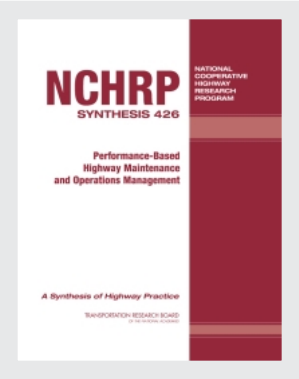

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Performance-Based Highway Maintenance and Operations Management

A Synthesis of Highway Practice

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The synthesis of national practice in chapter two and development of the four case examples in chapter three would not have been possible without the cooperation of knowledgeable state department of transportation (DOT0 personnel. The author is indebted to those agencies listed in Appendix B that participated in the survey. Their responses to the questionnaire reflected a degree of time and thought that signaled their understanding of the importance of this synthesis topic. Responses to open-ended questions provided additional insight into state DOT practice, and were particularly appreciated. Maintenance and operations managers in the four case example states—Florida, Mississippi, Washington, and Wisconsin—took the additional time to define and describe their proposed case, send documentation of relevant information, participate in follow-up telephone interviews, and review drafts of their respective cases. The author expresses his sincere appreciation and gratitude to the following managers who contributed so positively to the case examples: Tim Lattner, Director, Office of Maintenance, and Kirk Hutchison, Performance Management Manager, Office of Maintenance, Florida DOT; John Vance, State Maintenance Engineer (now retired), and Ken Hauser, Maintenance Management Coordinator, Mississippi DOT; Rico Baroga, Maintenance Accountability Process Manager, Washington State DOT; and Scott Bush, Compass Program Manager, Wisconsin DOT. The 42-06 Topic Panel made several helpful and meaningful suggestions to the initial draft of this report, which are reflected in this update and have strengthened the research product. The author thanks the Topic Panel for their careful review and insights. Finally, the author recognizes with sincere gratitude and appreciation the contributions of Ms. Jo Allen Gause, the NCHRP Senior Program Officer for this study, who throughout this project has continually provided helpful guidance, support, and encouragement.

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 Jo Allen Gause
Senior Program Officer
Transportation Research Board

This synthesis examines current performance-based management practices that are applied by state departments of transportation (DOTs) in highway maintenance and operations (M&O). Past studies have focused on the elements that make up a performance-based M&O approach, such as condition ratings, levels of service, performance measures, and threshold values. This study focuses on how state DOTs actually use performance-based measures to manage their highway programs.

Information used in this study was acquired through a review of the literature, a survey of state DOTs, and follow-up interviews with four state DOTs to develop case examples of highway M&O performance management.

Michael J. Markow, consultant, Teaticket, Massachusetts, 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.

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PERFORMANCE-BASED HIGHWAY MAINTENANCE AND OPERATIONS MANAGEMENT

SUMMARY

Interest in performance-based maintenance and operations (M&O) management is driven by both a growing recognition of the importance of highway M&O and by the increased focus on performance management. Although past studies have focused on the elements or components that make up a performance-based M&O approach—for example, condition ratings, levels of service (LOS), performance measures, and threshold values—comparatively little work has been reported on how managers actually use performance-based methods in understanding maintenance policy and investment options, reaching decisions, and accounting for the consequences of those decisions. The application of performance-based management to highway M&O is the subject of this synthesis.

Performance-based maintenance management has been influenced throughout the past decade by maintenance quality assurance (MQA) concepts. Although MQA has provided an overarching framework for a number of M&O management implementations by state departments of transportation (DOTs), this synthesis report has adopted the broader, more current concepts, methods, and nomenclature of performance-based management as an organizing principle. This shift is an evolutionary one, not a departure from the ideas and methods of MQA. Performance-based management is a more current usage that incorporates the elements and procedures recommended by MQA, but strengthens and re-emphasizes some aspects originally proposed in MQA and stresses additional capabilities and perspectives as well. A performance-based approach provides a more recognizable fit to a variety of broad-based performance-related initiatives by state, federal, and local governments. It anticipates performance-oriented provisions that may be included in the future reauthorization of the federal surface transportation legislation. Beyond providing consistency with these other developments, performance-based highway M&O management gives more explicit recognition and emphasis to several capabilities and perspectives that state DOTs are applying; for example, performance accountability reporting, inclusion of mobility-improvement goals more operations-related features and activities, and more comprehensive accounting of highway performance and cost.

