by organizational unit, level, or decision maker(s). The key decisions in the row headings are as follows:

- *Program Allocations:* The allocation of funds among different assets or programs (e.g., pavements, bridges, maintenance, or transit)
- *Performance Measures:* What performance measures will be used
- *Performance Targets:* What performance targets will be set
- *Bridge Funding Split:* The split of funds for bridge preservation, rehabilitation, and replacement
- *Major Bridge Projects:* The major bridge projects that will be funded
- *Bridge Project Selection:* Other state-owned bridge projects that will receive funding/some action in a given year
- *Local Non-Metro Bridges:* Local bridges outside metropolitan areas that will receive funding
- *Metro TIP Bridges:* Bridges in metropolitan areas that will be funded and included in a metropolitan Transportation Improvement Program.

The specific organizational units, levels, or managers that survey respondents identified have been consolidated within six categories to enable a broad view of variations in decision-making authority that occur across the types of decisions described earlier and among and within the responding

TABLE 9
ORGANIZATIONAL UNITS MAKING BRIDGE PROGRAMMING DECISIONS

Programming Decisions	Board—Commission	Agency Executive	Central Office—Bridge	Central Office—Other Units	Districts—Regions	Local—Regional
Program Allocations	4	7	1	10	2	0
Performance Measures	1	4	9	8	2	0
Performance Targets	2	3	7	5	1	0
Bridge Funding Split	0	3	9	7	9	0
Major Bridge Projects	3	8	8	4	5	0
Bridge Project Selection	0	3	13	6	11	0
Local Non-Metro Bridges	1	2	6	9	4	13
Metro TIP Bridges	2	3	6	7	8	12

Note: Data represent number of survey responses. Most frequently cited responses are in bold and underlined.
TIP = Transportation Improvement Program.

state DOTs. These organizational categories or levels are as follows, with typical examples of DOT positions or committees that are encompassed by each (equivalent units having different names or titles in other agencies are included by inference):

- *Board—Commission:* The highway/transportation board or commission; the provincial minister or (assistant) deputy
- *Agency Executive:* The DOT executive or front office, encompassing (as examples) the CEO, DOT director, or minister of transportation, highways or public works; agency deputy directors or ministers (and assistant deputies); chief engineer and deputy; executive boards or committees; others considered front-office with broad decision-making authority
- *Central Office—Bridge:* Senior central-office bridge managers, including the state (provincial) chief bridge engineer, chief bridge maintenance engineer, bridge program manager, bridge management engineer, and chief or head engineers of bridge design, construction, and operations
- *Central Office—Other Divisions:* Heads, directors, chiefs, and senior managers of other central-office divisions, offices, or units, including planning (and bridge management section if part of planning), capital programming, policy and strategy, highways, design, construction, maintenance, operations, finance, budget, programs and contracts, and project management. Also included are those state or provincial agency units related to local programs, particularly local or municipal bridge programs
- *Districts—Regions:* District or regional directors, engineers, bridge staff, and liaisons to local or regional organizations
- *Local—Regional:* Local (i.e., city and county) governments, transportation and public works agencies, MPOs, regional transportation or planning organizations, and bodies with recognized decision-making authority; for example, county engineer associations.

The entries in Table 9 tally the number of responses that link decision-making authority of an organizational category with each type of decision. Respondents often identified joint or multiple decision responsibility; in these cases, each such organizational unit was counted. After all responses were tallied and summed, the top two or three organizational levels that were most frequently identified as having decision-making authority were identified for each programming decision. These top-voted organizational levels are highlighted in bold in Table 9 to reveal basic patterns that reflect a high-level consensus of practice across agencies.

Generally speaking, the bridge office is significantly involved in all programming decisions that deal specifically with bridges, but this authority is shared with other groups within and outside the agency. For example, major bridge projects involve strong participation by agency executives and, in some states, the oversight board or commission. Regional and local officials will also be involved for major projects in urban areas. Local bridge programs involve significant roles by local and regional bodies together with the state agency's local or municipal assistance unit. Districts (or regions or divisions) have a strong say in decisions involving all categories of bridge projects within their jurisdiction: local, state-owned, and major bridges. Although the bridge unit also plays a key role in establishing performance measures and targets for bridge programs, the executive level has a clear interest in bridge condition and performance as an important component of agency performance statewide. There is also strong involvement in performance monitoring by other agency divisions, typically in planning, development or investment management, policy and strategy, and asset management.

The one programming decision in which the bridge unit is reported not to have a dominant role is the allocation of resources among competing agency programs: bridge versus pavement, safety, maintenance, and so on. The responding bridge engineers see this decision as an executive-level function with board or commission involvement in several states, or as a wider departmental decision by such units as planning, investment management, policy and strategy, project management, and (in Newfoundland and Labrador) the director of highway design and construction. In two states, this decision is seen as decentralized, with allocation decisions made by districts.

Table 9 is useful as a high-level summary of these survey responses. Readers interested in specific information by state may consult the tables of survey results in Appendix D (see Questions 26–33).

Although the numerical results in Table 9 convey the chief engineers' perceptions of where particular decisions are actually made, they should not be misinterpreted as "degree of influence" on decisions. For example, a state's transportation board or commission and the agency's executive office would typically exercise a strong influence on performance measures and targets through their interaction with and response to gubernatorial and legislative bodies; their communication with public interest groups and stakeholders; and their resulting formulation and communication of agency mission, policies, and priorities. A literal reading of the numbers in Table 9 belies the significance of upper-management influence on performance monitoring. Similar comments apply to the other programming decisions regarding resource allocation.

This somewhat different perspective on organizational decision making for bridges is captured in responses to another question in the survey. Respondents to the budgeting component were asked to identify which organizational units played “a key role” in making decisions regarding the following:

- Allocation of resources within the bridge program
- Allocation of resources between the bridge program and other programs in the department.

This inquiry was structured as a single question with a check-off list of 19 organizational units. Results are shown in Figure 20. Following are the four groupings of organizational units in terms of frequency of response:

- Organizational units that received the greatest number of responses (more than 60%) included the office of the chief executive, bridge maintenance, planning and programming, and the district or regional director or engineer.
- The group that received 35% to 45% of responses encompassed the central office budget, maintenance, operations, finance, and bridge construction divisions, and district planning, maintenance, and programming and budgeting offices.
- The group that received less than 25% of responses included central office and district construction units (the “other” responses were not further identified).

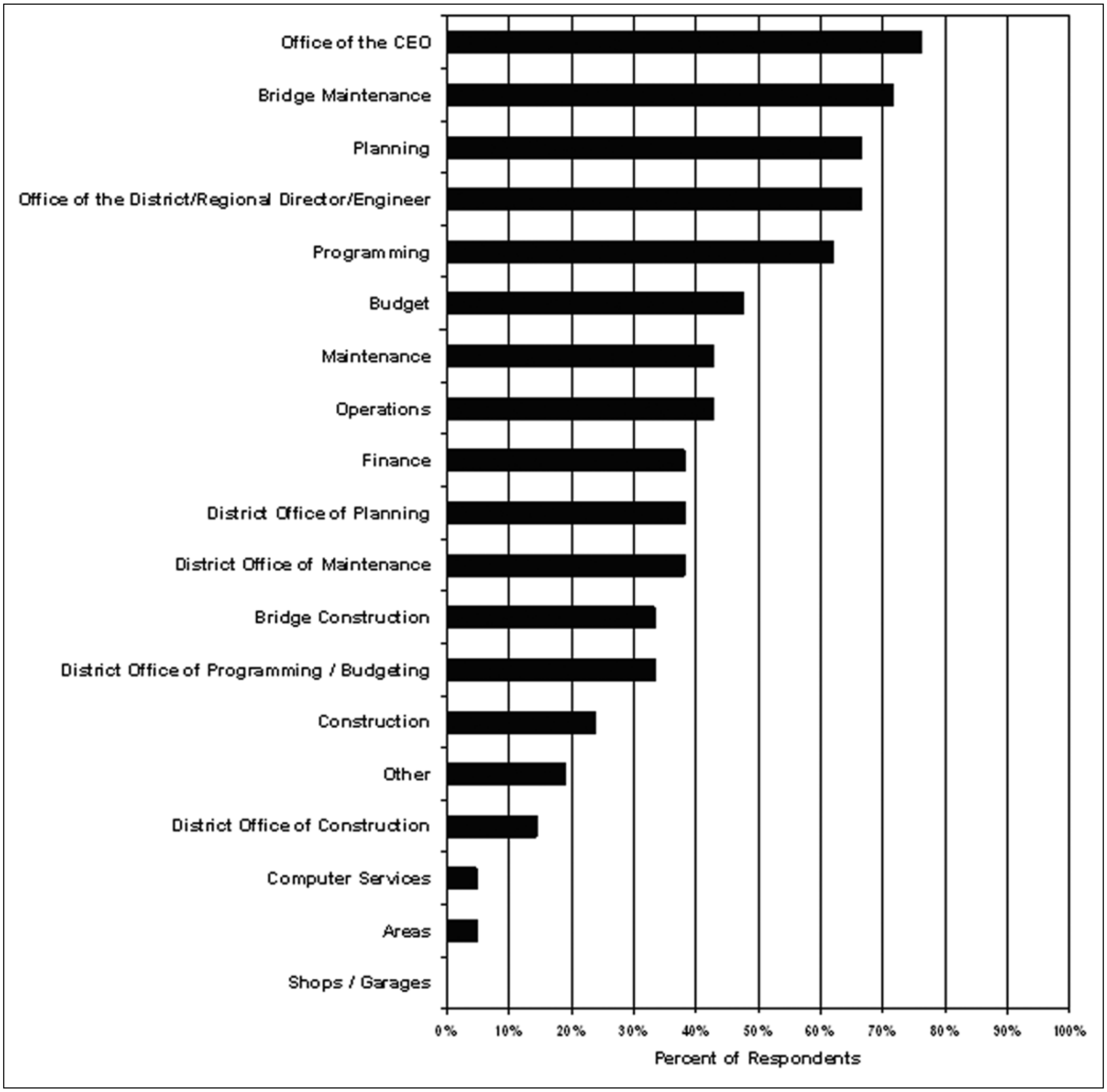

FIGURE 20 Organizational units with key roles in bridge program decisions. *Note:* CEO = chief executive officer.

- The fourth group that received few or no responses included computer services and local field offices.

Apart from the greater emphasis on the role of agency executives, the findings in Figure 20 are generally consistent with those of Table 9—that is, the strong participation in bridge resource allocation of the central office bridge unit, region or district directors, and central office planning and programming. These two sets of results were provided by somewhat different pools of respondents (with a degree of overlap), and the check-off list of organizational units underlying Figure 20 did not include all of the decision makers identified by respondents contributing to Table 9. Again, it is important to recognize the considerable variation in agency organizational structures and management culture, programming processes, functional roles and responsibilities, and attitudes toward centralized or decentralized decision making. Although an individual agency's practices may or may not conform exactly to the trends in Table 9 or Figure 20, a general overview of where bridge-related decisions are made is nonetheless helpful in understanding the other aspects of bridge resource allocation that are discussed in this chapter.

CHAPTER FOUR

EMERGING TRENDS

OVERVIEW

Several trends that are emerging industrywide will influence bridge management and its role in agency decision making. These trends have to do with basic advances in bridge management methodology and practice that result from research—including technical research in the mechanisms of bridge deterioration and in nondestructive technologies of bridge inspection—as well as broader principles of agency decision making that are evolving through such initiatives as asset management and systemwide bridge preservation. Developments that followed the I-35W bridge collapse in Minneapolis in August 2007 crystallized the following issues relevant to bridge program funding, management, and budgeting:

- The need for a review of the NBIS, which was formally requested by the U.S.DOT
- State agency perspectives on the administration of HBP funding, the need for a long-term, data-driven approach to bridge management, and their implications for executive decision making.

These issues were being addressed by some transportation agencies in an individual way up to that point, but now were elevated to national attention. Potential changes that may result in both bridge management practices and agencies' high-level decision making regarding their bridge programs are relevant to this synthesis and are summarized in this chapter, which is organized as follows:

- The first section summarizes suggestions for action regarding the NBIS, federal bridge program administration and funding guidelines, and communication and public awareness regarding the bridge program, which followed the I-35W bridge collapse.
- The second section provides an overview of general findings and suggestions that have resulted from several peer exchanges and program initiatives in asset management and bridge preservation.
- The third section compiles suggestions for further research to improve bridge management practice that were documented in the bridge-related TRB Millennium Paper or were submitted as part of the survey conducted in this synthesis.

AFTERMATH OF I-35W BRIDGE COLLAPSE

Introduction

The collapse of the I-35W bridge in Minneapolis on August 1, 2007, raised concerns about the condition of other bridges nationwide. Many concerns focused on bridges that were structurally deficient, as was the I-35W bridge, and set in motion several urgent initiatives. Actions included policy pronouncements at the federal, state, and local levels; proposed new federal funding programs for the nation's bridges; extensive congressional testimony on a wide range of bridge-related topics; extensive news coverage of the I-35W failure itself as well as broader coverage of the nation's structurally deficient bridges, funding needs, and safety concerns; and establishment of several websites to better inform the public about bridge-related matters. The causes of the bridge collapse and descriptions of the subsequent bridge replacement project are beyond the scope of this study. However, several actions taken in the aftermath of this tragedy have important implications for future bridge management; these are discussed in the sections that follow.

Review of National Bridge Inspection Standards

On August 2, 2007, the day after the I-35W bridge collapse, U.S.DOT Secretary Mary Peters announced a "rigorous assessment of the National Bridge Inspection Program" to be conducted by the U.S.DOT's Office of the Inspector General (OIG). The review was billed as "top to bottom" to prevent such a tragedy from ever happening again. The Inspector General will "determine if the current federal program delivers the highest level of bridge safety" and, if needed, will "make recommendations for future changes to the program" (U.S.DOT 2007). This U.S.DOT review was reinforced by Secretary Peters in subsequent congressional testimony, in which she referred to a "necessary national conversation [that] has begun concerning the state of the Nation's bridges and highways and the financial model used to build, maintain, and operate them." Cautioning that the bridge collapse, as tragic as it was, did not represent "a broad transportation infrastructure 'safety' crisis," she described the current and broader problem in U.S. highway transportation as "an increasingly flawed investment model and a system performance crisis" that required basic changes in how competing investment alternatives are analyzed and how existing bridge systems are managed. Secretary Peters outlined suggested process improvements, including a reduction in funding earmarks to promote greater reliance on proper prioritization methods, wider use of benefit-cost analysis, and greater use of performance-based management techniques (Peters 2007).

The U.S.DOT OIG elaborated upon the background and scope of the NBIS review in a subsequent memo (Scovel 2007a):

- Suggestions to improve FHWA's oversight of structurally deficient bridges had been made in an earlier OIG review in March 2006. The OIG further recommended at that time that FHWA "develop a risk-based, data-driven approach and metrics to focus its oversight efforts."
- The I-35W bridge collapse highlighted the importance of exercising oversight of the inspection and repair of SD bridges. An objective of the current review is therefore to evaluate FHWA's implementation of NBIS and to suggest improvements that ensure that the FHWA is effectively promoting bridge safety.
- The current audit will proceed in three concurrent phases with sequential reporting dates:
  - An assessment of the corrective actions by FHWA responding to the March 2006 OIG recommendations
  - A study of the HBP and discretionary funding provided to states to correct bridge structural deficiencies, which will assess the degree to which states use this funding to repair or replace SD bridges effectively and efficiently
  - A comprehensive review of the FHWA's oversight activities to ensure the safety of NHS bridges nationwide.

The U.S.DOT OIG review is ongoing as this report is submitted for publication.

Proposed Changes in Administration of the Federal Bridge Program

Proposals in Congressional Testimony

In congressional testimony through September 2007, state transportation agency executives outlined a number of proposals to revise current federal and state practices in bridge program administration. Suggestions that relate to the scope of this study included the following (Steudle 2007a):

- **Apply an asset management approach rather than a worst-first approach.** The current approach favors a worst-first strategy (fixing bridges that are rated SD or FO), which in the meantime allows other bridges to deteriorate to a poor condition, becoming the new "worst" problems. An asset management approach systematically addresses bridges according to performance targets and appropriate preventive and corrective treatments. Experience has shown that this proactive, efficient approach can reduce the percentage rated SD or FO over time.
- **Revise the administration of the federal HBP funding to allow allocation and expenditure of bridge funds under an asset management approach.** For example, eliminate or relax the use of the SR and its arbitrary thresholds (less than 80 for rehabilitation, less than 50 for replacement) used to determine eligibility for HBP funding. These thresholds have not changed in more than 30 years and do not encourage efficient bridge preservation. An effective asset management approach could preserve bridges more economically, and should be used to identify the eligibility of projects for HBP funds more flexibly.
- **Eliminate the 10-year rule.** This rule prevents DOTs from using HBP funds on a bridge more than once in 10 years. An asset management-based approach would benefit from a more flexible timing of bridge work and could preserve bridges more economically and proactively.

These recommendations were reinforced and expanded upon in subsequent congressional testimony (Steudle 2007b):

- Classifying a bridge as structurally deficient (as was the I-35W bridge and about 74,000 more throughout the country) does not necessarily mean it is unsafe, but it does mean that work is required.
- Additional federal bridge funding is needed, but should be combined with long-term, data-driven management practices that give state DOTs more flexibility in their bridge maintenance programs.
- Taking Michigan's asset management approach as an example, bridges are inspected more frequently and more thoroughly than required by federal law. Strategic goals are set and are met with capital preventive maintenance programs. This systematic approach has been far more successful in reducing the number of structurally deficient bridges than Michigan's earlier use of a worst-first approach.
- Concerns about state DOTs' transfers of available bridge funds reflect a misunderstanding of the reasons involved. Transfers of HBP apportionments to other federal programs do not imply a diminished priority for bridges, but rather a need by agencies to apply available funds more flexibly to their full range of needs. Current rules on HBP funding eligibility are too restrictive, and agencies may transfer bridge dollars to other programs that allow greater flexibility. Conversely, agencies may apply federal funds from other, more flexible

programs (as well as state funds) to meet their bridge needs. Available data indicate that state and local agencies spend more of their own funds on bridges than the amount needed for federal match.

- Although SAFETEA-LU allows federal HBP funds to be used for preventive bridge maintenance so long as a state undertakes systematic bridge preservation, "that requirement has been applied inconsistently by federal officials in terms of what is required of the states" (Steudle 2007b, p. 5). Systematic bridge preservation can be implemented with the help of a BMS.