The study approach has emphasized direct communication with state DOTs in terms of how they view and apply performance-based methods. Two approaches were employed to gather information on current practices; a survey of the DOTs in the 50 states and the District of Columbia, and a set of four case examples illustrating different uses of performance management, backed by source documents provided by each agency. Reviews of literature, interviews, and e-mail exchanges supplemented the information obtained from the state DOTs. The survey questionnaire was distributed by NCHRP with the cooperation of AASHTO, which provided the distribution list based on membership in its Subcommittee on Maintenance. Forty-one responses were received, a response rate exceeding 80%.

Seventy-six percent of the 41 respondents reported that their agency uses a performance-based approach, although the details and maturity of states' implementations varied. Performance-based management is applied to a range of highway features and for various purposes. Nonetheless, despite this variability and diversity in management practices and elements, the survey results

indicated general agreement on key aspects of management technique and supporting activities. For example:

- Performance measures and LOS thresholds currently tend to be defined on a relatively uniform statewide basis, with some variability allowed for such factors as differences in weather, traffic volume, and degree of urbanization.
- The majority of respondents identified a cluster of factors that are important in setting LOS targets: the projected M&O budget, commitments to an agency-established goal or objective, and analytic estimates of LOS values that can realistically be attained and sustained.
- State DOTs tend to look to several management tasks in common to be supported by performance-based methods including tracking condition, performance, and quality; M&O prioritization; budget development and justification; development of needs-based management estimates; resource allocation among field offices; and an understanding of the relationship between LOS and cost.
- Other examples are discussed in chapter two, which describes the survey results.

Four case examples reinforced and built upon the findings of the survey to illustrate how individual performance-based elements come together and are applied by agencies to different management needs and tasks. Two cases dealt with processes and procedures needed to build and sustain the performance-based approach itself, and two dealt with application of the approach to M&O program management. Mississippi DOT (MDOT) and Wisconsin DOT (WisDOT) were the process-oriented cases; Florida DOT (FDOT) and Washington State DOT (WSDOT) illustrated the program-oriented tasks.

The MDOT case illustrated the process used to implement a new performance-based approach accompanied by introduction of a new maintenance management system, AMMO (Accountability in MDOT Maintenance Operations). MDOT employed consultants and vendors to guide the two prongs of its new performance-based approach: identifying and instituting new business processes; and customizing, developing, testing, and implementing new AMMO software. Pilot testing was useful in merging these two efforts correctly, verifying AMMO accuracy, familiarizing MDOT personnel with the system, and identifying training needs. This approach to implementation represented a process that was thought out ahead of time to ensure that all pieces fit together properly.

WisDOT, FDOT, and WSDOT all represented agencies with mature LOS-based management systems for M&O.

- The WisDOT case focused on processes and procedures undertaken to keep its performance-based M&O system, Compass, current and prepared to address program-management tasks. The steps reviewed included field rating procedures, assigning priorities to highway features, quantifying LOS thresholds and grading curves, setting and communicating targets, and so forth. In part because WisDOT and its five regions deal with 72 counties who are the performing organizations for state highway maintenance in Wisconsin, WisDOT places a premium on good communication, coordination, effective data to support decisions, and shared responsibilities between the state and county participants.
- The FDOT case looked at how maintenance activities are prioritized throughout the year to ensure that the accepted statewide maintenance standard is met on all state highways. FDOT applies its Maintenance Rating Program to determine condition-based scores for each characteristic of its highway elements throughout the year. The department combines this objective analytic basis for determining the status of planned versus actual condition with a managerial check and a quality assurance review, which seeks to ensure that funding is actually redirected to those activities that will produce positive results regarding mandated statewide targets in the following period.
- The WSDOT case illustrated the application of its Maintenance Accountability Process (MAP) data to support its meeting the requirements of WSDOT's Phase II stormwater

permit. MAP data on service levels for affected drainage features have been incorporated into the permit's language to discuss the performance and maintenance level-of-effort implications of the permit requirements, to indicate how compliance with the permit would be monitored through MAP inspections and reports, and to establish the basis for a request to the legislature for additional funding to comply with permit requirements.

The synthesis also revealed barriers to more widespread use of performance-based M&O management. The primary reasons cited for non-use of performance-based methods by ten agencies were the following, in order of decreasing numbers of responses:

- The agency was evolving in its management approach, but no decisions had been made yet.
- The agency does not have the resources to support a performance-based approach.
- The agency's current management systems do not support a performance-based approach.
- The state government has not yet adopted a performance-based philosophy.

One other respondent noted that his or her agency was satisfied with their current management approach and did not see a need to consider moving to performance-based methods.

Among agencies that currently do employ performance-based methods, a common concern of agency personnel was that uncertainty in funding could impede the effective use of performance-based methods. Two agencies also mentioned limitations of maintenance management systems in dealing with insufficient or unpredictable levels of funding, and loss of specific analytic capabilities caused by upgrades to new products, which could constrain the use of formerly used performance-based computations.

The synthesis findings led to research recommendations in these areas:

- **Develop comparative descriptions of state DOT performance-based highway M&O management.** Two related projects (or a single project combining the two efforts) are proposed to extend the findings of this synthesis: one to research, identify, and synthesize more broadly and in greater detail how agencies conduct M&O management through the performance-based elements that have been described in previous research; and second, to identify success factors in effectively applying performance-based management of highway M&O.
- **Study the relationship between M&O LOS and cost.** The analytic relationship between LOS and cost is beset by a lack of agreement on practice and use among state DOTs. This research would develop a fuller understanding of what models are currently used, and what feasible approaches exist that agencies could employ in strengthening their own abilities to relate LOS to cost.
- **Develop paths to implementation.** At least ten agencies that do not now use performance-based methods for highway M&O could benefit from lessons learned in moving toward this type of management. Other candidates could include agencies that wish to upgrade their systems or to focus more directly on M&O assets and activities. Two separate research projects are proposed: The first focuses on the formulation of business decision-making processes needed to support performance-based management, as well as development and implementation of a complementary maintenance management system. The second project looks at the cost-effectiveness of performance-based M&O management.

CHAPTER ONE

INTRODUCTION

BACKGROUND

There has been a strong interest in what has become known as maintenance quality assurance, or MQA, over the past decade. This interest is driven by both the growing recognition of the importance of highway maintenance in preserving a valuable public works asset, and by the increased focus on performance management and accountability as an effective way of managing and investing in public works. *NCHRP Report 422: Maintenance QA Program Implementation Manual* defines MQA as:

> . . . the planned and systematic actions needed to provide adequate confidence that highway facilities meet specified requirements. Such requirements are usually defined by the highway agency but are intended to reflect the needs and expectations of the [road] user. *Source:* Stivers et al. (1999, p. 9).

As a practical matter, MQA deals with elements such as performance measures and levels of service (LOS) as expressions of performance requirements and how well a highway is meeting these requirements. LOS criteria are "clear and measurable definitions concerning the points at which deficiencies cause maintenance features or maintenance characteristics no longer to meet expectations. LOS criteria are usually expressed in terms of amount and extent of deterioration . . ." (Stivers et al. 1999, p. 10). Experience has shown that when applied correctly and effectively, MQA can assist in a number of maintenance-related management tasks including tracking facility condition and performance, budget analyses related to facility performance, needs-based estimates, resource allocation, and prioritization of maintenance needs, actions, and investments.