Additional support of these positions was provided in congressional testimony by others:

- The term "structurally deficient" does not mean "that [a bridge] is unsafe, though it may require the posting of a vehicle weight restriction . . . [structural deficiency] is not a description of the safety and strength of a bridge, [rather] it is a description created for the purpose of allocating federal bridge funds based on need" (Kerley 2007, p. 5).
- Classification of a bridge as structurally deficient may be the result of a poor rating in only one or two of the key bridge components: deck, superstructure, and substructure (as explained in chapter two). Moreover, not all SD ratings are equally critical in terms of needing more intensive inspection. For example, 95% of SD in California is the result of deck cracking and paint problems—matters to be corrected, but not serious enough to expose the bridge to imminent failure. Items such as waterway clearance and other factors not affecting the structural integrity of the bridge also may contribute to an SD rating. "It may be necessary to revisit the definition of 'structurally deficient' before requiring additional non-routine inspections" (Kerley 2007, p. 7).
- Transfers of HBP funding are done for program management reasons. They do not indicate a lack of adequate spending on bridges at the state level. Although transfers of HBP monies to other programs have attracted recent press attention, expenditures of other federal program funds as well as state funds on bridges have not been adequately reported. Moreover, "states are not credited with bridge spending when a bridge is rehabilitated as part of a larger transportation project" (Kerley 2007, p. 3). Therefore, actual expenditures by state DOTs on bridges are often higher than would be estimated solely by tracking the disposition of federal HBP funds.
- With respect to additional bridge funding that has been proposed by Congress, the most pressing bridge needs should be identified through a review of existing bridge data. Furthermore, regardless of how the funds are proposed to be distributed, flexibility is needed so that this funding is used in the most effective, efficient way (Kerley 2007, p. 8).

The testimony also addressed particular policy, administrative, and funding issues associated with correcting deficient bridge decks. The handling of these matters within the context of SAFETEA-LU provisions was clarified shortly thereafter by the FHWA as described in chapter two (Lwin 2007).

The extensive congressional testimony on bridge infrastructure covered several other areas also germane to this study:

- A review of the characteristics and requirements of the NBIS (Gee and Henderson 2007, pp. 2–3; Hermann 2007, pp. 2–4; Kerley 2007, pp. 10–11; Washer 2007, pp. 1–3)
- An overview of bridge inspection procedures, materials, research, and technology (Anderson 2007; Gee and Henderson 2007, pp. 3–10; James 2007, pp. 1–9; Washer 2007, pp. 3–11, 14–17)
- An explanation of how inspection data drive investment decisions in those agencies in which bridge inspection information is the primary constituent of their BMSs (Garrett 2007, pp. 2–8)
- An overview of federal bridge funding allocation to states (Gee and Henderson 2007, p. 3; Kerley 2007, p. 11).

Government Accountability Office Study

The GAO released a *Highway Bridge Program* report (2008) and accompanying congressional testimony (Siggerud 2008) on its review of the HBP following the I-35W bridge collapse. The study found that the existing HBP lacks focus in that the purpose and scope of federal funding of bridges have expanded through the years, and the federal interest in expending HBP funds is not clearly defined. As a result, no clear measures of performance guide HBP investments and assess their results. Moreover, existing funding levels do not provide a sustainable solution to meeting future bridge needs, particularly when cost inflation is factored in. GAO discussed these topics primarily with regard to the federal HBP alone, recognizing that other sources of funding also affect bridge work. The GAO researchers also found the following:

- Reductions in the number of structurally deficient bridges have occurred mostly in local and rural bridge inventories. Projects to improve the condition of larger structures on major highways and in urban areas are often too costly to be funded by the HBP alone, and must depend on funds from other sources as well.
- Comprehensive data are lacking on the total funding that is allocated to bridge programs, encompassing state and local dollars as well as HBP funding. It is therefore difficult to track the respective uses and benefits of these different bridge funding sources, the degree to which funds are transferred between bridge

rehabilitation or replacement and other transportation programs, and what substitutions occur among federal, state, and local funds in the bridge program.
- Lacking clear policy goals and performance measures, federal and state agencies are unable to determine the overall effectiveness of HBP investments in bridges nationwide.

The GAO noted that several steps could improve HBP administration and use of funds:

- Wider use of BMSs could provide a greater degree of systematic decision support in project prioritization and resource allocation.
- Linking bridge program goals to performance measures would enable managers to determine whether goals are being met, and to apply that information when selecting projects and reaching funding decisions. These capabilities would provide state and local governments with incentives to improve the performance of their bridge programs as well as of the overall transportation system.
- Aging bridge infrastructure, the impending revenue shortfall in the Highway Trust Fund, and continuing increases in the costs of bridge projects all point to the importance of ensuring the financial sustainability of the HBP.

The GAO recommended that the U.S.DOT secretary work with the Congress to achieve the following:

- Identify and define the specific national goals of the HBP.
- Determine the performance of the program through performance measures related to HBP goals.
- Identify and evaluate best-practice methods and tools that can be incorporated within the HBP, such as BMSs.
- Review and evaluate HBP funding mechanisms to align funding and performance, and to support a focused, sustainable federal bridge program.

Federal Surface Transportation Legislation

As a prelude to the 2009 reauthorization of federal surface transportation legislation, congressional bills to enact new policies and requirements of the federal HBP have been filed in the U.S. House of Representatives (H.R. 3999) and the Senate (S. 3338). Each of these companion bills bears the short title, "National Highway Bridge Reconstruction and Inspection Act of 2008" (Library of Congress, 110th Congress). Although the provisions of these bills are subject to further debate, they signal several topics of current congressional interest that relate to this synthesis. Key provisions of the proposed legislation as now drafted are as follows:

- **Definitions.** The legislation explicitly defines key terms relating to federal bridge program management, including structurally deficient, functionally obsolete, rehabilitation, and replacement. It defines "complex bridges" as highway bridges with "unusual characteristics, including movable, suspension, and cable-stayed highway bridges." It calls upon the U.S. secretary of transportation to issue regulations that define "critical finding" in the context of provisions discussed here.
- **Risk-Based Approach.** The secretary of transportation, in consultation with state DOTs, shall assign a risk-based priority for the rehabilitation or replacement of bridges that are rated structurally deficient or functionally obsolete. The secretary shall work with the states to establish a process for assessing these risk-based priorities. The costs of rehabilitating or replacing each bridge shall likewise be determined. The secretary shall submit a report to Congress on the risk-based approach that has been developed.
- **Independent Review.** The National Academy of Sciences shall conduct an independent review of the risk-based process described in the preceding bulleted item. The academy shall submit a report to the secretary of the U.S.DOT and Congress.
- **Performance Plan.** States shall develop, implement, and update annually a 5-year performance plan for bridge inspections and the rehabilitation or replacement of SD or FO bridges. Separate provisions may apply to historic bridges. The secretary of transportation will establish criteria for the approval of performance plans and annual updates, and will then conduct such approvals annually. If a plan is disapproved, the secretary will inform the state of the reasons and require resubmittal.
- **Bridge Management System.** Each state shall develop and implement a BMS.
- **National Bridge Inspection Program.** The NBIS shall be designed "to ensure uniformity among the states" in conducting bridge inspections and evaluations. The NBIS shall "establish procedures for conducting annual compliance reviews of state inspections, quality control and quality assurance procedures, load ratings, and weight limit postings of structurally deficient bridges." They shall establish procedures for states to report to the secretary of transportation (1) critical findings regarding bridge structural or safety deficiencies, and (2) monitoring and corrective actions to address these findings. They shall provide for testing with state-of-the-art technology to detect fatigue cracking on steel bridges that exhibit fatigue damage or that have fatigue-susceptible members.
- **Regulations on Critical Findings.** The secretary of transportation shall issue regulations by which states will report to the secretary critical findings of bridge deficiencies and resulting monitoring and remedial

actions. The regulations will define "critical finding," establish due dates for states' reports, describe requirements for actions following a critical finding determination, and provide for training of bridge inspectors regarding critical findings. Within 15 days of a critical finding that results in a bridge closure, the secretary of transportation shall report to the appropriate congressional committees on the impacts of the closure, including economic impacts and effects on regional transportation and transit. The report will also identify solutions to mitigate these impacts.

- **Inspectors' Training and Qualifications.** The secretary shall expand the bridge inspection training program to ensure that all persons inspecting highway bridges receive appropriate training and certification. Program managers of state inspection programs shall be licensed professional engineers. Team leaders engaged in inspecting complex bridges or bridges that have generated a critical finding must be licensed professional engineers. Team leaders inspecting all other bridges must either be licensed professional engineers or have at least 10 years of bridge inspection experience. (A grandfather provision imposes these requirements only on program managers and team leaders who are appointed after these revised regulations have been issued.)
- **State Participation Requirements.** To be eligible for federal funding of bridge rehabilitation and replacement, states must take several actions, including inspections of bridges and calculations of bridge load ratings at appropriate intervals according to criteria that are specified in this legislation; development of a 5-year performance plan for bridge inspections and for rehabilitation or replacement of structurally deficient or functionally obsolete bridges, with special considerations for historic bridges; and development and implementation of a BMS.
- **Funding Transfers.** States may transfer HBP funds to other federal aid programs "only if the state demonstrates to the satisfaction of the Secretary that there are not any bridges on the National Highway System located in the State that are eligible for replacement."
- **Reports to Congress.** The U.S. secretary of transportation shall report annually to the House Committee on Transportation and Infrastructure, and the Senate Committee on Environment and Public Works, on projects and activities performed under these provisions, information such as priorities for bridge rehabilitation and replacement on a national and state-by-state basis for SD and FO bridges, identification of projects or actions by states that are inconsistent with these priorities, and suggestions for improvement of the HBP.
- **GAO Studies.** Within 1 year after this bill has been enacted, the comptroller general shall conduct a study and report findings to the secretary of transportation regarding (1) factors that contribute to construction delays of bridge rehabilitation, and (2) any recommendations to simplify and expedite bridge rehabilitation. The comptroller general shall conduct a study of the effectiveness of FHWA's bridge rating system, including the use of the terms "structurally deficient" and "functionally obsolete" to describe the condition of U.S. highway bridges. The comptroller general shall also evaluate rating systems used by state DOTs and recommend how successful state methods can be incorporated within the FHWA's rating system.
- **Other Provisions.** Several other bridge-related provisions of the draft legislation relate to research studies and a pilot program for advanced condition assessment technology that can be applied to bridge inspections. A "Sense of Congress" section recommends that states prepare a corrosion prevention and mitigation plan for each project in bridge construction, rehabilitation, or replacement. Research-related provisions are discussed further in the section on Research Needs.

Public Awareness and Understanding of Bridge Issues

That the I-35W bridge had been rated structurally deficient focused considerable news attention on NBI ratings and reflected concern about a possible link between SD and potential failure. Public and political response grew with the realization that tens of thousands of other bridges nationwide were likewise rated SD. Articles quoted knowledgeable experts explaining the meaning of "structural deficiency" as a programmatic rather than a safety distinction—a designation that does not signal an imminent collapse (e.g., Heath 2007; Riccardi and Therolf 2007). The rapid response by states to reinspect their own structurally deficient bridges and to take quick remedial action where needed was also reported (Keen 2007). Some political leaders, however, wanted greater clarity regarding bridge safety. One California state senator summarized his frustration as follows:

> I want to know what is safe and what is not and how we measure it and how we inspect it.
>
> [Proposed hearings] will focus on how California inspects bridges, why so many are classified as "structurally deficient," and how to come up with money to upgrade aging spans (Bizjak 2007).

Other experts also voiced concern about the ambiguity of the designation "structurally deficient." A faculty member in bridge engineering asked why SD is not defined "the way most people see it. Why take so much pain explaining to people why it doesn't mean what it seems?" (Bizjak 2007).

More wide-ranging communication of the status of the nation's bridges has begun with the establishment or expansion of informational websites and documents on bridge infrastructure by the following transportation or engineering organizations:

- AASHTO, *Meeting the Needs of America's Bridges* (2007a) and its bridge information website at http://www.dot.state.ia.us/subcommittee/default.aspx (AASHTO 2007b)
- U.S.DOT and FHWA, I-35 *Bridge Collapse, Minneapolis, Minnesota* at http://www.dot.gov/affairs/factsheet080207.htm
- ASCE, 35-W *Bridge Collapse* at http://content.asce.org/35BridgeCollapse_MainPage.html
- ENR (*Engineering News-Record*), Bridge Collapse Update Center at http://enr.construction.com/news/special/bridges/default.asp

The House Committee on Transportation and Infrastructure has compiled all of the testimony during its hearings on structurally deficient bridges plus data on the distribution of SD bridges nationwide on its website at http://transportation.house.gov/hearings/hearingdetail.aspx?NewsID=285 and http://transportation.house.gov/us%20bridgemap.shtml.

State DOTs also engage in public communication and performance accountability, as described in chapter three and in an article focusing on bridge condition and safety following the I-35W failure (Stidger 2007).

ASSET MANAGEMENT AND BRIDGE PRESERVATION INITIATIVES

Asset management was formally launched in the United States early in this decade with the publication of guidelines by the FHWA (1999) and AASHTO (Cambridge Systematics, Inc. et al. 2002). These early references describe asset management as a strategic approach to managing transportation infrastructure that aims to get the best results or performance in the preservation, improvement, and operation of infrastructure systems given the resources available. Good asset management practice is policy driven and performance based, considers alternatives or options in developing solutions to transportation problems, evaluates competing projects and services based on cost-effectiveness and the anticipated impact on system performance, considers tradeoffs among programs, employs systematic and internally consistent business processes and decision criteria, and makes good use of quality information and analytic procedures (Cambridge Systematics, Inc. et al. 2002). Because of this initial work, asset management has been studied and implemented at the national, state, and local levels. International scans have broadened U.S. understanding of relevant methods and management system capabilities.

Bridge management is a prime candidate for application of asset management principles. Bridge assets are important, highly visible, and costly. Moreover, today's BMSs are relatively sophisticated and are able to fulfill most of the analytic expectations of state-of-the-art asset management. It is reasonable to assume that future trends in bridge management will be influenced by evolving concepts and techniques of asset management, as well as other initiatives. Following are recent developments in these areas that relate to the scope of this synthesis.

Peer Exchange: Asset Management in Planning and Operations

Introduction

The desire for strengthened asset management capabilities in bridge management as described in the first section of this chapter was echoed in a peer exchange that looked at DOT planning and operations more broadly (Hendren 2005). Many of the themes, noteworthy accomplishments, and current and future challenges that were identified in this peer exchange both reinforce the comments by agency respondents to the synthesis survey and indicate that a broader agency effort to improve management capability is possible, including bridge management as well as other key functions. The peer exchange participants included representatives of agencies with varying size, jurisdiction, and experience with asset management. The resulting themes, accomplishments, and challenges reflect the collective insights of multiple participants, suggesting a degree of consensus on basic themes and challenges, the value of lessons provided by agencies that have had success stories with asset management, and the likely applicability of these findings to bridge management across a wide spectrum of DOTs.

Peer Exchange Findings: Key Themes and Accomplishments

The key themes crystallized by peer exchange participants included the following partial list (Hendren 2005):

- Asset management encourages a performance-based management approach, management accountability, and fact-based decision making. It has moved rapidly from its conceptual beginnings to practical implementation in agencies at different levels of government.
- Asset management is best implemented incrementally, beginning with one asset or function and gradually expanding to a broader set of agency operations. As one peer exchange participant noted, "[Asset management] implementation began small and grew from budget development, through resource allocation, to project scope, and finally performance measures" (Hendren 2005, p. 39).
- Performance measurement is central to asset management. However, data [to support performance measure development and comparison with targets] are expensive to obtain, and need to be selected carefully.
- Asset management has already enjoyed successes in agencies' abilities to improve their system condition,

to justify funding increases, and to sharpen their management tools (e.g., applying historical trend data to extract useful new deterioration models that provided new insights into the surprisingly high rate of pavement deterioration early in life). Success stories need to be shared more widely.
- Agencies with more sophisticated asset management systems that enable what-if and trade-off analyses obtain significant benefits from these capabilities. For example, one agency displays both economic and non-economic decision criteria in its trade-off analyses. These analyses can be conducted for a variety of assets (e.g., bridges, pavements, intelligent transportation systems, and ferries), program objectives (e.g., improvement in physical condition, safety, or operations), and levels of analysis (e.g., network, region, corridor, and project).

Peer Exchange Findings: Asset Management Challenges

Although asset management has progressed rapidly in the past several years, the peer exchange participants identified several challenges that need to be addressed to promote successful implementation in a wider group of agencies (Hendren 2005).

- **Systems and data challenges.** Several issues regarding management systems and data reinforce the responses to the synthesis survey described earlier. These include the lack of advanced capabilities such as scenario testing and trade-off analyses in legacy systems; the expense of collecting, processing, and maintaining quality data; and the need to integrate data across agency functions or disciplines, as through a geographic information system.
- **Jurisdictional challenges.** Bridges within a state are owned by state DOTs, local governments, the federal government, and other parties, including the private sector. State DOT involvement in bridge management (including inspection and data collection) is generally limited to the state-owned and local bridges. Although states differ in their specific arrangements with local governments, typically the state DOT will have some involvement in inspection, reporting of NBI data to the FHWA, and possibly assistance in bridge management and project funding. Exactly how these local bridge responsibilities are allocated between state and local governments will influence the type of improvements in management practice and decision making within each state. From the perspective of customers, bridge serviceability and safety, not bridge ownership, are the key concerns.
- **Institutional challenges.** The institutional environment of state transportation programs presents many challenges to better management and resource allocation. Among these are the "silos" into which agencies are forced by different modal and funding programs; the difficulty of maintaining a sustained, consistent, and strategic asset management direction in a shifting political environment; and how to continue to advance agency accountability for transportation system performance.

Peer Exchange Findings: Next Steps

The peer exchange participants identified several next steps to advance broader implementation of asset management:

- **Research.** The challenges described earlier should be addressed through additional research to provide analytic tools with more sophisticated capabilities, address the issues in maintaining and integrating databases, enable more effective communication among organizations involved in managing assets, and overcome jurisdictional and institutional impediments to better asset management.
- **Education and training.** Existing programs of education and training in asset management should be continued or expanded, including continuing peer exchanges, coordination with local governments through the Local Technical Assistance Program, expansion of the existing National Highway Institute training courses to include regional and local asset management content, additional training within agencies (e.g., for new employees and for upper management), and migration of asset management to graduate school curricula.
- **Communication.** Communication mechanisms and resources can spread the word and help agencies identify how the potential benefits of asset management can be realized in their own organizations. These objectives can be met in several ways; for example, through documented case studies, adoption of more standardized nomenclature, examples of successful communication tools and methods, compilation of an accurate directory of asset management contacts, and additional resources for local governments and MPOs.