Much of the research related to MQA to date has focused on the elements and tools needed (e.g., the set of performance measures that best represents maintained features or maintenance services), and the analytic relationships needed to make MQA work (i.e., the linkage between facility or feature performance and the cost of maintaining it in an operable state). Less attention has been paid to how managers actually use MQA concepts, methods, and tools in their day-to-day procedures and decisions. Furthermore, since the publication of *NCHRP Report 422,* the somewhat broader and more widely applicable framework provided by performance-based management (PBM, also referred to as performance management) has emerged to begin gradually superseding the concept of MQA as an organizing principle, as will be explained shortly.

Both MQA and PBM approaches allow for elements and procedures that have become familiar to highway maintenance managers; for example, performance measures, LOS, the use of field data collection to quantify measures and service levels, and LOS targets. For purposes of this report, the terminology of PBM will be used as the primary nomenclature; MQA will be used only when referring to the historical development of highway maintenance management practice or to state DOT practices that have been specifically labeled as MQA.

EMERGENCE OF PERFORMANCE-BASED MANAGEMENT

Incorporating Maintenance Quality Assurance

Highway maintenance management that applies measures of condition or performance, or of LOS, will be referred to in this synthesis as "performance-based management (PBM)" or a "performance-based" approach. PBM incorporates the elements and procedures inherent in MQA within two phases that an agency might consider based on the recommendations of *NCHRP Report 422.*

- **Phase I—Program Development.** This phase concerns the design and establishment of an MQA program. Focusing solely on the tasks related to highway maintenance management, this phase involves the following one-time tasks:
  - Identification of the maintenance activities and roadway features and characteristics to be included.
  - Development of a sampling process for the highway network based on network segmentation.
  - Development of proposed LOS data collection, analysis, and reporting procedures.
  - Identification of customer expectations for the highway maintenance program.
  - Determination of LOS rating criteria (e.g., threshold values for passing or failing and range or interval values defining service levels), and weighting factors needed for various computations (i.e., maintenance priorities or service levels that represent several condition measures that will be combined).
  - Development and documentation of an LOS rating system.
  - Development of a statement of maintenance priorities.
- **Phase II—Program Implementation.** This phase concerns the application of the designed MQA program to

actual maintenance management. Again focusing solely on tasks related to highway maintenance management (and for the time being passing over tasks having to do with pilot studies, budget and funding administration, training, etc.), this phase involves the following annual or cyclic events:

- Data collection through LOS inspections, processing of data, and LOS reporting to yield information on current highway system conditions and service levels of maintained features.
- Quality assurance (QA) and quality control (QC) checks on the practices of ratings teams to promote uniformity of data collection procedures and LOS determinations.
- Development of current unit cost data for each maintenance activity, and computation of the total funding needs for the activity.
- Updates of service-level targets and estimates of the cost to achieve these targets.
- Application of maintenance activity priorities and consideration of data from customer satisfaction surveys (once the program has been implemented and in use).
- Use of the program for management to assess the costs of meeting LOS targets, evaluate costs against available budget, propose alternate scenarios for LOS targets, conduct sensitivity analyses, develop proposed budgets, organize of data to justify maintenance program recommendations, development of develop maintenance program guidance for field offices, and so forth.

Performance-Based Management

These recommendations in *NCHRP Report 422* anticipated many features and procedures that are still in use or are now being implemented in selected performance-based methods reviewed in this synthesis. However, PBM is a more current usage that incorporates the elements and procedures envisioned in MQA, but recognizes additional capabilities as well (discussed later). A performance-based approach provides a more recognizable fit to the considerable work now underway at the federal, national, and state levels regarding performance measurement and accountability. A number of reports and guidelines involving applications of performance-based approaches to highway activities and decision making have been produced by AASHTO, NCHRP, U.S. General Accountability Office, U.S.DOT/FHWA, and other organizations. A performance-based approach anticipates provisions in the future federal reauthorization of the surface transportation act: Both House and Senate proposals for this bill currently include mention of accountability for performance (Mica et al. July 7, 2011; "Senator Boxer and Senator Inhofe . . ." July 19, 2011). Beyond consistency with these other developments, a performance-based approach to highway maintenance and operations (M&O) gives more explicit recognition and emphasis to the following capabilities:

- **Management accountability reporting.** Accountability reporting is a key part of governmental applications of PBM. Accountability reports typically involve a comparison of proposed target service levels to actual LOS values attained. They indicate not only the resulting maintained condition of the highway as compared with forecasts, but also a measure of the quality of stewardship exercised by the state DOT in the management of its M&O program and its results. As an example, Washington State Department of Transportation (WSDOT) includes an annual summary of maintenance program accomplishments, service levels, and trends within *The Gray Notebook,* its quarterly report of departmental performance and accountability.
- **Customer satisfaction.** The MQA process described earlier in this section explicitly considered customer input in both the design and the implementation phases. Subsequent research has observed that since 2000 (the date of a maintenance performance-measure workshop in Scottsdale, and one year following publication of *NCHRP Report 422*), the measurement of customer satisfaction had evolved independently of MQA to the point that agencies began to consider customer satisfaction as "related to but separate from their MQA programs" (*Maintenance Quality Assurance—Synthesis of Measures* Aug. 2005, p. 33). The research also noted that state DOT documents in the MQA Document Library contained very little on customer satisfaction. Performance-based approaches restore the importance of customer outreach as part of the consideration of factors used to set M&O priorities, threshold values, and grading curves for LOS definition.
- **Comprehensive processes for updating and renewing performance-based components.** Current performance-based approaches treat updates and renewals comprehensively, encompassing reviews of unit costs, LOS targets, maintenance priorities, condition and performance measures, and thresholds/ranges of values defining LOS grading curves, among other items.
- **Expanded approaches for incorporating maintenance priority.** The MQA guidelines envisioned maintenance priority as a weighted-value calculation. Although some performance-based approaches continue to use this method, others apply different methods, such as the contribution category matrix used by the Wisconsin DOT (WisDOT) in the chapter three case example, with resulting adjustments in LOS grading curves to reflect priority.
- **Inclusion of mobility and operations-related features and activities.** The MQA examples included many features and activities with performance measures expressed in terms of physical asset condition. Policy objectives of maintenance were described in terms of safety, preservation of investment, user comfort and convenience, and aesthetics. Performance-based maintenance management today increasingly recognizes the importance of operations-type activities and of traffic mobility as a fifth core maintenance objective. Although condition

measures may still apply to some operations activities, such as the physical condition of signs and signal components, other types of performance measures may need to be developed in terms of response times, system reliability, traffic throughput or delays, replacement-component compatibility with an existing system, and so forth. The MQA implementation plan recognized other potential M&O policy objectives such as environmental protection. Performance measurement continues this thinking. The WSDOT case example in chapter three provides an illustration of environmental implications for maintenance, and vice versa, focusing on stormwater quality.

- **More comprehensive accounting of highway performance and cost.** Whereas the MQA guidance focused solely on features and activities within the scope of the maintenance program, some M&O organizational units are moving to a more broad-based communication of performance-based results. The case examples in chapter three will show that WisDOT's Compass program takes field measurements in four categories of maintained assets, but it has overall reporting responsibility for additional categories of assets: pavements, bridges, signs, and winter maintenance. Similarly, the Mississippi DOT's (MDOT's) new maintenance management system (MMS) includes asset performance measures from sources other than maintenance; for example, pavement and bridge management (refer to chapter three for additional details). The survey results in chapter two indicate that the California DOT (Caltrans) has developed a budget model that captures all maintenance allocations; that is, for pavement and bridge maintenance in addition to the field maintenance function managed through Caltrans' Integrated Maintenance Management System.