Peer Exchange: Information Assets to Support Transportation Decision Making

Decision Making

An earlier peer exchange focused on data and information as assets and their roles in agency decision making. The scope of the discussion was broad, encompassing the full range of transportation assets and DOT functions. The perspectives of participants were primarily in areas of planning, policy, and IT, although agency executives and engineering and statistical professionals also participated. Although program management and resource allocation for bridges per se were not a focus of this exchange, its findings and recommendations nonetheless reinforced and gave broader context to the survey comments of DOT managers and engineers discussed at the beginning of this chapter. In particular, participating DOTs provided examples of a number of relevant data applications (Schofer 2007):

- Use asset condition data across multiple jurisdictions to develop deterioration models.
- Use an integrated state condition-performance database to support investment programming and STIP development.
- Use data on system condition and unit replacement costs for needs-based budgeting decisions.
- Use performance measures and targets to identify needs and priorities.
- Use an asset management database with statutory performance measures to guide resource allocation and provide decision support for the agency and the legislature.
- Apply an integrated project management database to display multiple dashboard views of project status and progress, providing accountability for agency responsibilities.

The peer exchange report provided an interesting observation on these and the other example data applications:

> Each [data application] illustrates the use of objective measures of transportation system status to support resource allocation, management decisions, customer decisions, and accountability. Together they emphasize the high value of objective local condition and status measures for management.
>
> In contrast, no examples of forecasting were presented. During the peer exchange, although the usefulness of forecasts became clear, the reluctance of decision makers to rely on models was a contradictory theme, motivated by concerns about model complexity and obscurity and the risk of forecasting errors.
>
> … Together the data application patterns in this small sample underscore the key decision value of timely data describing current system conditions and performance (Schofer 2007, pp. 8–9).

These points call to mind the apparent contradictions in managers' perceptions of BMS features they would find desirable—particularly in "predictive" capabilities of scenario testing and trade-off analyses, as noted at the beginning of this chapter—versus the set of available capabilities they actually use (refer to the survey responses in chapter three). The report summarizes key implications of these examples of successful data application: greater efficiency through multiple uses of data, the advantage of data integration and sharing within and among agencies in more consistent and useful analyses, and the significant value added by spatial referencing and display of data (Schofer 2007, p. 9).

U.S. Domestic Scan: Best Practices in Asset Management

Site visits were conducted in 2006 among U.S. transportation agencies at different levels of government to identify best practices in applying asset management principles and methods. The scan team visited state DOTs in Florida, Michigan, Minnesota, Ohio, Oregon, and Utah, as well as three city and county transportation departments, two MPOs, a tollway authority (Florida's Turnpike Enterprise), and two statewide asset management councils or user groups. Although the scope of the study related to transportation assets and management practices broadly, several findings echoed the positions of experts quoted earlier in attempting to advance bridge management practice. Scan findings included the following, among other observations (Cambridge Systematics, Inc. and Meyer 2007):

- The most successful asset management processes had enabled the agency to transition from a worst-first approach to one based on long-term cost-effectiveness, employing LCC principles.
- The existence and demonstrated application of an asset management process could bolster an agency's credibility when seeking additional funding from the legislature. The information gathered in a well-functioning asset management approach signaled good stewardship of public assets and a willingness to assume accountability, as well as serving to inform legislators and stakeholders of investment needs and the consequences of different budget scenarios.
- Performance measures and targets were part of the normal business process at many of the agencies visited, and also tended to characterize successful asset management implementations. Agencies that had suitable management systems could answer with some precision how a change in investment would affect performance—that is, the basis of scenario analyses with respect to budget levels.
- Extending the point described earlier, agencies reported scenario analyses showing the consequences of different budget levels on performance to be one of the most effective ways of communicating the importance and the outcomes of needed infrastructure investments. Scenario analyses were an effective way to translate engineering and cost information into a basis for political discussion of transportation funding.
- There was no single successful organizational model for good asset management. Rather, agencies with effective asset management track records exhibited a number of organizational approaches to how and by whom asset management could be successfully institutionalized. A cross-disciplinary team effort in implementing their process, the skill of one or more champions in embedding asset management within standard operating procedures, and the backing of

agency leadership were the most critical organizational success factors.

- There was little evidence of risk assessment (also referred to as risk analysis or risk management) among the agencies contacted. Risk assessment refers to a determination of the economic costs of infrastructure failure and the inclusion of these costs in analyses of infrastructure condition and investment needs. The scan team noted that other countries already apply formal procedures of risk assessment, and U.S. agencies may adopt these management techniques in the future.
- High-quality data and cost-effective methods of data collection, processing, and use are other hallmarks of good asset management practice. In the best-case examples, "agencies become better consumers of data once they understand their asset management process" (Cambridge Systematics, Inc. and Meyer 2007, p. ES-4). Effective communication further serves to leverage the value of the data collected. Moreover, new technology has the potential to render data collection for infrastructure management more effective and efficient.

FHWA Systemwide Bridge Preservation Initiative

Although states such as Pennsylvania and Florida have practiced systemwide bridge preservation for several years, this approach recently has been elevated to a national initiative by the FHWA. This program is motivated by the need to sustain the bridge inventory, cost-effectively given the combined pressures of increasing traffic demands, continuing bridge aging and deterioration, and financial constraints on transportation infrastructure programs. The addition of preventive maintenance as an eligible activity for federal bridge funds in January 2002 provides an additional financial incentive to consider a preservation approach (FHWA 2002, 2007a). FHWA has proposed a roadmap of actions to assist agencies in understanding and applying bridge preservation strategies. These actions include establishment of a website dedicated to supporting agency efforts and addressing questions regarding bridge preservation and maintenance; identification and formation of a community of practice on this subject; identification of best practices and needs for further research and development; promotion of more effective use of maintenance and BMSs to encourage moving from a worst-first to a more systematic, proactive strategy of preventive maintenance and preservation; establishment of regional bridge working groups and a series of periodic workshops; and other organizational and institutional actions (FHWA 2007e). The first National Bridge Preservation Workshop was held in April 2007, focusing on roundtable discussions of current bridge preservation strategies reported by state DOTs across the country, coverage of specific technical and financial topics, and question-and-answer sessions (FHWA 2007a, c).

Peer Exchange: Applications of Asset Management in Programming and Budgeting

A peer exchange on Applications of Asset Management in Programming and Budgeting was held in 2007 under the sponsorship of the FHWA and AASHTO. Sessions addressed several topics relevant to the scope of this synthesis (Guerre et al. 2007):

- Experiences of several state DOTs, a turnpike authority, and a regional planning authority in planning, programming, and budgeting
- Use of asset management systems to support planning and programming
- Incorporating performance measures and targets in programming and budgeting
- Incorporating risk analysis techniques in programming and budgeting
- Cross-asset analysis and programming
- Barriers to success and ways to overcome them
- Potential research topics, education opportunities, and follow-up activities.

The common themes identified by peer exchange participants included the following:

- Several agencies have implemented management systems that can predict infrastructure performance, and they use this information to inform budget decisions. However, final budget decisions consider other, qualitative factors as well.
- Most technical analysis, budgeting, and programming are done within organizational silos that are identified with specific assets. Cross-asset analyses are done implicitly rather than explicitly. Although some agencies identified technical impediments to these analyses, the main barriers are organizational and institutional.
- All of the participating agencies described asset management efforts that included data collection, performance measurement and tracking, and application of analytic methods and procedures. However, a direct link between these capabilities and final programming decisions is less common.
- In all participating agencies, programming decisions regarding asset preservation are made separately from those for system capacity expansion. Although these agencies could describe asset management principles and techniques applied to preservation, few could do so for capacity expansion. The reason cited most often was the importance of political considerations in the prioritization of capacity expansion projects. Participants believed that improved understanding of the impacts of capacity-project decisions on system performance could help promote a more asset-management-oriented approach.

- All participating agencies had established performance measures and had procedures to set performance targets and track progress toward them. However, the approaches used to set targets vary widely, and the technical and road-user-related implications are not well understood. For example, "many agencies struggle with questions like: Is a target of 80% of the network in good condition the 'right' target?"
- The most often cited risk considered in programming and budgeting is the possibility of project overruns. Labor and materials cost inflation have superseded scope creep as the primary cause in many agencies. Agencies use several strategies to deal with this risk, including applying contingencies, tracking on-budget performance, improving cost-management accountability, implementing a risk mitigation program, and applying a financial plan rather than a detailed program-project plan in program out-years (i.e., specifying an overall program budget but not specific projects and their costs).
- Research opportunities identified by participants focused on application of asset-management methods to other assets besides pavements and bridges, and to other types of work besides preservation (e.g., operations and system expansion).

RESEARCH NEEDS TO FILL GAPS IN KNOWLEDGE

TRB Millennium Paper

The TRB Millennium Paper on Bridge Maintenance and Management identified several research, development, and implementation needs that are relevant to this synthesis (Hearn et al. 2000):

- To exploit technology and processes to gather data more cost-effectively and reliably (i.e., of higher quality). Candidate approaches include better visual inspection, nondestructive testing, and automated data collection.
- To develop improved data (e.g., regarding bridge deterioration, costs, and impacts of maintenance) and algorithms (e.g., more powerful and flexible optimization procedures and economic analysis tools) to enable more comprehensive, detailed, and realistic analyses.
- To integrate bridge management within an agency's overall asset management program.
- To pursue fundamental advances in bridge-monitoring technology (e.g., permanent sensors and wireless communication) to be able to shift from current visual inspections and condition ratings to completely automated gathering of comprehensive, objective, quantitative data on bridge condition and performance.
- To emphasize bridge preventive maintenance actions and integrate proactive, preventive strategies from the start of a bridge's life.

Topic 37-07 Survey

Two questions in the survey of state and provincial DOTs probed respondents' perceptions of needed improvements in bridge management processes or systems that would better serve upper management in resource-allocation decision making:

- What desired capabilities are *not* now provided by the agency's bridge management business processes or BMS?
- What desired capabilities either are unavailable in the agency's BMS or are available but not currently used? (This question was part of the budgeting component of the survey.)

Responses to these questions focused on two broad topic areas: perceived gaps in existing knowledge and capabilities, and suggested ways to strengthen existing capabilities.

Gaps in Existing Knowledge and Capabilities

One set of responses pointed to shortcomings perceived by individual agencies in the following areas:

- Gaps in basic planning, programming, and budgeting information in agency business processes—for example, funding levels, district priorities, and local priorities; funding availability from various sources; and the level of funding authorization from the federal government for the federal HBP
- BMS information or capabilities that were lacking within a particular responding agency. Examples of features that respondents said were not available or being used within their agencies included the following:
  – Scenario analysis, trade-off analysis, and LCC analysis
  – Performance tracking and comparison with targets
  – Tracking of past and planned bridge work by organizational unit or geographic area.

Although existing, full-featured BMSs provide several of these features, some respondents noted their agency's inability to acquire such a BMS because of resource limitations. Other possible reasons for not using these BMS features include the need to train staff or to customize certain BMS features to produce results that better meet agencies' expectations.

Strengthening Existing Capabilities

A second set of responses suggested ways to strengthen business processes, BMS capabilities, and information needed for sound, cost-effective investment decisions through advances such as the following:

- Coordination of the bridge program with other programs and projects (e.g., roadways) across a broader set of policy objectives (e.g., preservation versus capacity).
- An ability to explore choices and trade-offs and to calculate LCCs of each alternative.
- Long-term effects (benefits and other impacts) of proposed expenditures on bridges.
- Comparisons of performance measures versus target values and outcomes for alternative scenarios.
- Total project costs, not just those related to work on the bridge structure proper. Additional items include, for example, the costs of right-of-way, detours, utilities, roadway approaches and embankments, and so forth.
- Socioeconomic and political considerations related to bridge projects.
- A more complete bridge management package, able to help evaluate achievement of performance targets, to generate alternative scenarios subject to budget constraints, to explore choices and trade-offs, and to calculate resulting road-user costs, which would be beneficial from a budgeting perspective.
- Information on key parameters (e.g., regarding condition, performance, and budget) that would facilitate delegating to lower-level managers the responsibility for selecting what work to do on specific bridges on the network.
- BMS predictions of the funding levels needed to maintain structural condition, described by the respondent as a derivative of alternative scenario generation subject to budget constraints. Just as important would be BMS estimates of bridge investments and their timing to be able to identify bridge network maintenance at the lowest LCC.
- Strengthened BMS algorithms in the calculation of LCCs, scope of bridge performance analysis, and treatment selection. (These comments related to Pontis specifically.)

There is a perception that BMS recommendations now lean toward selecting indefinite maintenance or repair strategies rather than eventual bridge replacement (two states made this comment; in one respondent's opinion, this is owing to the way the BMS computes benefits). Another agency questioned the current calculation of LCCs, and mentioned that its BMS lacks the capability to suggest projects driven by traffic capacity.

One agency reinforced these points by noting that its BMS does not contain all information and capabilities needed for funding and programming decisions—other resources are consulted during decision making. Although these gaps were not specifically identified, they related generally to performance tracking, needs analysis, and resource allocation and trade-off analyses. The agency also noted that it applies other tools to the program development process, including a project management system that tracks pavement and bridge projects and the deficiencies that are removed by project work.

The perceptions of bridge management practitioners regarding current BMS models are somewhat contradictory and present a complicated picture as to how to advance this aspect of the state of practice. Although some survey respondents noted the lack of certain BMS capabilities and suggested research to develop additional types of analyses, other respondents reported using these same features, which are readily available today in BMS products. Still others voiced concern about the "black box syndrome" and the usurping of managers' decision-making prerogatives by high-level BMS operations. These contradictory feelings are not limited to bridge management. The proceedings of the peer exchange on information and decision making (discussed earlier in this chapter) observed a similar mix of reactions to the use of forecasting models to support decision-making in asset management generally.

Blanket Responses

Consider again the two questions posed at the beginning of this survey section: (1) What desired capabilities (of those listed in the survey questionnaire) are *not* now provided by the agency's bridge management business processes or BMS? (2) What desired capabilities either are unavailable in the agency's BMS or are available but not currently used?

Almost one-third of responding agencies provided blanket affirmative or negative responses (evenly divided) to these survey questions. Those that responded simply "yes" might be thought to imply a need for strengthened BMS capability in their agency. Those that responded "no" might be thought to imply either that they already had these capabilities, or they did not believe that these BMS features were needed in their current business and decision processes.

Congressional Legislation

The pending congressional bridge legislation discussed earlier (H.R. 3999 and S. 3338) includes the following provisions for research:

- Existing provisions of federal law governing surface transportation research are revised to (1) include enhanced bridge safety as a research objective in investigating new methods, materials, and testing techniques, and (2) call explicitly for research in nondestructive evaluation equipment to assess bridge structural integrity for existing as well as next-generation facilities that use advanced materials.
- The draft legislation establishes a Bridge Advanced Condition Assessment Pilot program to encourage application of new technologies to bridge condition evaluation. Examples of new technologies may

include, but are not limited to, fiber optic, vibrating wire, acoustical emissions, and peak-strain displacement. The technologies will perform real-time sensing to gather data for accurate assessments of critical bridge elements.
- The secretary of transportation shall conduct a study of the costs and benefits of using carbon-fiber composites in lieu of traditional materials in bridge rehabilitation and reconstruction.

Support of Government Accountability Office Recommendations

Research may be needed to support GAO's recent recommendations on the federal HBP. Research could potentially help in several areas:

- To define the specific national goals of, and federal interests served by, the HBP
- To develop performance measures that respond to, and reflect progress toward, these federal goals and interests
- To identify best-practice methods and tools that can be incorporated within the HBP, drawing on existing approaches such as BMSs and leading-edge techniques applied by state DOTs
- To review and evaluate mechanisms that can align HBP funding with performance to achieve a focused, sustainable federal bridge program.

CHAPTER FIVE

CONCLUSIONS

The objective of this synthesis has been to gather information on current practices that agency CEOs and senior decision makers use to make network-level funding decisions for their bridges, and how they apply their agency's bridge management capabilities to support these decisions. A better understanding of these issues could help agencies identify areas of improvement for their own bridge management process and their application to agency decision making. The study has considered the role of automated bridge management systems (BMSs) in planning, programming, resource allocation, and budgeting; increasing application of asset management principles, which could influence future bridge program management; implications of recent actions at the federal level that will affect bridge inspection, management, and research; impediments to applying BMSs more effectively; and research proposals to improve BMSs and practice.

SYNOPSIS OF MAJOR FINDINGS

The National Bridge Inspection Standards (NBIS), which were implemented in the 1970s, established a single, unified method of collecting data on the nation's public-highway bridges. These data are submitted annually by state DOTs to the FHWA, which compiles them within the National Bridge Inventory (NBI) database. The NBIS have enabled the FHWA and state departments of transportation (DOTs) to monitor bridge condition and performance nationally on a consistent basis, identify bridge needs, define criteria of project eligibility for federal bridge funding, and thereby promote the public safety through better stewardship of bridge assets. Bridge Structural Deficiency (SD) and Functional Obsolescence (FO), two ratings defined by the NBIS, became key performance measures that agencies continue to monitor today. Similarly, the bridge Sufficiency Rating (SR) is embodied in the eligibility formula for federal bridge funding. Although some revisions to NBIS have occurred, the definition and application of these bridge ratings has remained essentially unchanged for more than 30 years.

Considerable advances in U.S. bridge management have occurred since the implementation of the NBIS, with significant accomplishments at the federal and state levels. Today all state DOTs have a bridge management process. Most employ some type of automated BMS with an associated database. Bridge-related information tracked by DOTs typically includes NBIS data and ratings, but often incorporates additional, more detailed data or customized data. Agencies that were addressed in this study appear to have integrated their bridge management procedures and systems well within their individual planning, resource allocation, programming, and budgeting processes. Philosophies of bridge management may differ across agencies (e.g., centralized versus decentralized decision making; use versus nonuse of predictive analytic models). Yet, in each example that was studied in this synthesis, the agency has configured its bridge program management to fit within its organizational, financial, managerial, and technical modes of operation. It has tailored its internal communications of information and its institutional relationships with other agencies accordingly.

This variability in bridge management and resource allocation practices among state DOTs is driven by several factors, among them the following:

- Different philosophies of bridge management
- Different approaches to planning, programming, and budgeting
- The characteristics of each agency's transportation system and its infrastructure
- The policy, financial, technical, and institutional environment in which the agency operates.

These factors are not equal in their effects, however. For example, although the current condition of an agency's bridge inventory obviously affects its investment priorities, it did not appear to be a strong driver of management approach in any of the states interviewed. Rather, important influencing factors that several agencies mentioned included the level, stability, flexibility, and predictability of bridge funding; the definition of bridge performance measures appropriate to the agency's transportation system and geographic setting; and the need to maintain effective communication and buy-in up and down organizational levels, regardless of where ultimate decision-making responsibility lay.

The role of bridge management in agency functions such as planning, programming, and resource allocation can be better understood when the characteristics of different BMSs are considered. BMSs vary in analytic capabilities and sophistication, ranging from straightforward repositories of bridge data to full-fledged management systems, including forecasting models, comparative analyses, and optimization procedures or decision rules. Full-featured systems operate at both the program level and at the level of individual bridges or projects. Agencies that have a full-featured BMS thus *have the capability* to apply higher-end analyses such as project planning, network-level budget scenarios, trade-off analyses, and economic analyses of agency and user costs and benefits. However, *the actual use* of these capabilities is by no means a given. A study of Pontis implementation among state DOTs indicated, for example, that half of these agencies limited the functionality of Pontis to managing bridge inspection data (see Figure 10). Moreover, the other half that did apply more advanced Pontis functionality often used only a subset of available features. These findings were reinforced in the current synthesis study. Although some individual agencies do use virtually the full set of Pontis features and might therefore be viewed at the leading edge of BMS practitioners (e.g., States D and E in Table 8), more generally, the characteristic use of bridge management for state DOT decision making is as follows:

- BMS results used in decision making are mainly technical (focusing on bridge condition and performance) rather than economic (e.g., benefit-cost) or social (e.g., impacts on different categories of road users on affected transportation corridors).
- BMS results are for near-term rather than long-term analysis horizons.
- Recommended actions are reactive to current conditions rather than proactive or anticipatory of future conditions.
- Recommended actions focus on a single strategy rather than a comparative analysis of several options or scenarios.
- Calculated costs are solely those attributed to the agency rather than including the costs borne by road users as well.
- Costs are calculated for near-term budgets rather than for the bridge life cycle.
- The BMS functionality that is used entails well-defined, basic management procedures (e.g., data management) rather than higher-level procedures such as predictive models, scenario analyses, trade-off analyses, and economic analyses.

Again, these are general findings across the population of state DOTs that participated in this study (refer to Figures 12 and 14–16). They do not necessarily reflect the characteristics and practices of any single agency. The gap that exists between the state-of-the-art practice versus the general state of practice of BMSs has persisted for more than 10 years [see Neumann (1997) and subsequent studies in the first section of chapter three]. All of these studies show that the capabilities of BMS products are underutilized. These systems are applied most frequently for tasks such as database management and standard types of analyses. Higher-end applications, such as those used to evaluate the costs and benefits of different network investment strategies, to evaluate long-term as well as near-term needs, or to apply BMS outputs in budgeting and Statewide Transportation Improvement Program development, are used by only a relatively small subset of DOTs.

The ability to tailor bridge management practices and system outputs to individual agency needs, and to compensate for gaps and constraints in existing practice, helps to strengthen the relevance of bridge-related information to agency decision making. Several examples illustrate this point:

- Regardless of whether their BMS is simple or sophisticated, many agencies have customized their own data and analytic procedures to reflect the particular characteristics of their road network, bridge structures, and vehicle loads, as well as their philosophy of bridge management. Among agencies that were interviewed in this study, these customizations are important to ensuring that bridge management information remains relevant to agency decisions across all affected organizational units and levels.
- In particular, customized performance measures such as deficiency-point calculations and custom bridge condition and health indexes in several cases were believed to be critical to advancing state-specific practices technically, managerially, and procedurally. These indicators were entirely acceptable to upper management and served the bridge-office as well as executive-level informational needs for investment planning, resource allocation, and budgeting. Some agencies saw customized bridge rating indexes as a way to get better guidance on bridge investment needs and benefits, to compensate for what they believed were shortcomings in the SR as a criterion for bridge replacement and rehabilitation.
- Some senior bridge managers have introduced broader performance-based or asset management-related considerations. For example, they have asked their personnel to think beyond BMS outputs and consider wider implications of different bridge investments, such as operational impacts and criticality of needs. Other respondents mentioned political and social impacts. In discussing the evaluation of project priorities, one manager noted that it is not sufficient to consider just the volume of traffic (average daily traffic) that is affected, or the associated cost-benefit totals. He encouraged his staff to consider highway operations more broadly in terms of the type of road usage (e.g., trip purposes and relationship to local economy), in addition to the standard BMS results.

Current bridge management practices reflect several characteristics of good asset management practice—for example, a reliance on a suite of both standard and custom performance measures, a well-defined data structure founded in the NBI database, standardized and customized element-level data in many agencies, and a number of management systems and other analytic tools, again with custom features in many cases. Agencies that apply more advanced features of the BMS are able to take advantage of economic as well as technical data and analyses, scenario and trade-off analyses, and decision support procedures. Successful asset management processes have enabled agencies to transition from a worst-first approach to one based on long-term cost-effectiveness, employing life-cycle cost principles.

Impediments to greater use of BMS results that survey respondents mentioned included limited resources for implementation and training, lack of credibility of the suggested actions and economic assumptions, results that did not reflect all factors that needed to be considered in decisions, a co-opting of managers' prerogatives in reaching decisions, and reliability problems with software, data, and analyses. Some of these comments echoed responses in the Topic 27-09 survey (*NCHRP Synthesis 243*) more than 10 years ago, including the expense of system development and implementation and limitations in the usefulness of management systems generally to the programming process. (It should be noted that the 27-09 survey responses applied to a number of management systems, not just BMS.)

FACTORS DRIVING POTENTIAL CHANGE IN BRIDGE MANAGEMENT

The NBIS inventory data, ratings, and appraisals continue to have an important influence on bridge management after almost 40 years in service. They influence public perceptions of bridge condition and performance, determination of project eligibility for federal HBP funding, and project priority. The NBI database, which stores the bridge inventory, rating, and appraisal data collected by state DOTs, serves several important functions. It is the most comprehensive, up-to-date, unified source of bridge information nationwide. It has amassed an almost 40-year history of bridge characteristics, condition, and performance. NBIS data contribute to the bridge portion of the biennial Conditions and Performance report submitted to Congress, and tabulations of deficiency and sufficiency ratings are widely known and consulted. The NBIS were originally established to protect public safety by developing information on bridge structural and operational integrity. Although they were not conceived as a stand-alone management tool, they exert a major influence on bridge investments, federal apportionments, and project funding eligibility.

Several trends and events reviewed in this synthesis study point to potential changes in bridge management and in the NBIS specifically. Upcoming reviews of the NBIS may drive potential changes in (1) the composition and quality of NBI data; (2) the application of NBIS to bridge inspection and management; (3) FHWA oversight of the NBIS; (4) identification and funding of remedial work on structurally deficient bridges nationwide; and (5) use of NBI deficiency and sufficiency ratings in administering the life-cycle cost HBP, as well as the introduction of a new program to address structurally deficient bridges. These trends and events that will influence bridge management in future years are summarized in the following subsections.

State Department of Transportation Bridge Management System Improvements for Decision Making

Several DOTs interviewed for this study described customized BMS improvements in a number of areas that go beyond the NBIS requirements; for example, new bridge condition and performance measures or indexes, collection and processing of additional bridge data beyond that required by NBIS, and development of custom BMS models to estimate the near-term and long-term impacts of bridge investments. These state-specific initiatives, supplementing the NBI SR, were believed to provide the following:

- Better descriptors of state highway bridge condition
- Better guidance for needed bridge investments
- Better information on the benefits of bridge investments.

Asset Management Peer Exchanges

A series of peer exchanges involving state DOT personnel, TRB, and FHWA has considered several topics in asset management pertinent to this synthesis: planning and operations, programming and budgeting, and data and information. Several issues identified at these sessions mirror those discussed for bridge management and decision making in chapter three—for example, a lack of advanced analytic capabilities such as scenario testing and trade-off analysis in legacy systems, contradictory feelings about the value versus the complexity and potential error of predictive modeling used for forecasts, and the expense of management systems and continuing data collection. Recommendations of these peer exchanges may suggest ways to improve bridge program management as well—for example, research to strengthen analytic capabilities within BMS where needed, the value of integrated data that have multiple uses, the significant added value of spatial referencing and display of data, the value of a solid asset management approach in building agency credibility when justifying additional funding, and the desirability of moving from worst-first to more proactive, preventive investment strategies.

U.S. Department of Transportation Office of Inspector General Review of National Bridge Inspection Standards

U.S.DOT Secretary Mary Peters announced a comprehensive review of NBIS the day after the I-35W bridge collapse.

This review, now under way by the U.S.DOT's Office of Inspector General,(OIG) comprises three phases:

1. An assessment of the FHWA's progress in responding to recommendations of a prior OIG review in March 2006, which addressed FHWA oversight of structurally deficient bridges and its pursuit of risk-based, data-driven methods to guide its oversight efforts.

2. A review of how efficiently and effectively state DOTs have applied federal HBP funding and discretionary funding to correct bridge structural deficiencies.

3. A review of FHWA's oversight of the safety of National Highway Safety-system bridges nationwide.

Public Reaction to Bridge Collapse

There was much public reaction following the I-35W bridge collapse. This synthesis study has reviewed those aspects of public reaction that bear on the scope of work. It has not addressed the cause of the bridge collapse or the subsequent completion of the bridge replacement project, topics that are not within the scope of work. Regarding NBIS ratings, news accounts reported confusion over the meaning and clarity of the term "structural deficiency," reflecting the difficulty general audiences had in understanding what the designation means for bridge condition and public safety. Federal and state transportation agencies, professional organizations, and congressional committees set up websites to explain NBIS ratings and statistics and provide information on bridge projects and programs.

Changes Proposed in State Department of Transportation Congressional Testimony

Changes in HBP procedures and criteria were proposed in congressional testimony following the I-35W bridge collapse. State DOT executives, some of whom represented both their respective departments and AASHTO, recommended that Congress and the FHWA allow state DOTs greater flexibility to apply HBP funding according to bridge management principles, methods, and criteria. The federal government should remove (or at least relax) some of the arbitrary project eligibility thresholds associated with the SR. DOTs that were using systematic, data-driven, performance-based asset management techniques could then achieve more efficient preventive and corrective investment strategies that were superior to existing, worst-first methods.

The DOT executives before Congress also addressed concerns regarding how state DOTs apply HBP funds. They noted that the total amount of investment in bridge programs exceeds what would be needed simply to match the federal HBP contribution. Moreover, the combined funding from all sources is managed to provide a degree of flexibility (e.g., through decisions on resource allocation and funding transfers) to better match available funds to eligible needs, and address needs better than would have been the case using solely the SR criterion. It was proposed that at a minimum, the federal government should update procedures and criteria by which NBI sufficiency and deficiency ratings influence bridge program funding decisions. (Following this testimony, the FHWA did clarify policies allowing greater flexibility in funding bridge deck repairs, as permitted by SAFETEA-LU.)

Other aspects of bridge management addressed in the congressional testimony included bridge inspection procedures and innovative inspection technologies; performance of bridge materials; use of inspection data for decision making; and needed research. The testimony sought to correct misimpressions regarding the designation of a bridge as structurally deficient. Executives also voiced support for newly proposed bridge funding to reduce structural deficiencies nationwide.

Government Accountability Office Report

A recent Government Accountability Office (GAO) report and accompanying testimony before Congress raised several issues regarding the focus of the federal HBP, the data and techniques now available for bridge management, and results achieved to date in correcting structurally deficient bridges. The GAO recommended the following actions:

- Define the national goals of the HBP.
- Determine HBP performance relative to goals.
- Identify and evaluate bridge management best practices that can improve performance of the HBP, such as BMSs.
- Evaluate HBP funding mechanisms to identify how funding can be aligned more closely with performance, supporting a more focused and sustainable federal bridge program.

Federal Bridge Legislation

Legislation now before Congress portends change in the future practice and technology of bridge management. The current bills before the House and Senate include the following provisions, subject to further congressional deliberation:

- **BMS.** Each state shall develop and implement a BMS.
- **Performance Plan and Risk-Based Priorities.** States shall develop a 5-year performance plan for bridge inspections and for rehabilitating or replacing structurally deficient and functionally obsolete bridges. The secretary of transportation, in consultation with the states, shall establish a process for assessing risk-based priorities of bridge actions, and assign such a

risk-based priority to rehabilitating or replacing structurally deficient and functionally obsolete bridges.

- **National Bridge Inspection Program and Critical Deficiencies.** Several aspects of the NBIS will be improved to promote greater uniformity of practices among states in areas of quality and compliance reviews. NBIS will include procedures for detecting, monitoring, correcting, and reporting on critical findings regarding bridge deficiencies, and provide for the use of state-of-the-art technology to detect fatigue damage. The secretary of transportation shall establish regulations governing the training of inspectors regarding critical findings and state reporting of critical findings to the U.S.DOT, with subsequent reports to Congress. The secretary shall expand the bridge inspection training program to ensure that all persons inspecting bridges receive appropriate training and certification. Required qualifications of bridge inspection team leaders will be strengthened.
- **Funding and State Participation Requirements.** To be eligible for federal funding of bridge rehabilitation and replacement, states must meet several requirements spelled out in this legislation, including the use of a BMS, development and implementation of a 5-year performance plan, and bridge inspections that satisfy criteria specified in the legislation. States will be permitted to transfer HBP funds to other federal aid programs as long as no NHS-system bridges are eligible for replacement.
- **Independent Reviews and Research.** The legislation calls for several studies by independent agencies and research groups. These studies include a review by the NAS of the risk-based priority approach for bridges discussed previously, and GAO studies of the effectiveness of the current FHWA bridge rating system, bridge rating approaches now used by state DOTs, and construction delivery-related issues that affect bridge rehabilitation. The legislation identifies several research needs and a pilot program regarding advanced technologies that could be applied to bridge inspection and condition assessment.

Summary: Direction of Bridge Management and Its Use for Decision Making

The several influences identified in the preceding subsections will overlay the current practices and initiatives by state DOTs described at the beginning of this chapter. These combined effects will shape the future of bridge management and how its practices, systems, and information will be used in coming years to inform investment and resource allocation decisions. Although these interactions are just evolving and their outcome is not yet determined, it appears likely—based on the numerous and significant federal and state actions described previously—that changes will occur in state DOT bridge inspection and condition assessment, bridge program management, and application of the NBIS. It also appears likely that federal oversight of state DOT bridge inspection, program management, and treatment of deficient bridges and critical findings may be strengthened. If current federal legislation is passed substantially as now written, federal responsibilities for bridge program oversight may be backed in part by a greater focus on accountability to relate funding to performance, quality assurance, quality control, and increased compliance reporting among state DOTs, the FHWA and U.S.DOT, and Congress. This is the direction in which the state of practice in applying bridge management to state-agency decision making is proceeding as of the end of 2008.

The following paragraphs provide conclusions on additional, specific topics that were requested to be addressed in the scope of work.

ORGANIZATIONAL UNITS MAKING PROGRAM DECISIONS

Various offices and organizational levels are involved in different types of bridge-program decisions (see Table 9). Decisions often are made with joint or multiple-office participation. Generally speaking, an agency's bridge office is significantly involved in all programming decisions that deal specifically with bridges, but this authority is shared with other groups within and outside the agency. For example, major bridge projects involve strong participation by agency executives and, in some states, the transportation board or commission. Regional and local officials will also be involved for major bridge projects in urban areas. Local bridge programs engage local and regional bodies to work with the state agency's local or municipal assistance office. Districts (or regions or divisions) generally have a strong say in decisions involving all categories of bridge projects within their jurisdictions: local, state-owned, and major bridges. Although the bridge unit plays a key role in establishing performance measures and targets for bridge programs, agency executives also have a clear interest in bridge condition and performance as an important dimension of agency performance statewide. Other state agency units are strongly involved in bridge program performance monitoring, including offices responsible for planning, development or investment management, policy and strategy, and asset management.

One programming decision where the bridge unit does not have a dominant role among reporting agencies is in the allocation of resources among competing agency programs: bridge versus pavement, safety, maintenance, and so on. Leadership on this decision is seen either as an executive-level function, with transportation board or commission involvement as well in several states, or as a broader departmental decision involving units such as planning, investment management, policy and strategy, project management, and (in a Canadian province) the director of highway design and construction. In two states, this decision is decentralized, with program allocations made by districts. In some states, this decision may be moot if bridge funding is allocated "off the top" or is reserved in a noncompeting set-aside. However, even with off-the-top funding of the bridge program, there may be resource allocation issues if the funding level has remained level over time and is now insufficient to meet bridge needs.

Agencies range along the entire spectrum from highly centralized to totally decentralized cultures, although many of the examples that were provided in interviews stress repeated consultation and agreement between central office and district personnel, regardless of approach. In many agencies, the management style is mixed, with centralized techniques often applying to bridge replacement and rehabilitation (i.e., projects that are eligible for federal HBP funding), and more decentralized responsibility typically applying to bridge maintenance and repair (i.e., projects that tend to be funded by state money). Decisions thus flow in both directions, top down and bottom up (see Figure 1). Even in decentralized organizations, the central office often handles major bridge projects and also may retain responsibility for bridges on "trunk line" or "backbone" networks that have statewide significance (e.g., refer to State B in Table 7).

One state bridge maintenance engineer noted that his agency's adoption of a BMS helped the bridge maintenance office to promote a stronger identity for its bridge program, which up to that time had been viewed more as an adjunct of the road investment program that addressed primarily pavements. With the support of a BMS and its data, the bridge maintenance unit was able to strengthen its role in bridge program leadership and decision making within the agency (refer to State D in Table 8). Its district involvement in bridge replacement decisions was strengthened as well.

USE OF ECONOMIC METHODS

Agencies use economic methods to varying degrees, but overall the practices do not represent wide use (see Figure 19). Common examples of use for individual structures are the application of methods such as benefit-cost to major bridge projects, or life-cycle cost comparisons of rehabilitation versus replacement options for specific structures. Agencies that have full-featured BMS such as Pontis are more likely to employ economic analyses in network-level bridge management tasks, such as determining optimum investment strategies. These network analyses may include user costs as well as agency costs. Even in these cases, however, there may be reservations about the transparency of the analytic procedures or disagreement with the methods' assumptions (refer to Tables 7 and 8 for examples). Several agencies remarked in interviews that they are planning to apply economic analyses to a greater degree in bridge management in the future. FHWA division offices have encouraged the use of economic analysis techniques, together with better definition and documentation of programming and resource allocation procedures.

STANDARD REPORTS

The standard reports that are available on bridge management depend on the functionality of an agency's BMS and the built-in reporting features and options. Two BMSs with quite different analytic capabilities that were described in chapter two are used as examples.

The first example is the Alabama Bridge Information Management System (ABIMS), which is essentially a manager of bridge data. Its database is a repository of descriptive information on bridge structural characteristics, traffic loads, geographic and route location, functional class, age, and so forth, as well as current and historical records of inspection data. NBI data are included for annual reporting to the FHWA, and custom data defined by the agency are likewise included. Standard reports therefore focus on breakouts of bridge characteristics, bridge condition, and information on related management tasks such as inspection and maintenance. The categories of reports that are available include lists of the bridge inventory and bridge characteristics in various formats, current and historic NBI ratings, bridges scheduled for inspection, bridge maintenance needs, bridge posting status, and bridge projects. The inclusion of custom data often creates the need for a corresponding set of reports. The ABIMS thus provides a list of bridges by priority in terms of several categories of Deficiency Points, which is Alabama's custom measure of bridge condition.