Definitions

The following definitions will be used in this synthesis, within the context of performance-based highway M&O management:

- **Performance measures:** indicators of road-related physical condition, quality of M&O services provided, or operational behavior of highway traffic.
- **LOS:** translations of performance-measure information to a defined scale that indicates degree of acceptability or degree to which current performance meets expectations. Although performance measures are defined by a highway agency, they are often intended to reflect customer needs and expectations. LOS may be expressed on different types of scales—numerical scores, letter grades, or qualitative descriptions such as high/moderate/low—but in each case the method of arriving at a particular LOS is clearly defined and replicable by different individuals. LOS are also referred to as service levels or by agency-specific identifiers; for example, Florida DOT's (FDOT's) Maintenance Rating Program (MRP) ratings.
- **PBM:** techniques based on performance measures or LOS that can be used to describe current highway system status, define goals and targets for accomplishment, evaluate strategic and tactical options to attain those goals and track progress, relate both identified needs and actual work performed to cost, and report on the results or outcomes of these tasks.
- **M&O:** actions devoted to keeping a highway in serviceable condition. Because agencies treat the relationship between maintenance versus operations differently, hard and fast distinctions between the two will be avoided. For this synthesis, "maintenance" will refer to the preservation and repair aspects of M&O, while "operations" will refer to actions promoting safe, predictable traffic movement. "M&O" will be used when it is desired to stress the total program or the comprehensive function. In general descriptions with no qualifications, maintenance may be used with the implicit understanding that the term encompasses operations as well.
- **MQA:** planned and systematic actions needed to provide adequate confidence that highway facilities meet specified requirements. Such requirements are usually defined by the highway agency, but are intended to reflect the needs and expectations of the road user (Stivers et al. 1999).

A number of support tasks are needed for PBM: data gathering, information technology system development and operation, periodic meetings to review and update the performance-based approach when needed, internal and external communication, etc. Characteristics of these support activities will be discussed as part of the presentations later in this synthesis. Support tasks are included to add context and to fill in the blanks in the discussions of management practice. This synthesis does not, however, devote detailed coverage to these support tasks; the focus is on how these tasks affect management processes and decisions, help coordinate actions across the DOT organization, contribute to getting program work done, and maintain institutional information exchange.

Other terminology in this synthesis and in the literature should be interpreted in context. For example, to describe their physical highway system, state DOTs may use such words as element, feature, asset, characteristic, and facility differently. The meanings will usually be clear from definitions, discussions, and examples provided by the source.

OBJECTIVE AND SCOPE

The objective of this synthesis is to examine current performance-based management practices that are applied by state DOTs in highway M&O. It was acknowledged in the scope of work that state DOTs are known to have taken different approaches in developing their respective PBM processes. Previous research, conferences, and peer exchanges had already examined these differences primarily by comparing

the building blocks of a performance-based approach—condition ratings, performance measures, LOS definitions, threshold values, and so forth—that are used by different state DOTs. In a conference call with the Topic Panel at the inception of the study, it was agreed that it would be redundant to repeat this work in the current synthesis. Rather, this synthesis should focus on how state DOTs actually use PBM to manage their highway M&O programs. Similarly, significant work had recently been conducted by NCHRP on performance-based maintenance contracting. It was also agreed that contracted maintenance as a method of delivery would not be a major component of this synthesis. (Asking state DOTs about the application of performance-based measures to contracts was agreed to be within scope, however, as noted below.) The particular topics in the scope of work to be addressed therefore included, but were not limited to, the following:

- The extent to which state DOTs use performance measures or LOS, with examples of how these components are incorporated into their management practices.
- Examples of performance measures that underlie LOS for selected M&O activities.
- Methods of quantifying threshold values governing pass–fail evaluations, and values defining individual service-level boundaries.
- The consequences of not meeting (or exceeding) targeted M&O service levels at state and district/division levels.
- Application of LOS to contractors versus maintenance forces.
- How performance measures or LOS are used to establish M&O priorities and to manage performance in the short and long term.
- Methods of communicating M&O performance targets and results internally, to legislators, other stakeholders, and the public.