A manager can tailor all of these reports to focus on particular areas of interest as appropriate to the report structure. These selections include geographic jurisdictions, specific bridge structures, responsibility codes for inspections and for maintenance, specific types of inspections or of maintenance to be displayed, the years to be displayed in historical reports, and so forth. Some categories of reports, such as those related to identified bridge needs and actual maintenance work performed or to explanations of bridge engineering characteristics, may be available in both summary and detailed formats. All reports in ABIMS represent current or historical snapshots of bridge status. Because the BMS has no predictive models, it offers no forecasts, scenario analyses, or other future-oriented reports.

The second example is Pontis, a full-featured BMS in use in more than 40 state DOTs. Pontis presents a broader selection of standard reports, reflecting its more extensive features and functionality. The reports are organized by Pontis system modules, examples of which are listed here. Reports are available in metric or English measurement units. If a report pertains to a given structure (as opposed, for example, to summaries for a bridge network), the bridge(s) may be selected by district, county, owner agency, custodian agency, function class, NHS or non-NHS, defined administrative area, defined bridge grouping, or inspector responsibility. The categories of standard reports are as follows:

- **Inspection Reports** present information on the bridge inventory, current and historical information on bridge condition and performance, and inspection schedules.
- **Bridge Preservation Needs and Projected Work** are presented in a series of network-level reports covering unconstrained and constrained needs, details on recommended preservation actions and their cost and performance implications, and tabulations of programmed and unmet needs and related performance measures.
- **Project Reports** produce information on needs, work candidates, projects, estimated costs versus available budget, and funding sources and amounts as applying to proposed work on individual bridge structures.

RESEARCH NEEDS

Recommendations by industry experts, responses to the survey conducted in this synthesis, provisions of congressional legislation defining research needs, and research-related implications of the recommendations of the recent GAO HBP review are consolidated and summarized in the following research topics.

- **To improve management practices and their capability to support agency decision making**, research is needed.
  - To attain more comprehensive, detailed, and realistic analyses of bridge condition and performance through better data and analytic procedures; and
  - To create a more risk-based, data-driven approach to bridge management and resource allocation, advancing beyond the current limitations of relying solely on NBIS-based investment criteria for bridge rehabilitation and replacement.
- **To seek fundamental advances in bridge inspection and condition- and performance-monitoring technology.** This research need has been identified by several sources, among them state DOT executives, other industry experts, and Congress in its draft legislation. The stated goals of this research range from more reliable and cost-effective gathering of bridge condition and performance data to a completely automated method of gathering such quantitative data comprehensively and objectively. As examples, the current House and Senate bills, H.R. 3999 and S. 3338, mandate the following technological research studies:
  - To investigate nondestructive evaluation equipment that can assess bridge structural integrity for facilities that use advanced materials;
  - To study the costs and benefits of using carbon-fiber composites in lieu of traditional materials in bridge rehabilitation and reconstruction; and
  - To study establishing a Bridge Advanced Condition Assessment Pilot program to encourage application of new, real-time technologies to bridge condition evaluation, particularly for critical bridge elements. These technologies will include fiber optic, vibrating wire, acoustical emissions, and peak-strain displacement.
- **To respond as needed to other provisions of H.R. 3999 and S. 3338.** If these provisions are passed into law substantially in their current form, specific research efforts may be needed to assist the FHWA and U.S.DOT in responding to the following congressional requirements:
  - To develop an analytic method to assign risk-based priorities for rehabilitating or replacing SD and FO bridges;
  - To define procedures and approval criteria for 5-year performance plans by state DOTs covering bridge inspections and rehabilitation or replacement of SD and FO bridges;
  - To design procedures and criteria for the annual compliance reviews of state DOT bridge inspections, quality assurance and quality control procedures, load ratings, and weight-limit postings of structurally deficient bridges;
  - To define "critical findings" regarding bridge deficiencies and establish the procedures, materials, and criteria for reporting such critical findings and monitoring and correcting these deficiencies; and
  - To develop a training program for inspectors on critical findings
- **To provide research that may be needed to support GAO's recent recommendations on the federal HBP (see chapter four).** Research could potentially help in the following areas:
  - To define the specific national goals of, and federal interests served by, the HBP;
  - To develop performance measures that respond to, and reflect progress toward, these federal goals and interests;
  - To identify best-practice methods and tools that can be incorporated within the HBP, drawing on existing approaches such as BMSs and leading-edge techniques applied by state DOTs; and
  - To review and evaluate mechanisms that can align HBP funding with performance to achieve a focused, sustainable federal bridge program.

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APPENDIX A

SURVEY QUESTIONNAIRE

QUESTIONNAIRE

NCHRP Project 20-5

Synthesis Topic 37-07

Use of Bridge Management for Transportation Agency Decision making

All state departments of transportation (DOTs) have a bridge management process or system in place and in use. The extent to which these processes are used in network level planning and programming decisions may vary significantly from one agency to another. It will be beneficial for state transportation agencies to know how other agencies use and benefit from their bridge management processes in making resource allocation decisions relating to bridges.

This synthesis is gathering information on current practices that agency senior decision makers use to make network level funding decisions for their bridges, and the use they make of their bridge management processes for these decisions. Also, information is being collected on future plans for upgrading and better utilizing bridge management processes. The focus is on both funding allocations for bridges within the overall agency programs, and allocations within the bridge program for replacement, rehabilitation, and maintenance needs.

This is a three part questionnaire to elicit different perspectives regarding the bridge management process:

Part I. To be completed by the Chief Bridge Engineer responsible for the bridge management process within the State. If the Chief Bridge Engineer or the person(s) he or she delegates can complete all three parts, please do so, otherwise have the following individuals complete the remaining two parts concerning budgeting and planning.
Part II. Head of budgeting with significant responsibility in helping the CEO make decisions concerning the allocation of funds across different programs including bridges.
Part III. Head of State transportation planning.

Please return all three parts of the completed questionnaire by April 10, 2006 to:

William Hyman **Principal Investigator** **Applied Research Associates, Inc.** **7184 Troy Hill Drive, Suite N** **Elkridge, MD 21075**	**E-mail: bhyman@ara.com** **Phone: 410-540-9949** **Cell: 301-593-7842** **Fax: 410-540-9288**

QUESTIONS FOR THE CHIEF BRIDGE ENGINEER

Respondent Information

Bridge Engineer

Name:

Title:

Agency:

Address:

City: **State:** **Zip:**

Phone: **Fax:** **e-mail:**

To make effective decisions regarding the bridge program, to your knowledge does the Chief Executive Officer (CEO) and his or her management team use each of the following types of information with regard to bridges throughout the State? Please respond by using the following rating scale:

1 – Currently uses
2 – Uses with significant data manipulation
3 – Would like to use, but limited by the capabilities of the Bridge Management System
4 – Does not or is unlikely to use.

Information on Bridge Condition and Performance

1. An overall measure of the current condition or health of bridges. Rating:

2. A measure of the condition of key components of bridges that involve significant expenditures (e.g., bridge decks). Rating:

3. Key bridge safety problems that should be addressed such as piers subject to scour, bridges that could be exposed to hurricane storm surges, and bridges potentially affected by seismic activity. Rating:

4. The number of bridges that are currently structurally deficient. Rating:

5. The number of bridges that are currently functionally obsolete. Rating:

6. Progress in achieving bridge condition performance targets set in the prior year. Rating:

7. A measure of the *future* condition or health of bridges. Rating:

8. The target level of maintenance required that would be consistent with the requirements of the Governmental Accounting Standards Board. Rating:

Programming and Budgeting

9. Future bridge expenditure needs for bridge preservation and improvement over the forthcoming budget cycle assuming no budget constraints. Rating:

10. Short-term (1–5 year) projections of future bridge expenditure needs under alternative budget assumptions. Rating:

11. Mid-term (6–10 year) projections of future bridge expenditure needs under alternative budget assumptions. Rating:

12. Long-term (11–50 year) projections of future bridge needs under alternative budget assumptions. Rating:

13. A single recommended bridge budget for the forthcoming budget cycle. Rating:

14. Analysis of choices and tradeoffs regarding expenditures within the recommended bridge budget or program—maintenance, rehabilitation, replacement, and major projects. Rating:

15. A breakdown of the recommended bridge budget by main or important types of structures. Rating:

16. Breakdown of the recommended bridge budget by in-house work versus contract work. Rating:

17. Descriptions, locations, and costs of candidate and recommended major bridge projects. Rating:

18. A breakdown of the recommended bridge budget by political jurisdiction or administrative unit. Rating:

19. A breakdown of major bridge projects in the recommended budget presented by political jurisdiction or administrative unit. Rating:

20. Reports and graphics showing the results of changing the resource allocation between the bridge program and other program areas such as pavements and operations. Rating:

Economic Criteria Used in Resource Allocation

21. Network level benefit-cost ratios for alternative bridge programs. Rating:

22. Network level estimates of life-cycle costs. Rating:

23. Network level estimates of avoidable road user costs (accidents, travel time, vehicle operating costs). Rating:

24. Benefit-cost ratios of major bridge project alternatives. Rating:

District-Level Information

25. Does the CEO and management team generally use the same type of district-level analysis and information as you checked above for the state? Check a box: ☐ Yes ☐ No. If no, please explain:

For each of the following identify the organizational unit, level, or decision maker(s) where bridge program decisions are made:

26. The allocation of funds among different assets (e.g., pavements, bridges, maintenance appurtenances, transit)

27. What the performance measures will be.

28. What the performance targets will be.

29. The split of funds for bridge preservation, rehabilitation, and replacement.

30. The major bridge projects that will be funded.

31. Who picks the state-owned bridges that will receive some action in a certain year?

32. Local bridges outside metropolitan areas that will receive funding.

33. Bridges in metropolitan areas that will be funded and which are included in a metropolitan Transportation Improvement Program.

In regards to each of the following statements, describe how your agency uses your computerized bridge management system. Please use the following rating scale:

1. Based primarily on the Bridge Management System
2. Manipulation of BMS data occurs outside the BMS
3. Not used or seldom used

Performance Measures for Needs Assessment and Resource Allocation

34. Calculates a measure of the current condition of each bridge (e.g., condition rating, sufficiency rating, health index). Rating:

35. Identifies current condition of each bridge on the network and key sub-networks such as districts or Interstate bridges (composite index, health index). Rating:

36. Projects into the future the condition of each bridge in the inventory. Rating:

37. Calculates a composite index of the projected network level condition of all bridges in the state (e.g., network-level health index). Rating:

38. Determines the depreciated value of the bridge inventory or uses the modified procedure for public reporting under the Governmental Accounting Standards Board Statement 34. Rating:

Needs Analysis

39. Identifies bridge needs (maintenance, rehabilitation, improvement and replacement) that can be used as input to the statewide budgeting and programming process by using engineering judgment and basic bridge data (e.g., inventory and inspection data, condition ratings, sufficiency ratings, whether a bridge is structurally deficient and/or functionally obsolete, and safety or other serious problems that are flagged in the data base). Rating:

40. Identifies major project needs. Rating:

41. Uses project level analysis to identify options (candidates) as input to the network level analysis. In other words, analysis of network level needs is derived from project options for each bridge stored in the bridge management system data base. Rating:

42. Determines network level needs unconstrained by budgets by using benefit-cost analysis or other similar techniques. Rating:

43. Determines multi-year, network level bridge needs subject to annual budget constraints by using benefit-cost analysis, optimization, or other procedures. Rating:

44. Produces reports useful for building a recommended bridge budget for each organizational unit responsible for some portion of the bridge inventory (e.g., districts). Rating:

Resource Allocation and Tradeoff Analysis

45. Has a network level dashboard for communicating the effects of different budget levels on various factors of concern to bridge managers (e.g., a health index for bridges on the network, the benefits in relationship to the costs that can be achieved for a given budget levels). Rating:

46. Has a project level dashboard for communicating the effects of deferring bridge work on the condition of bridge elements, life-cycle costs, etc. Rating:

47. Provides network-level analysis to help allocate funds for all agency bridges. Rating:

48. Provides network-level analysis to help allocate funds among organizational units within your agency (e.g., districts and possibly lower levels of the organization). Rating:

49. Provides network analysis to help allocate bridge funds by functional class, corridors, or other sub-networks of the highway system. Rating:

50. Produces reports useful for allocating the bridge portion of the budget approved by the governor and legislature to each organizational unit responsible for some portion of the bridge inventory (e.g., districts). Rating:

51. ***If your bridge management system has most of the capabilities listed above, do you use them to help the CEO and top management team do planning, programming, and budgeting, especially resource allocation within the bridge program?*** ☐ ***Yes*** ☐ ***No***

If your answer is no, check each box that provides part of the explanation:

52. ☐ The recommended actions from the bridge management system are too different from the actions our bridge inspectors and engineers recommend.

53. ☐ The bridge management system gives too much emphasis to economic considerations relative to other considerations, especially conditions we observe in the field.

54. ☐ The economic assumptions are not accurate.

55. ☐ The bridge management system is perceived by too many managers as a black box—it uses analytic procedures we really do not understand

56. ☐ Management's capabilities include the ability to assess current and future needs. A bridge management system detracts from the bridge manager's prerogatives.

57. ☐ We have found it difficult to implement a bridge management system, train personnel, and obtain buy-in from managers that must depend upon it.

58. ☐ We have had problems with reliability (software, data, and/or analysis)

59. ☐ Other:

Additional Questions

60. ***Is there anything—perhaps something distinctive or unique— about your bridge management process or your computerized bridge management system that significantly helps, hinders or constrains bridge decision making in regards to the following:***

    a) ***Choices and tradeoffs within the bridge program concerning expenditures on maintenance activities, rehabilitation, and replacement.***

    b) ***Choices and tradeoffs between the bridge program and other programs such as pavements, operations, and the broader set of maintenance activities.***

61. ***Do you have any future plans to upgrade and allow top management to better utilize the bridge management process (including analysis from the computerized bridge management system)?***

62. ***Please provide examples of the most useful reports, tables, charts, maps, PowerPoint presentations, screenshots, or other material you provide to the CEO and management team for purposes of bridge decision making.*** (Mail them to William Hyman, the Principal Investigator, at the address shown on the first page)

63. ***OPTIONAL BUT DESIRABLE. Please provide documentation on your bridge management business process. How resource allocation decisions are made within the bridge program area and between the bridge and other program areas is of primary interest. You can satisfy this request in one of two ways, the first being much simpler than the second:***

    c) Provide existing documentation that is already available within your agency. This documentation may be ***descriptive material or flow charts*** and may be found in published papers, reports, policies and procedures, various types of plans, and completed requirements analysis that documents existing business processes for bridge decision making or resource allocation within and across different types of assets such as bridges and pavements. Your Information Technology group may have this type of system documentation.

d) Begin from scratch and develop a flow chart or list of steps that describes how key bridge decisions are made. Identify the title of the person or organizational unit responsible for each step. Identify which steps involve the use of a computerized bridge management system. In a flow chart, show key decision points and decision branches.

Whether you provide existing documentation or document the bridge management process from scratch, please try to address each of the following bridge related decisions:.

- Establishing performance measures and targets
- Determining which bridges warrant some action based upon condition, safety, functional obsolescence, or economics (i.e. benefits exceed costs)
- Determining those bridges for which actions must be deferred or down-scoped due to insufficient funds.
- Recommending a funding level for bridges to be incorporated into the budget to the governor and legislature
- Determining the allocation of the recommended and approved budgets among maintenance, rehabilitation, and capital expenditures including replacement, new construction, and major projects
- Determining the allocation of the recommended and/or approved budget between bridges and other program areas (e.g. pavements and operations)
- Determining local and metropolitan bridges that will be funded.
- Adjusting performance targets based on periodic review and feedback

(Please mail your documentation of the bridge management process to William Hyman, the Principal Investigator, at the address shown on the first page)

64. ***What information do top decision makers require for funding and programming decisions that are not being provided by your bridge management process?***

65. ***Other comments:***

QUESTIONS FOR HEAD OF BUDGETING (IF NOT COMPLETED WITHIN THE OFFICE OF THE CHIEF BRIDGE ENGINEER)

BACKGROUND

All state departments of transportation (DOTs) have a bridge management process or system in place and in use. The extent to which these processes are used in network level planning and programming decisions may vary significantly from one agency to another. There may also be great variation in the familiarity of senior decision makers with the basic assumptions underlying the bridge management process and with its potential to produce useful reports regarding bridge condition, performance, and resource allocation needs. It will be beneficial to all transportation agencies to know how other agencies use and benefit from their bridge management processes in making resource allocation decisions relating to bridges.

This synthesis is gathering information on current practices that agency CEO's and senior decision makers use to make network level funding decisions for their bridges, and the use they make of their bridge management processes for these decisions. Also, information is being collected on future plans for upgrading and better utilizing bridge management processes. The focus is on both funding allocations for bridges within the overall agency programs, and allocations within the bridge program for replacement, rehabilitation, and maintenance needs.

This is a three part questionnaire to elicit different perspectives regarding the bridge management process:

Part I. To be completed by the Chief Bridge Engineer responsible for the bridge management process within the State. If the Chief Bridge Engineer or the person(s) he or she delegates can complete all three parts, please do so, otherwise have the following individuals complete the remaining two parts concerning budgeting and planning.
Part II. Head of budgeting with significant responsibility in helping the CEO make decisions concerning the allocation of funds across different programs including bridges.
Part III. Head of State transportation planning.

Respondent Information

<u>Head of Budgeting (if not completed within the Office of the Chief Bridge Engineer)</u>

Name:

Title:

Agency:

Address:

City: **State:** **Zip:**

Phone: **Fax:** **e-mail:**

PLEASE RETURN THIS PORTION OF THE COMPLETED QUESTIONNAIRE TO YOUR AGENCY'S CHIEF BRIDGE ENGINEER WHO WILL SEND IT TO THE PRINCIPAL INVESTIGATOR, WILLIAM HYMAN, APPLIED RESEARCH ASSOCIATES, INC.

1. ***Please rate on a scale from 1(unimportant) to 5(very important) the importance of each of the following factors in the budgeting process:***

   a) The budget level for the previous budget cycle. Rating:

   b) The budget level for the previous fiscal year. Rating:

   c) Giving first priority to bridge preservation projects. Rating:

   d) Giving first priority to capital expenditures for bridges – replacement and major projects. Rating:

   e) Giving first priority to major bridge projects, with the balance of bridge funds going to the rest of the bridge program. Rating:

   f) The political jurisdictions in which bridge replacement work and major bridge projects occur. Rating:

   g) Bridge needs determined at the district and/or lower levels of the organization, possibly with input from local government or Metropolitan Planning Organizations. Rating:

   h) Documented bridge needs, tempered by engineering judgment, based on results of the computerized bridge management system. Rating:

   i) Quantitative analysis of choices and tradeoffs from the bridge management system regarding the allocation of funds among bridge maintenance, rehabilitation and replacement work. Rating:

   j) Quantitative analysis of choices and tradeoff from one or more computerized management systems regarding the allocation of funds between the bridge program and other programs such as pavements and operations. Rating:

   k) Subjective analysis of top managers and professionals concerning the choices and tradeoffs within the bridge program and between the bridge program and other programs such as pavements. Rating:

   l) An analysis of bridge work that should be performed by in-house staff versus contractors. Rating:

2. ***Does your budget office use your agency's computerized bridge management system to help support the budgeting process?*** ☐ *Yes* ☐ *No*
If yes, which of the following features are used?

a) ☐ Generate summary information about the inventory, condition, structural deficiency, functional obsolescence at the network and district level

b) ☐ Identify safety or other serious problems such as scour, presence of fracture critical elements or seismic vulnerability

c) ☐ Produce information that can be compared with performance targets set by management

d) ☐ Generate alternative scenarios subject to budget constraints for planning, programming, budgeting and resource allocation

e) ☐ Explore choices and tradeoffs for allocation of resources within the bridge program (maintenance, rehabilitation, replacement)

f) ☐ Calculate bridge life-cycle costs and/or minimum component life-cycle costs

g) ☐ Calculate avoidable road user-costs (accidents, travel time, vehicle operating costs) as a function of alternative budget levels

h) ☐ Provide information to satisfy public reporting requirements under the Governmental Accounting Standards Board

i) ☐ Provide information helpful in setting parameters (performance targets, budget levels by organizational unit, other guidelines) to effectively delegate to lower level managers the responsibility for selecting what work to do on specific bridges on the network

j) ☐ Past and planned bridge work by organizational unit or geographic area

3. ***Of the items you did not check in response to Question 2, would any be useful to you for budgeting?***

4. ***Please check which of the following organizational units in the department play a key role in making decisions regarding the allocation of resources within the bridge program and between the bridge program and other programs in the department. Note that some of these functions, such as budget and finance, may be found within the same organizational unit.***

   a) ☐ Office of the CEO
   b) ☐ Budget
   c) ☐ Finance
   d) ☐ Planning
   e) ☐ Programming
   f) ☐ Construction
   g) ☐ Bridge Construction
   h) ☐ Maintenance
   i) ☐ Bridge Maintenance
   j) ☐ Operations
   k) ☐ Computer Services
   l) ☐ Office of the District Director, District Engineer or similar district head
   m) ☐ District Office of Planning
   n) ☐ District Office of Programming/Budgeting
   o) ☐ District Office of Construction
   p) ☐ District Office of Maintenance
   q) ☐ Areas
   r) ☐ Shops/Garages
   s) ☐ Other:
   t) ☐ Other:
   u) ☐ Other:

5. ***Please provide examples of the most useful tables, charts, maps, slide presentations, or other material you provide to the CEO and management team for purposes of budget development and resource allocation within the bridge program and between the bridge and other program areas*** (Please return these materials to the Chief Bridge Engineer to be mailed to William Hyman, the Principal Investigator)

6. ***Other Comments:***

QUESTIONS FOR HEAD OF PLANNING (IF NOT COMPLETED WITHIN THE OFFICE OF THE CHIEF BRIDGE ENGINEER)

BACKGROUND

All state departments of transportation (DOTs) have a bridge management process or system in place and in use. The extent to which these processes are used in network level planning and programming decisions may vary significantly from one agency to another. There may also be great variation in the familiarity of senior decision makers with the basic assumptions underlying the bridge management process and with its potential to produce useful reports regarding bridge condition, performance, and resource allocation needs. It will be beneficial to all transportation agencies to know how other agencies use and benefit from their bridge management processes in making resource allocation decisions relating to bridges.

This synthesis is gathering information on current practices that agency CEO's and senior decision makers use to make network level funding decisions for their bridges, and the use they make of their bridge management processes for these decisions. Also, information is being collected on future plans for upgrading and better utilizing bridge management processes. The focus is on both funding allocations for bridges within the overall agency programs, and allocations within the bridge program for replacement, rehabilitation, and maintenance needs.

This is a three part questionnaire to elicit different perspectives regarding the bridge management process:

Part I. To be completed by the Chief Bridge Engineer responsible for the bridge management process within the State. If the Chief Bridge Engineer or the person(s) he or she delegates can complete all three parts, please do so, otherwise have the following individuals complete the remaining two parts concerning budgeting and planning.
Part II. Head of budgeting with significant responsibility in helping the CEO make decisions concerning the allocation of funds across different programs including bridges.
Part III. Head of State transportation planning.

Respondent Information

<u>Head of Planning (if not completed within the Office of the Chief Bridge Engineer)</u>

Name:

Title:

Agency:

Address:

City: **State:** **Zip:**

Phone: **Fax:** **e-mail:**

WOULD THE HEAD OF PLANNING PLEASE RETURN THIS PORTION OF THE COMPLETED QUESTIONNAIRE TO YOUR AGENCY'S CHIEF BRIDGE ENGINEER WHO WILL SEND IT TO THE PRINCIPAL INVESTIGATOR, WILLIAM HYMAN, APPLIED RESEARCH ASSOCIATES, INC.

1. ***Please indicate which of the following capabilities of a computerized bridge management system your department uses to help support the planning process? For each item that applies, place a check in the box.***

    a) ☐ Provide summary reports on the inventory and condition of bridges for the state and the districts.

    b) ☐ Provide statewide and district reports on the number of bridges that structurally deficient and functionally obsolete

    c) ☐ Identify or flag safety or other serious problems such as scour, presence of fracture critical elements or seismic vulnerability

    d) ☐ Provide an overall network and district level condition or health index

    e) ☐ Provide information that can be compared with performance targets set by management

    f) ☐ Explore alternative scenarios subject to budget constraints for planning, programming, budgeting and resource allocation

    g) ☐ Identify choices and tradeoffs for allocation of resources within the bridge program (replacement, rehabilitation, maintenance)

    h) ☐ Identify life-cycle costs of bridges

    i) ☐ Identify avoidable road user costs as a function of alternative budget levels

    j) ☐ Provide information to satisfy public reporting requirements under the Governmental Accounting Standards Board

    k) ☐ Provide the CEO and other top managers recommended parameters (performance targets, budget levels by organizational unit, other guidelines) to effectively delegate to lower level managers the responsibility for selecting what work to do on specific bridges

    l) ☐ Identify past and planned bridge work by organizational unit or geographic area

    m) ☐ Identify past and planned bridge work by political jurisdiction

2. ***Please provide examples of the most useful tables, charts, maps, slide presentations, or other material you provide to the CEO and management team for purposes of making planning decisions regarding bridges.*** (Please give this information to the Chief Bridge Engineer to be mailed to the Principal Investigator, William Hyman).

3. ***Please describe any recent trends in planning that are likely to help top management make improved decision making regarding bridges. These trends may concern management theory, systems, technology, research, organizational development, communications, etc.***

4. ***Other Comments:***

APPENDIX B

INTERVIEW GUIDES

Two interview guides follow:

- One in interviews with ten chief engineers; and
- The second, in interviews with five bridge unit engineers.

NCHRP SYNTHESIS PROJECT 37-07

ROLE OF BRIDGE MANAGEMENT IN TRANSPORTATION AGENCY DECISION MAKING

Guide for Interviewing Chief Engineers

PRINCIPLES

- Conduct in-person or telephone interviews
- Interview a representative set of Chief Engineers from 10 to 15 states
- Explain that we wish to know what key bridge-related decisions the CEO and Chief Engineer makes, what information is used to make those decisions, and what additional information would be helpful.
- Focus on resource allocation within the bridge program and between the bridge and other program areas.
- Promote an open discussion to elicit what is important to the top management team; use the key decisions below as a catalyst for discussion
- Learn what bridge decisions top management delegates to lower levels
- Find out how the bridge management process (including the BMS) informs bridge related decision making.

KEY DECISIONS

- Ensuring accountability
- Setting goals and objectives for bridges
- Establishing performance measures and targets for bridges
- Making commitments to meet future needs in different time frames based on projected deterioration of different types of bridges or important bridge components (e.g., decks)
- Establishing resource levels for bridges in the budget process
- Allocating the bridge budget among capital expenditures, rehabilitation, maintenance, and operations (e.g., automated anti-icing, electronic toll collection, movable bridges)
- Allocating the department budget between the bridge program and other program areas such as pavements, maintenance appurtenances, operations, and transit.
- Allocating the bridge budget among districts and other subunits of the DOTs

- Other allocations of bridge funds to support specific bridge programs such as homeland security, scour prevention, and protection and mitigation of storm surge in hurricane prone states.
- Determining how different types of bridges will be funded (federal, state, local, tolls as a part of a public/private partnership)
- Determining which bridges will receive various treatments each year.

NCHRP Synthesis Topic 37-07
Use of Bridge Management in Transportation Agency Decision making

INTERVIEW GUIDE—DISCUSSION ITEMS
August 2007

1. Current BMS(s) used by agency
    - Central Office
    - Districts/Regions
2. What rating systems are used in bridge management
    - NBI: SD and FO (percent of inventory? trends?)
    - Other?
3. Executive decision criteria for evaluating and deciding bridge investment and resource allocation
    - What do they ask for?
    - What does the bridge unit provide them?
4. Resource allocation/project programming and selection process—who makes decisions and on what basis in each of these areas?
    - Setting policy objectives and performance targets
    - Resource allocation between Bridge and Other Programs
    - Within the Bridge Program, allocations among districts/regions
    - Bridge project prioritization (statewide? by district/region?)
5. Are methods of economic evaluation (e.g., benefit-cost, life-cycle cost) used at any organizational level?
6. Does your agency have a defined program of performance measurement, established performance targets, and management accountability for meeting targets?
7. Does your agency have a regular program of communication of Bridge Program information to external stakeholders (e.g., legislature, executive branch, public at large)?

APPENDIX C

SURVEY AND INTERVIEW PARTICIPANTS

Survey Respondents

Alaska Department of Transportation and Public Facilities
P.O. Box 112500
Juneau, AK 99811

Arizona Department of Transportation
205 S. 17th Ave.
Phoenix, AZ 85007

Arkansas State Highway & Transportation Department
P.O. Box 2261
Little Rock, AR 72203

California Department of Transportation (Caltrans)
1120 N Street
Sacramento, CA 95814

Florida Department of Transportation
605 Suwannee Street MS 52
Tallahassee, FL 32399

Hawaii Department of Transportation
601 Kamokila Blvd., Room 611
Kapolei, HI 96707

Illinois Department of Transportation
2300 South Dirksen Parkway
Springfield, IL 62764

Kansas Department of Transportation
700 SW Harrison Street
Topeka, KS 66603-3754

Maine Department of Transportation
16 State House Station
Augusta, ME 04333

Michigan Department of Transportation
8885 Ricks Road
Lansing, MI 48909

Minnesota Department of Transportation
3485 Hadley Ave. North
Oakdale, MN 55128

New Mexico Department of Transportation
PO Box 1149, Room 214
Santa Fe, NM 87504

New York State Department of Transportation
50 Wolf Road, POD 4-3
Albany, NY 01232

Ohio Dept. of Transportation
1980 West Broad St. 3rd Floor
Columbus, OH 43223

Oklahoma Department of Transportation
200 N.E. 21st
Oklahoma City, OK 73105

Oregon Department of Transportation
355 Capitol St., NE Room 301
Salem, OR 97301

Tennessee Department of Transportation
Suite 1100, James K. Polk Building, 505 Deaderick Street
Nashville, TN 37243

Texas Department of Transportation
125 East 11th Street
Austin, TX 78701

Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219

Washington State Department of Transportation
PO Box 47341
Olympia, WA 98504

Alberta Infrastructure & Transportation
Twin Atria Building, 4999 - 98 Avenue
Edmonton T6J 0J6, Alberta

Manitoba Transportation and Government Services
600-215 Garry Street
Winnipeg R3C 3Z1, Manitoba

Department of Transportation and Works,
Provincial Government of Newfoundland and Labrador
6th floor Confederation Building, West Block
St. John's A1L 1Y2, Newfoundland

Transport Quebec
930 Chemin Sainte-foy 7th Floor
Quebec GIS 4X9, Quebec

Interviewees

Chief Engineer or Representative

Bob Walters, Chief Engineer, Arkansas State Highway & Transportation Department

Ananth Prasad, Chief Engineer, Florida Department of Transportation

Jerry Younger, Assistant Secretary and State Transportation Engineer, Kansas Department of Transportation

Ken Sweeney, Director, Bureau of Project Development, Maine Department of Transportation

Doug Differt, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation

Max Valerio, Deputy Chief Engineer and Division Manager, Program Delivery and Support Division, New Mexico Department of Transportation

Kathy Nelson, Chief Engineer, Oregon Department of Transportation

Paul Degges, Chief Engineer, Tennessee Department of Transportation

Mal Kerley, Chief Engineer, Virginia Department of Transportation

John Conrad, Assistant Secretary, Engineering and Regional Operations, Washington State Department of Transportation

Bridge Unit Managers

George Conner, Assistant State Maintenance Engineer-Bridges, Alabama Department of Transportation

Paul Jensen, Bridge Management System Coordinator, Montana Department of Transportation

R. Lee Floyd, Bridge Maintenance Engineer, South Carolina Department of Transportation

Finn Hubbard, State Bridge Engineer, Wisconsin Department of Transportation

George Fredrick, State Bridge Engineer, Wyoming Department of Transportation

APPENDIX D

RESPONSES TO SELECTED SURVEY QUESTIONS

TABLE D1

Questions 1-8: **Use of the Following Condition and Performance Data by CEO and Top Management Team?**	**Currently Uses** **R: 1**	**Uses with Significantly Manipulated Data** **R: 2**	**Doesn't Use Due To BMS Limitations** **R: 3**	**Does Not or Unlikely to Use** **R: 4**
Overall measure of the current condition or health of bridges	18 (75%)	2 (8%)	3 (12%)	1 (4%)
Measure of the condition of key components of bridges that involve significant expenditures	18 (75%)	2 (8%)	2 (8%)	2 (8%)
Key bridge safety problems (i.e., bridges exposed to hurricane storm surges, etc.)	14 (58%)	4 (16%)	6 (25%)	0 (0%)
Number of bridges that are currently structurally deficient	21 (87%)	0 (0%)	1 (4%)	2 (8%0
Number of bridges that are currently functionally obsolete	17 (70%)	4 (16%)	0 (0%)	3 (12%)
Progress in achieving bridge condition performance targets sent in prior year.	10 (41%)	6 (25%)	4 (16%)	4 (16%)
Measure of the *future* condition or health of bridges	4 (16%)	5 (20%)	12 (50%)	3 (12%)
Target level of maintenance required that would be consistent with the requirements of the Governmental Accounting Standard Board	2 (8%)	4 (16%)	9 (37%)	9 (37%)

TABLE D2

Questions 9–20: **Use of the Following Analyses and Information by the CEO and Top Management Team?**	**Currently Uses** **R: 1**	**Uses with Significantly Manipulated Data** **R: 2**	**Doesn't Use Due To BMS Limitations** **R: 3**	**Does Not or Unlikely to Use** **R: 4**
Future bridge expenditure needs for bridge preservation and improvement over the forthcoming budget cycle assuming no budget constraints	8 (33%)	9 (37%)	3 (12%)	4 (16%)
Short-term (1–5 year) projections of future bridge expenditure needs under alternative budget assumptions	9 (37%)	10 (41%)	4 (16%)	1 (4%)
Mid-tern (6–10 year) projections of future bridge expenditure needs under alternative budget assumptions	4 (16%)	10 (41%)	7 (29%)	3 (12%)
Long-term (11–50 year) projection of future bridge needs under alternative budget assumptions	1 (4%)	6 (25%)	10 (41%)	7 (29%)
A single recommended bridge budget for the forthcoming budget cycle	12 (50%)	9 (37%)	1 (4%)	2 (8%)
Analysis of choices and tradeoffs regarding expenditures within the recommended bridge budget or program-maintenance, rehabilitation, replacement and major projects	6 (25%)	4 (16%)	13 (54%)	1 (4%)
A breakdown of the recommended bridge budget by main or important types of structures	7 (29%)	5 (20%)	6 (25%)	6 (25%)
Breakdown of the recommended bridge budget by in-house work versus contract work	5 (20%)	3 (12%)	5 (20%)	11 (45%)
Descriptions, locations, and costs of candidate and recommended major bridge projects	16 (66%)	5 (20%)	2 (8%)	1 (4%)
A breakdown of the recommended bridge budget by political jurisdiction or administrative unit	13 (54%)	3 (12%)	2 (8%)	6 (25%)

Questions 9–20: **Use of the Following Analyses and Information by the CEO and Top Management Team?**	**Currently Uses** **R: 1**	**Uses with Significantly Manipulated Data** **R: 2**	**Doesn't Use Due To BMS Limitations** **R: 3**	**Does Not or Unlikely to Use** **R: 4**
A breakdown of major bridge projects in the recommended budget presented by political jurisdiction or administrative unit	11 (45%)	4 (16%)	2 (8%)	7 (29%)
Reports and graphics showing the results of changing the resource allocation between the bridge program and other program areas such as pavements and operations	3 (12%)	5 (20%)	11 (45%)	5 (20%)

TABLE D3

Questions 21–24: **Use of Economic Analysis by the CEO and Top Management Team?**	**Currently Uses** **R: 1**	**Uses with Significantly Manipulated Data** **R: 2**	**Doesn't Use Due To BMS Limitations** **R: 3**	**Does Not or Unlikely to Use** **R: 4**
Network level benefit-cost ratios for alternative bridge programs	3 (12%)	1 (4%)	15 (62%)	5 (20%)
Network level estimates of life-cycle costs	2 (8%)	2 (8%)	15 (62%)	5 (20%)
Network level estimates of avoidable road user costs (accidents, travel time, vehicle operating costs)	1 (4%)	2 (8%)	13 (54%)	7 (29%)
Benefit-cost ratios of major bridge project alternatives	5 (20%)	3 (12%)	11 (45%)	4 (16%)

TABLE D4

State or Province	**Question 26: Organizational Unit(s) That Allocate(s) Funds Among Different Assets (e.g., Pavements, Bridges, Maintenance Appurtenances, Transit)?**
Alaska	Headquarters, Planning
Arizona	Agency upper management
Arkansas	Highway Commission
California	The Executive SHOPP (State Highway Operational Protection Plan) Committee
Florida	The Executive Board (made up of the Secretary, assistants secretaries, and district secretaries)
Hawaii	Highways Project Management Staff
Kansas	Priority & Optimization for funding is Statewide and is developed by Planning with input from others: PMS, Materials and Research; BMS, State Bridge Office
Maine	Bureau of Planning/Executive Office
Michigan	Planning Division
Minnesota	Office of Investment Management (OIM)
New Mexico	Districts
New York	Policy and Strategy
Ohio	Majority of decisions are made at the District level
Oklahoma	CEO
Oregon	Statewide Transportation Commission
Tennessee	Department of Administration
Texas	TxDOT administration
Virginia	Asset Management; Operations Planning; Programming; Fiscal
Washington	Headquarters Program Management Office
Newfoundland and Labrador	Director of Highway Design and Construction, Assistant Deputy Minister, Deputy Minister and Minister of the Department of Transportation and Works
Quebec	Deputy Minister

TABLE D5

State or Province	Question 27: Organizational Units That Establish What Are the Bridge Performance Measures?
Alaska	Not applicable
Arizona	Bridge Program Manager
Arkansas	Chief Engineer
California	Bridge Program Manager
Florida	Executive Board
Hawaii	Bridge Design Section
Kansas	Information provided not applicable
Maine	Bridge Management Section (BMS)—located within the Bureau of Planning
Michigan	Combined, planning division development delivery, transportation commission
Minnesota	Jointly: Bridge and Office of Investment Management
New Mexico	Upper Management, Districts, and Design Groups
New York	Policy and Strategy
Ohio	Performance measures are established and monitored both at the Central Office and the District level
Oklahoma	Bridge Division
Oregon	Director of Highway Division
Tennessee	Division or Unit
Texas	Texas DOT Administration
Virginia	Asset Management; Bridge
Newfoundland and Labrador	No formalized system of "performance measurement" used.