Investigations of these topics will be described in two ways: through a review of current nationwide practice based on a survey of U.S. state DOTs, supplemented by a literature review; and documentation of four case examples that take a more detailed look at particular problems or situations in which DOTs have applied PBM to highway M&O. The survey covers several characteristics of performance-based concepts and methods as applied to highway maintenance, among them the highway assets that are maintained, how these maintenance services are delivered, what factors influence performance goals and targets, how DOTs perceive the management tasks that can be supported by performance management, and the importance of communication and input by others to the process. The case examples have been selected to illustrate a spectrum of management issues and to reflect geographic diversity; selected agencies were also able and willing to provide the information and insights needed for a successful presentation.

The survey for this synthesis was conducted through the NCHRP in cooperation with AASHTO. AASHTO provided an e-mail distribution list to all voting members of its Subcommittee on Maintenance, representing the 50 states and the District of Columbia. The survey questionnaire was developed by the synthesis principal investigator and pre-tested among state DOT members on the Topic Panel. The survey was revised and distributed as a web-based questionnaire. Follow-up calls and e-mail messages were sent periodically to recipients to encourage participation. Of 51 questionnaires distributed, 41 responses were received, a response rate above 80%.

OUTLINE OF SYNTHESIS

The following chapters summarize the synthesis findings. This synthesis was conducted with substantial input from state DOTs, both through the survey and the case examples. It was felt that the cooperation and insight of agency personnel were critical to developing an accurate picture of how performance-based methods were used. Accordingly, the survey is summarized and reported comprehensively in chapter two as the core of understanding nationwide practice. Survey results are presented in tabulations of responses to each question and a paraphrasing of additional comments provided by respondents. This material is supplemented by findings in the literature, including an overview of prior work in the field.

Chapter three presents the four case examples illustrating: (1) an agency just launching its performance management program; (2) the components of a performance-based methodology and the components and processes used, for example, to set LOS targets; (3) application of performance management results to prioritization of maintenance needs; and (4) application of a performance-based system to address the maintenance-related implications of an environmental stormwater permit. This case is used also to illustrate a recently developed dual approach to performance monitoring.

Chapter four concludes the report. Appendix A contains the survey questionnaire. Appendix B lists the survey participants. Appendix C contains a customer telephone questionnaire used by MDOT, one of the case example subjects in chapter three. Appendix D presents the detailed responses of each state DOT to each question of the synthesis survey.

CHAPTER TWO

SYNTHESIS OF NATIONWIDE PRACTICE

BACKGROUND

Historical Context

Recognition of the importance of highway maintenance performance goes back at least four decades in U.S. practice. Although several agencies and research efforts have explored the concepts of M&O service levels (referred to at first as quality standards), maintenance as a business process, and customer-oriented outcomes, it was not until the 1990s that these ideas began to take hold in a meaningful way. This change was the result of several factors, including a shift in focus from new capacity to the more efficient use of the existing transportation system, increasingly constrained funding, growing emphasis on performance accountability, and the rapid pace of developments in computer hardware (including mobile devices), software, and networking that enabled advances in management system implementation and use. Within highway M&O practice, the completion of NCHRP Project 14-12 (*NCHRP Report 422*) on MQA was influential (Stivers et al. 1999). Success stories with innovations such as the use of dashboards, automated field data collection, and WSDOT's effective use of clear service-level definitions with photographs to communicate the meaning of LOS, also spurred other agencies to take note.

Several efforts have since been devoted to compiling information on (1) condition or performance measures and LOS used by state agencies; (2) the results of quantifying them and establishing thresholds of acceptability; and (3) how LOS values are applied in maintenance management tasks.