TABLE D6

State or Province	Question 28: Organizational Unit(s) That Establish(es) What Are the Bridge Performance Targets?
Alaska	Not applicable
Arkansas	Chief Engineer
California	Bridge Program Manager
Florida	Executive Board
Hawaii	Bridge Design Section
Kansas	PMS: Materials and Research; BMS: State Bridge Office
Maine	Suggested by BMS
Michigan	Combined, planning division development delivery, transportation commission
Minnesota	Bridge
New Mexico	Upper Management
New York	Policy and Strategy
Ohio	Performance targets are set at the Central office level in consultation with the District teams
Oklahoma	Bridge Division
Oregon	Director of Highway Division
Tennessee	Division or Unit
Texas	Texas Transportation Commission
Virginia	Asset Management; Bridge
Quebec	55% of bridges in good condition
Newfoundland and Labrador	No formalized system of "performance measurement" used

TABLE D7

State or Province	**Question 29**	**Organizational Unit(s) That Establish(es) Funding Split Among Bridge Repair, Rehabilitation, and Replacement?**
Alaska	Regions and Bridge Section	
Arizona	Line item allocation	
Arkansas	Director/Chief Engineer	
California	Bridge Program Manager	
Florida	Executive Board	
Hawaii	Bridge Design Section	
Kansas	State System: BMS is used for maintenance set-asides. Priority & Optimization Formula is used to determine funding for replacements. New bridges/enhancements are by DOT formula and management selection	
Maine	Bridge Management Engineer, Assistant Bridge Maintenance Engineer, and Bridge Program (Design) Engineer	
Michigan	Combined, planning division development delivery.	
Minnesota	Jointly: Districts, Bridge, Office of Investment Management	
New Mexico	Districts	
New York	Region Offices, Policy and Strategy	
Ohio	Central office, initially determines the need in each category. Districts can change the allocations.	
Oklahoma	Field Division (District)	
Oregon	State Bridge Engineer	
Tennessee	Division or Unit	
Texas	District level	
Virginia	Fiscal: Programming; Operations Planning: Districts	
Quebec	Regional Administration	
Alberta	Division Executive Committee with input from representatives from the Programming Section	

State or Province	Question 29	Organizational Unit(s) That Establish(es) Funding Split Among Bridge Repair, Rehabilitation, and Replacement?
Newfoundland and Labrador	Chief Bridge Engineer, Director of Highway Design and Construction	

TABLE D8

State or Province	Question 30:	Organizational Unit(s) That Determine(s) the Major Bridge Projects to be Funded?
Alaska	HQ Planning and Region using the STIP Process	
Arizona	Five year program item	
Arkansas	Director/Highway Commission	
California	Bridge Program Manager	
Florida	Executive Board	
Hawaii	Project Management Staff with Bridge Section recommendations.	
Kansas	Priority & Optimization for funding is statewide	
Maine	Executive Office/Bridge Management Engineer, Assistant Bridge Maintenance Engineer, and Bridge Program (Design) Engineer	
Michigan	Combined bridge operations and Regions	
Minnesota	Districts	
New Mexico	Upper Management	
New York	Region Offices	
Ohio	Major bridge projects are primarily funded at the Central office level	
Oklahoma	CEO	
Oregon	State Bridge Engineer	
Tennessee	Department Administration	
Texas	Texas Transportation Commission	
Virginia	Commonwealth Transportation Board (CTB)	
Quebec	Deputy Minister	

State or Province	Question 30: Organizational Unit(s) That Determine(s) the Major Bridge Projects to be Funded?
Alberta	Division Executive Committee with input from representatives from the Programming Section
Newfoundland and Labrador	Chief Bridge Engineer, Director of Highway Design and Construction, Assistant Deputy Minister, Deputy Minister and Minister of the Dept. of Transportation and Work
Manitoba	Combination of Bridge Branch, Regional, and political requirements.

TABLE D9

State or Province	Question 31: Organizational Unit(s) That Select(s) State-Owned Bridges to Receive Some Treatment in a Given Year?
Alaska	HQ Planning and Regions—Using the STIP Process
Arizona	State Bridge Engineer
Arkansas	District Engineers Programs and Contracts Engineer
California	District Office
Florida	District Bridge Maintenance Office
Hawaii	Project Management Staff with Bridge Section Recommendation
Kansas	Priority & Optimization for funding is Statewide is Statewide Replacements. Maintenance Repair & Rehabilitation determined by State Bridge Office & Construction & Maintenance
Maine	Bridge Management Engineer, Assistant Bridge Maintenance Engineer, and Bridge Program (Design) Engineer
Michigan	Combined bridge operations and Regions
Minnesota	Jointly: Districts, Bridge
New Mexico	Districts
New York	Region Offices
Ohio	Decisions are generally made at the District Level
Oklahoma	Field Division
Oregon	State Bridge Engineer
Tennessee	Repair-Unit Level Replacement—Department and Division with FHWA concurrence

State or Province	Question 31: Organizational Unit(s) That Select(s) State-Owned Bridges to Receive Some Treatment in a Given Year?
Texas	Jointly—District/Bridge Division/Transportation Planning & Programming Division
Virginia	For maintenance actions-the districts decide; for improvement actions, rehabilitation and replacement actions, the districts and bridge division
Quebec	Assistant Deputy Minister (ADM)
Alberta	Bridge Managers
Newfoundland and Labrador	Chief Bridge Engineer, Director of Highway Design and Construction, Assistant Deputy Minister, Deputy Minister and Minister of the Dept. of Transportation and Work
Manitoba	Generally Bridge Branch requirements

TABLE D10

State or Province	Question 32: Organizational Unit(s) That Select(s) Local Bridges Outside Metropolitan Area to Receive Funding?
Alaska	STIP Process
Arizona	Local Government Section appropriations procedure.
Arkansas	County Judges State Aid Engineer
California	Local Agencies (cities and counties)
Florida	Work Program Office from those nominated by the districts with the consent of the local owner.
Hawaii	Planning Branch
Kansas	Local system bridges are not included in the DOT formula or selection process, this is a local funding issue only. Local authorities submit candidates through Bureau of Local Projects for selection.
Maine	Bridge Management Engineer, Assistant Bridge Maintenance Engineer, and Bridge Program (Design) Engineer.
Michigan	Local bridge working under local agency bridge program process
Minnesota	Jointly: State Aid Division and local agencies
New Mexico	Regional Planning Organizations
New York	Region Offices, Local Government

State or Province	Question 32: Organizational Unit(s) That Select(s) Local Bridges Outside Metropolitan Area to Receive Funding?
Ohio	ODOT provides funds for county bridges. We contract with the County Engineers Association of Ohio (CEAO) to act as a program Manger, which includes making funding decisions. We use a criteria-driven selection process
Oklahoma	Local government
Oregon	Statewide Local Bridge Selection Committee
Tennessee	Repair—Local Government; Replacement—Department with concurrence of local Government and FHWA
Texas	Jointly—Local Governments/District/Bridge Division/Texas Transportation Commission
Virginia	For maintenance actions—the districts decide; for improvement actions, rehabilitations and replacement action—local government, districts, and bridge division.
Quebec	Regional Directors
Alberta	Bridge Managers
Newfoundland and Labrador	Chief Bridge Engineer, Director of Highway Design and Construction, Assistant Deputy Minister, Deputy Minister and Minister of the Dept. of Transportation and Work

TABLE D11

State or Province	Question 33: Organizational Unit(s) That Select(s) Bridges in Metropolitan Areas to Receive Funding and Be Included in the Transportation Improvement Program (TIP)?
Alaska	Unknown
Arizona	Regional Transportation System (RTS) appropriation committee
Arkansas	Metropolitan Planning Organizations/Programs and Contracts Engineer
California	Metropolitan Transportation Improvement Program. District offices.
Florida	Work Program Office from those nominated by the districts with the consent of the local owner.
Hawaii	Planning Branches with input from Project Management Staff & Bridge Design Section
Kansas	Priority & Optimization for funding is statewide or Local Authorities through Bureau of Local projects both work with MPO

State or Province	Question 33: Organizational Unit(s) That Select(s) Bridges in Metropolitan Areas to Receive Funding and Be Included in the Transportation Improvement Program (TIP)?
Maine	Bridge Management Engineer, Assistant Bridge Maintenance Engineer, and Bridge Program (Design) Engineer
Michigan	Local bridge working under local agency bridge program process
Minnesota	Jointly: Mn/DOT Metro District and the Metropolitan Transportation Planning Agency
New Mexico	Upper Management, Districts & Regional Planning Organizations
New York	Region offices
Ohio	ODOT maintains a Municipal Bridge Program in which any municipality can apply to our office for funding for bridges that meet the Federal definition. We use a criteria-driven selection process. ODOT allocates funds to Metropolitan Planning Organizations (MPOs) who make their own funding decisions.
Oklahoma	State budget by field division. City budget by MPO
Oregon	Statewide Local Bridge Selection Committee
Tennessee	Repair—Local Government Replacement—Department with concurrence of local government and FHWA
Texas	Jointly—Districts/Metropolitan Planning Organizations/Bridge Division
Virginia	For maintenance actions—the districts decide; For improvement actions, Rehabilitation and replacement actions—local government, districts, and bridge division
Alberta	Divisional Executive Committee based on recommendations of Bridge Manager
Newfoundland and Labrador	Chief Bridge Engineer, Director of Highway Design and Construction, Assistant Deputy Minister, Deputy Minister and Minister of the Department of Transportation and Work

TABLE D12

Questions 34–38: **Use of BMS in Generating Following Performance Measure(s)?**	**Based Primarily on BMS** **R: 1**	**BMS Data Plus Additional Processing** **R: 2**	**Seldom or Never Used** **R: 3**
Calculates a measure of the current condition of each bridge (e.g., condition rating, sufficiency rating, health index)	18 (75%)	5 (20%)	1 (4%)
Identifies current condition of each bridge on the network and key sub-networks such as districts or Interstate bridges (composite index, health index)	13 (54%)	6 (25%)	5 (20%)
Projects into the future the condition of each bridge in the inventory	9 (37%)	6 (25%)	9 (37%)
Calculates a composite index of the projected network level condition of all bridges in the Stat (e.g., network-level health index)	8 (33%)	7 (29%)	9 (37%)
Determines the depreciated value of the bridge inventory or uses the modified procedure for public reporting under the Governmental Accounting Standards Board Statement 34	4 (17%)	9 (39%)	10 (43%)

TABLE D13

Questions 39–44: **Use of BMS in Estimating the Following Bridge Needs?**	**Based Primarily on BMS** **R: 1**	**BMS Data Plus Additional Processing** **R: 2**	**Seldom or Never Used** **R: 3**
Identifies bridge needs that can be used as input to the statewide budgeting and programming process by using engineering judgment and basic bridge data	13 (54%)	9 (37%)	2 (8%)
Identifies major project needs	7 (29%)	14 (58%)	3 (12%)
Uses project level analysis to identify options (candidates) as input to the network level analysis	4 (16%)	9 (37%)	11 (45%)
Determines network level needs unconstrained by budgets by using benefit-cost analysis or other similar techniques	6 (25%)	8 (33%)	10 (41%)
Determines multi-year, network level bridge needs subject to annual budget constraints by using benefit-cost analysis, optimization, or other procedures	3 (12%)	10 (41%)	11 (45%)

Produces reports useful for building a recommended bridge budget for each organizational unit responsible for some portion of the bridge inventory	7 (29%)	11 (45%)	6 (25%)

TABLE D14

Questions 45–50: **Use of BMS in Resource Allocation and Tradeoff Analyses?**	**Based Primarily on BMS** **R: 1**	**BMS Data Plus Additional Processing** **R: 2**	**Seldom or Never Used** **R: 3**
Has a network level dashboard for communicating the effects of different budget levels on a various factors of concern to bridge managers	0 (0%)	6 (31%)	13 (68%)
Has a project level dashboard for communicating the effects of deferring bridge work on the condition of bridge elements, life-cycle costs, etc.	3 (12%)	8 (33%)	13 (54%)
Provides network level analysis to help allocate funds for all agency bridges	8 (33%)	8 (33%)	8 (33%)
Provides network-level analysis to help allocate funds among organizational units within your agency	1 (4%)	12 (57%)	8 (38%)
Provides network analysis to help allocate bridge funds by functional class, corridors or other sub-networks of the highway system	4 (16%)	12 (57%)	8 (38%)
Produces reports useful for allocating the bridge portion of the budget approved by the governor and legislature to each organizational unit responsible for some portion of the bridge inventory	5 (20%)	11 (45%)	8 (38%)

TABLE D15

Questions 51, 52–59: **If Your BMS Has the Capabilities to Help Support Performance Measurement, Needs Analysis, Resource Allocation, and Tradeoff Analyses, Do the CEO and Upper Management Use BMS Information for Planning, Programming, and Budgeting?**	**Number of Respondents**
YES	12
NO	10
If Your Answer Above Was NO: What Are Reasons Why the BMS Is Not Used to Help the CEO and Top Management Team Do Planning, Programming, and Budgeting?	**Number of Respondents**

The recommended actions from the bridge management system are too different from the actions our bridge inspectors and engineers recommend	2
The bridge management system gives too much emphasis to economic considerations relative to other considerations, especially conditions we observe in the field	1
The economic assumptions are not accurate	2
The bridge management system is perceived by too many managers as a black box—it uses analytic procedures we really do not understand	1
Management's capabilities include the ability to assess current and future needs. A bridge management system detracts from the bridge manager's prerogatives	1
We have found it difficult to implement a bridge management system, train personnel, and obtain buy-in from managers that must depend upon it	2
We have has problems with reliability (software, data, an/or analysis)	1

Budget-Related Survey Questions

TABLE D16

Question 1: Importance of the Following Factors in Budgeting?	R: 1	R: 2	R: 3	R: 4	R: 5
The budget level for the previous budget cycle	0 (0%)	4 (22%)	7 (38%)	6 (33%)	1 (5%)
The budget level for the previous fiscal year	1 (5%)	3 (16%)	5 (27%)	5 (27%)	4 (22%)
Giving fist priority to bridge preservation projects	2 (11%)	2 (11%)	5 (27%)	7 (38%)	2 (11%)
Giving first priority to capital expenditures for bridge replacement and major projects	1 (5%)	0 (0%)	6 (33%)	8 (44%)	3 (16%)
Giving first priority to major bridge projects with the balance of bridge funds going to the rest of the bridge program	3 (16%)	6 (33%)	4 (22%)	4 (22%)	1 (5%)
The political jurisdictions in which bridge replacement work and major bridge projects occur	7 (35%)	5 (25%)	6 (30%)	0 (0%)	2 (10%)
Bridge needs determined at the district and/or lower levels of the organization, possibly with input from local government or Metropolitan Planning Organization	3 (14%)	1 (4%)	4 (19%)	7 (33%)	6 (28%)
Documented bridge needs, tempered by engineering judgment, based on results of the computerized bridge management system	2 (10%)	1 (5%)	2 (10%)	5 (26%)	9 (47%)
Quantitative analysis of choices and tradeoffs from the bridge management system regarding the allocation of funds among bridge maintenance, rehabilitation and replacement work	3 (16%)	5 (27%)	4 (22%)	4 (22%)	2 (11%)
Quantitative analysis of choices and tradeoff from one or more computerized management systems regarding the allocation of funds between the bridge program and other programs such as pavements and operations	3 (17%)	6 (35%)	5 (29%)	1 (5%)	2 (11%)
Subjective analysis of top managers and professionals concerning the choices and tradeoffs within the bridge program and between the bridge program and other programs such as pavements	1 (4%)	0 (0%)	6 (28%)	10 (47%)	4 (19%)
An analysis of bridge work that should be performed by in-house staff versus contractors	9 (47%)	4 (21%)	2 (10%)	3 (15%)	1 (5%)

TABLE D17

Question 2: **BMS Features and Capabilities Used by DOTs?**	**Yes**	**No**
Generate summary information about the inventory, condition, structural deficiency, functional obsolescence at the network and district level	14 (63%)	8 (36%)
Identify safety or other serious problems such as scour, presence of fracture critical elements or seismic vulnerability	9 (40%)	13 (59%)
Produce information that can be compared with performance targets set by management	10 (45%)	12 (54%)
Generate alternative scenarios subject to budget constraints for planning, programming, budgeting and resource allocation	5 (22%)	17 (77%)
Explore choices and tradeoffs for allocation of resources within the bridge program (maintenance, rehabilitation, replacement)	3 (13%)	19 (86%)
Calculate bridge life-cycle costs and/or minimum component life-cycle costs	3 (13%)	19 (86%)
Calculate avoidable road user-costs (accidents, travel time, vehicle operating costs) as a function of alternative budget levels	2 (9%)	20 (90%)
Provide information to satisfy public reporting requirements under the Governmental Accounting Standards Board	9 (40%)	13 (59%)
Provide information helpful in setting parameters to effectively delegate to lower level managers the responsibility for selecting what work to do on specific bridges on the network	7 (31%)	15 (68%)
Past and planned bridge work by organizational unit or geographical area	7 (31%)	15 (68%)

TABLE D18

State	Question 3: BMS Features Potentially Useful for Budgeting That Are Not Currently Used?
Arkansas	Yes
California	No
Maine	Yes
Minnesota	Both being able explore choices and tradeoffs and being able to calculate life-cycle costs would be particularly useful in making sound, cost-effective investment decisions. Most useful would be a derivative of alternative scenario generation subject to budget constraints for purposes of planning, programming, and budgeting. Here at Mn/DOT we would like to be able to use our BMS to predict funding levels needed to attain performance targets for structural condition. Just as important would be to have a BMS that produced bridge investments and their timing so that we could maintain our bridges at the lowest life-cycle cost.
New Mexico	Don't believe they would be
New York	Information on parameters that would facilitate delegation to lower level managers the responsibility for selecting what work to do on specific bridges on the network.
Oklahoma	Yes
Tennessee	No
Virginia	All of the unchecked items will be useful.
Newfoundland	I certainly feel that a more complete bridge management program would be a benefit. A system which was able to help evaluate achievement of performance targets, generate alternative scenarios subject to budget constraints, explore choices and tradeoffs, and calculate road user costs, would be beneficial from a budgeting perspective.
Quebec	No

TABLE D19

Question 4: **Organizational Unit(s) Involved in Resource Allocation?**	**Number and Percent of Respondents**
a) Office of the CEO	16 (73%)
b) Budget	10 (45%)
c) Finance	8 (36%)
d) Planning	14 (63%)
e) Programming	1 (4%)
f) Construction	5 (22%)
g) Bridge Construction	7 (31%)
h) Maintenance	9 (40%)
i) Bridge Maintenance	15 (68%)
j) Operations	9 (40%)
k) Computer Services	1 (4%)
l) Office of the District Director, District Engineer or similar district head	14 (63%)
m) District Office of Planning	8 (36%)
n) District Office of Programming/Budgeting	7 (31%)
o) District Office of Construction	3 (13%)
p) District Office of Maintenance	8 (36%)
q) Areas	1 (4%)
r) Shops/Garages	0 (0%)
s) Other	4 (18%)

Planning-Related Survey Question

TABLE D20

Question 1: Use of the Following BMS Features to Support the Planning Process?	Number and Percent of Respondents
a) Provide summary reports on the inventory and condition of bridges for the state and districts	14 (82%)
b) Provide statewide and district reports on the number of bridges that structurally deficient and functionally obsolete	12 (70%)
c) Identify or flag safety or other serious problems such as scour, presence of fracture critical elements or seismic vulnerability	11 (64%)
d) Provide an overall network and district level condition or health index	10 (58%)
e) Provide information that can be compared with performance targets set by management	10 (58%)
f) Explore alternative scenarios subject to budget constraints for planning, programming, budgeting and resource allocation	6 (35%)
g) Identify choices and tradeoffs for allocation of resources within the bridge program (replacement, rehabilitation, maintenance)	6 (35%)
h) Identify life-cycle costs of bridges	1 (5%)
i) Identify avoidable road user-costs as a function of alternative budget levels	2 (11%)
j) Provide information to satisfy public reporting Governmental Accounting Standards Board	9 (52%)
k) Provide the CEO and other top managers recommended parameters to effectively delegate to lower level managers the responsibility for selecting what work to do on specific bridges	7 (41%)
l) Identify past and planned bridge work by organizational unit or geographic area	10 (58%)
m) Identify past and planned bridge work by political jurisdiction	5 (29%)

APPENDIX E

SURVEY RESPONSES: FACTORS AFFECTING BUDGETING

The budgeting component of the study survey elicited agency responses on the importance of several factors to budget development. These factors included the following:

- **Importance of previous budgets on the current budgeting cycle**: the budget in the previous cycle, and the budget in the previous fiscal year.

- **Importance of "top-priority" designations to the budgeting process**: first priority given to preservation, first priority to bridge replacement and major bridge capital projects, and first priority to major bridge projects with the balance to the remainder of the bridge program.

- **Importance to budgeting of methods of determining needs or identifying projects**: needs determined by BMS-assisted estimates tempered by engineering judgment; needs determined by districts, MPOs, or others through a bottom-up process; and needs analyzed in terms of the political jurisdictions in which major bridge projects or replacement projects occur.

- **Importance of different tradeoff analyses to budgeting**: tradeoffs based on subjective executive and managerial judgments; tradeoffs analyzed across bridge maintenance, rehabilitation, and replacement needs; and tradeoffs between the bridge program and other transportation programs.

- **Importance of project delivery method to budgeting**: performance of bridge work by in-house forces versus contract forces.

Respondents rated the importance of each factor on a scale of 1 (unimportant) to 5 (very important). Results are presented in a series of histograms that allow for easy comparison. For each budgeting factor, its histogram shows the numbers of responses by degree of importance, 1 through 5. The histograms are drawn compactly so several can be viewed at a time; the horizontal and vertical scales in each histogram are identical so they can be readily compared to one another "by eye." Up to 21 respondents participated in this survey component; the exact numbers that answered each question varied from 17 to 21, however, which also affects the heights of the histogram bars.

The basic shape of a given histogram enables one to get a quick impression of the overall importance of that budgeting factor as judged collectively by the survey respondents. For example, a histogram skewed to the right (value of 5 on the horizontal scale) indicates consensus on the high importance of that factor to budgeting. A skew to the left (value of 1 on the horizontal scale) reflects agreement that it is unimportant. A distribution with a central peak (i.e., many ratings at or around 3 on the horizontal scale) indicates relative indifference to that factor in budgeting. A uniform distribution (equal numbers of responses for each rating 1 through 5) indicates the absence of consensus on the importance of that factor—for every agency that claims the factor to be significant, there is another indicating its lack of significance. Of course, a given histogram may combine more than one of these simple patterns.

The results of this budgeting survey component reinforce in several ways the findings in chapter three on agency bridge management approaches and organizational roles in bridge decision making. The budgeting results are presented below in a series of figures displaying the histograms for each factor that was evaluated by the survey participants.

Figure E1 compares the factors representing previous budget levels, whether the amount submitted in the prior budgeting cycle or as expended in the last fiscal year. Results likely reflect the degree to which budgeting is based on some prior level plus adjustments such as for inflation or updated revenue projections or splits. Opinions in both examples in Figure E1 are divided, with the previous fiscal year receiving a somewhat greater vote of importance. These varying opinions may be driven by the mix of federal versus state dollars that are funding an agency's bridge program, and how the state dollars are allocated. Federal bridge program dollars are dedicated and the apportionment is known beforehand. State funding depends on variable revenue projections and may be subject to competition with other state programs, although some states report taking bridge funds "off the top" or using set-asides. The inconclusive results displayed in Figure E1 likely reflect differing state situations and practices regarding funding mix and allocation in budgeting.

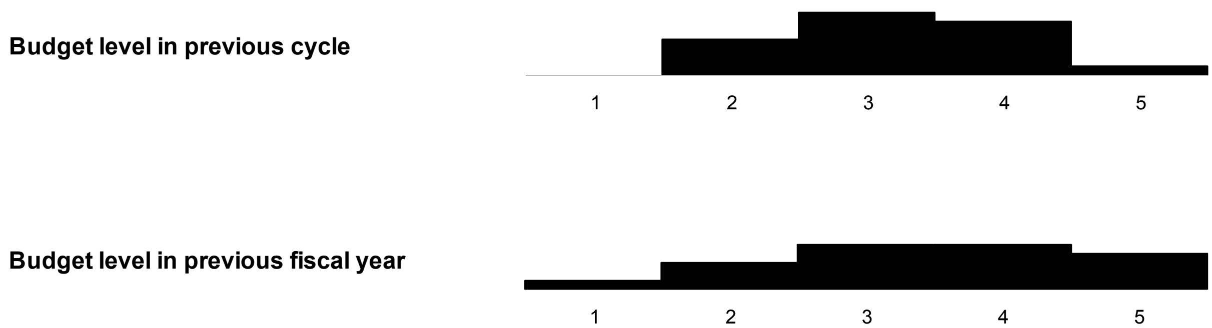

FIGURE E1 Importance of previous budgets on current budgeting cycle.

Figure E2 addresses the influence of different top-priority activities or projects on budgeting. Of the three options shown, replacement projects and major bridge projects were reported to have the strongest influence on budgeting. Bridge preservation as a first priority was judged to be moderately important, although some agencies rated this factor as minimally important. This difference of opinion may be due to varying composition and condition of agencies' bridge inventories. The third option, giving first priority to major bridge projects solely, received comparatively little support as an influence on budgeting, probably because major bridge projects are relatively few. Rather, bridge replacement work tends to drive the application of federal (and matching state) dollars in budgeting, according to the interviews with DOT bridge managers.

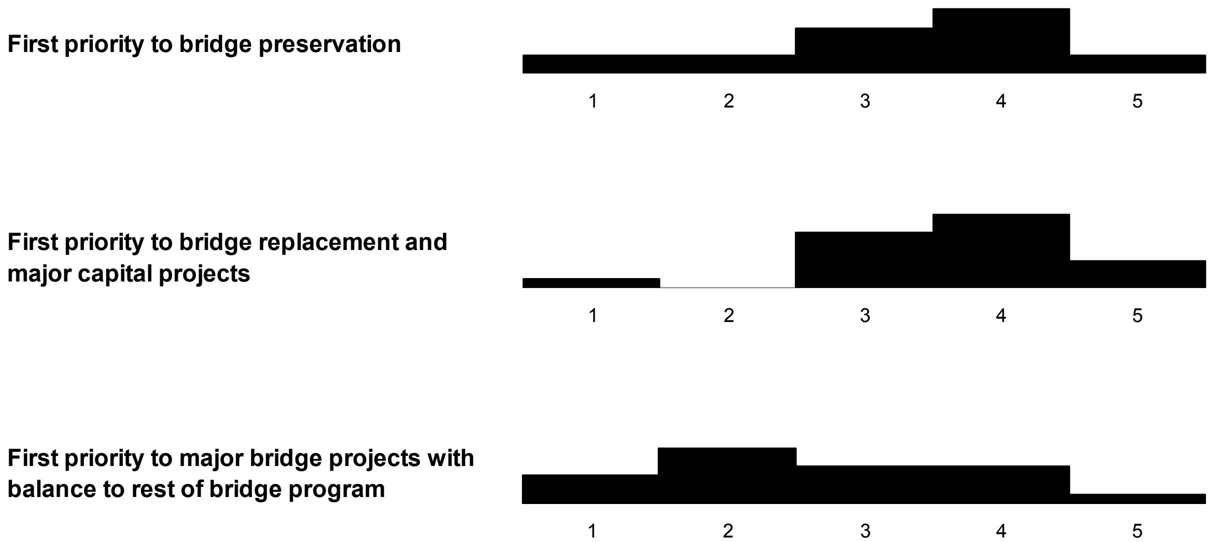

FIGURE E2 Importance of “top-priority” designations to the budgeting process.

The importance of different methods of compiling and expressing bridge needs is illustrated in Figure E3. The use of a BMS combined with professional judgment is unambiguously felt by respondents to be of paramount importance to budgeting. The interviews with bridge managers affirm that both elements of this statement are relevant: an agency’s bridge management system irrespective of its analytic design, condition and performance measures, and decision-support algorithms; and the professional judgments of the agency’s executives and managers, which are applied to evaluate and refine the BMS results. The second graphic in Figure E3 reflects the importance of DOT field offices, regional and metropolitan planning organizations, local governments, and other stakeholders in prioritization and project selection under new planning and programming guidelines initiated in ISTEA. The third graphic in Figure E3 demonstrates the relative unimportance of the jurisdictional distribution of major bridge projects and bridge replacement projects to statewide budgeting. Major projects are relatively few in number and, unless mandated by law, are judged on their individual merits. Bridge replacement is typically driven by NBI and other findings on structural or functional deficiency. Because they are costly, bridge replacements and major projects are often funded using federal bridge program monies, unless other mechanisms such as bonds backed by toll revenues or public-private partnerships are used. In any case, the jurisdictions in which these projects are located are not the main drivers of programming and budgeting.

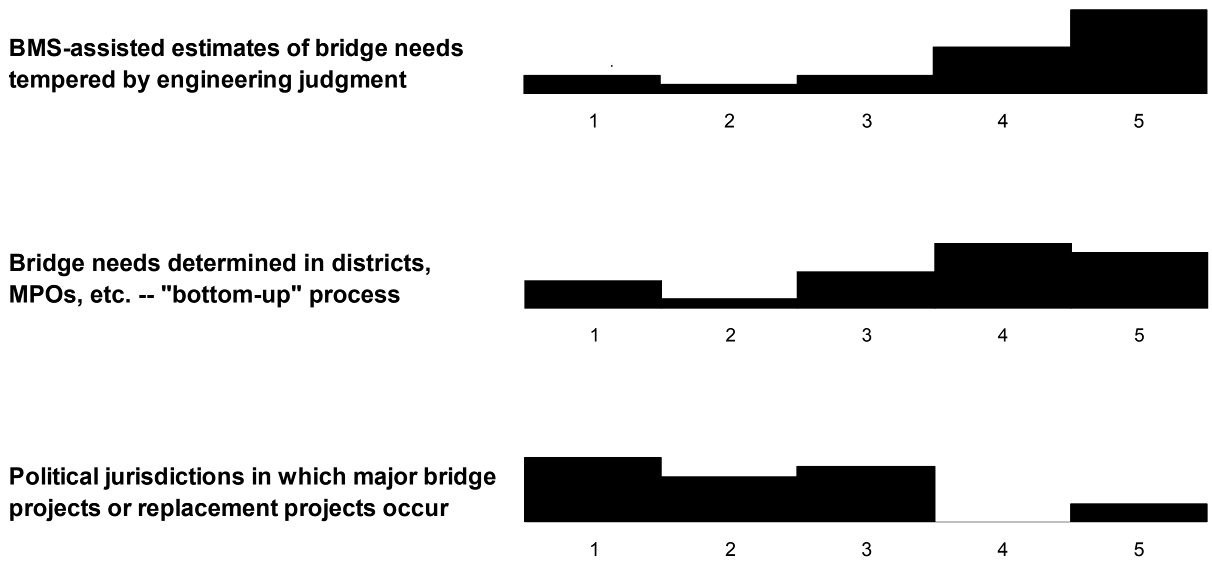

FIGURE E3 Importance to budgeting of methods of determining needs or identifying projects. MPOs = Metropolitan Planning Organizations.

Agencies have different perspectives on tradeoff analyses, and the variability in survey ratings of the importance of these analyses to budgeting reflects this diversity. One point agencies do agree on is the key role of professional judgment in assessing tradeoffs (first graphic in Figure E4), reinforcing the findings in Figure E3 regarding subjective managerial judgments in needs estimates as well. Surveyed opinion on tradeoffs among bridge treatments is very mixed (second graphic, Figure E4), probably due to the variety of programming methods and criteria used among agencies and the different ways in which budget constraints are dealt with. The third aspect of tradeoff analyses in the survey—to evaluate resource allocation between the bridge program and other programs—was not rated highly in importance by the respondents. The reasons very likely are as follows:

- Bridge projects involving replacement, substantial rehabilitation, and major structures typically involve federal bridge program funding, which is a dedicated source and not subject to tradeoffs. Matching state money, which might be subject to tradeoffs, is often (according to interviews) taken off the top or from set-asides. Even if this portion of state funding is theoretically subject to competition and, therefore, tradeoff analysis, many agencies regard a full state match of available federal funding as a high priority in itself.

- This type of program-level tradeoff is high-level, involves several executive and organizational units within a DOT, and may occur early in the resource allocation process. It may therefore be viewed as somewhat removed from the nuts-and-bolts of subsequent budgetary decisions.

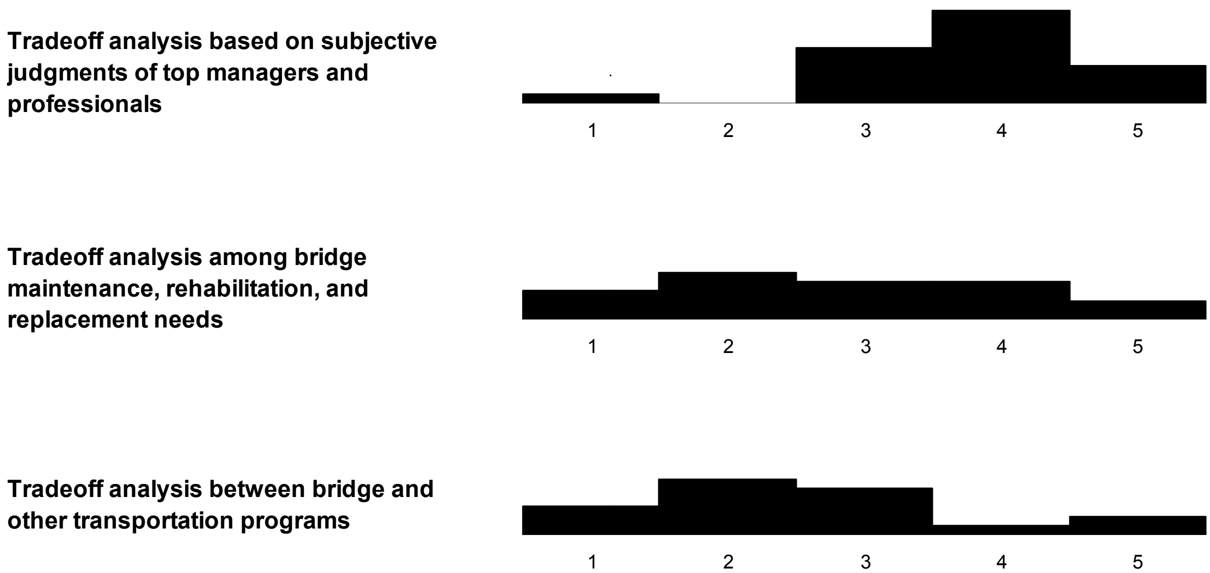

FIGURE E4 Importance of different tradeoff analyses to budgeting.

The final factor that was evaluated by budget survey respondents is the proposed method of bridge project delivery: in-house forces versus contracted forces. Results in Figure E.5 indicate a very strong rejection of the importance of this factor to budget decisions.

FIGURE E5 Importance of project delivery method to budgeting.

A more general way to assess the overall relative importance of these factors to budgeting is to identify those that received the greatest number of responses in categories 4 and 5. The four factors that were judged most important according to these criteria are listed below, with the percentages of total responses they each received:

- BMS-assisted estimates of bridge needs tempered by engineering judgment (67%).
- Tradeoff analyses based on subjective judgments of top managers and professionals (67%).
- Bridge needs determined in districts, MPOs, etc.—i.e., a “bottom-up” process involving other stakeholders (62%).
- First priority to bridge replacement and major capital projects (52%).

Other factors received votes from less than a majority of the respondents.

Abbreviations used without definition in TRB Publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETY-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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