- A workshop to explore Common Maintenance Performance Measures, sponsored by the AASHTO Subcommittee on Maintenance, was held in Scottsdale in 2000. This peer exchange initiated inter-agency communication on topics such as the evolving characteristics of M&O management, key issues in what to measure and by what criteria, and how best to achieve the desired outcomes of performance measurement. State DOT personnel and other experts presented proposed approaches for common measures in several maintenance areas: pavement surfaces, shoulders, roadsides and landscape maintenance, safety features and appurtenances, highway surface drainage systems, traffic signs, and pavement striping. The workshop, however, also highlighted differences in agency practices and the difficulty of achieving a true set of common measures.
- *NCHRP Report 422* documented the LOS concepts used by several state DOTs and how these concepts are incorporated in management and budgeting. The report also illustrated variations in LOS approaches used by state DOTs; for example, pass–fail scoring versus A through F-type grading. The report served as a manual for agencies wishing to develop a maintenance management approach based on LOS. The components of this implementation plan have been outlined in chapter one.
- In the early 2000s, the Midwest Regional University Transportation Center (MRUTC) established an online document library of North American MQA information ("Maintenance Quality Assurance—Document Library" n.d.), a compilation of field data collection guides, rating manuals, reports, and data-collection forms submitted by state DOTs and Canadian provincial transportation departments and ministries. Two national peer exchanges were organized by the MRUTC in 2004 and 2008, results of which have been documented in synthesis reports to be discussed in the following section. This material provides a comprehensive nationwide summary of information that is relevant as background to this synthesis.

Products of Peer Exchanges and Related Analyses

2004 Peer Exchange

A product of the 2004 MQA Peer Exchange was an MRUTC synthesis report of MQA measures, accompanied by a definition of key terms to facilitate communication among agencies having different practices and nomenclature (*Maintenance Quality Assurance—Synthesis of Measures* Aug. 2005). These definitions related primarily to the structure of information on maintenance measures that was presented in the remainder of the report. The information was organized according to the following framework:

- **Categories** are logical groups of maintained assets based on their function or location on the highway. Examples include roadways, bridges, drainage, roadside and vegetation, and traffic management. This definition is modified for snow and ice control, which constitutes a service performed on the highway.
- **Features** are the particular maintained assets that are addressed by measures. For example, roadway features include flexible pavements, rigid pavements, and

shoulders. Bridge features include the approach, deck, railings, structure, and so forth. Drainage features include catch basins and drop inlets, culverts, curbs and gutters, ditches, etc. Similar examples pertain for other highway categories that involve physical assets. This definition is modified for snow and ice control, where features are interpreted primarily in terms of hours to achieve bare lane, with a few state DOTs also including statewide salt usage and plowing activity.

- **Characteristics** are specific qualities or defects in those features that can be evaluated on the basis of condition; for instance, rigid pavement characteristics include cracking, depressions and bumps, faulting, missing joint seals, and longitudinal cracks. Characteristics were explicitly defined only for roadway features; that is, pavements and shoulders. For other features, they are implied by the "standards" used, as illustrated in the next item.
- **Standards** are tolerance levels or criteria that help to identify whether a characteristic requires maintenance, or whether a feature is not functioning as intended and requires maintenance. Within the framework defined by the 2005 MRUTC synthesis, standards are explicitly assigned to "characteristics" for the roadway category only, and to "features" for all other categories. An example of a standard for traffic signs (a feature) includes insufficient reflectivity, worn or missing characters in the sign message, incorrect sign height, insufficient lateral clearance, or an evident deviation of post alignment from the vertical. Note that the characteristics that would have been associated with the traffic sign feature are implicitly described in these standards.
- **Measures** as defined in the 2005 MRUTC synthesis are descriptions of how to quantify the deficiency of a maintained feature or characteristic, typically on a per-highway-segment basis. For the traffic sign example, measures per segment include the number of signs, number of signs with poor reflectivity, number of missing, damaged, or illegible signs, number of signs with incorrect sign height, and so forth, with an all-inclusive measure of number of signs deficient to encompass all signs with any of the problems identified in the standard.

Based on data from 26 state DOTs, the 2005 MRUTC synthesis presented tables that compiled the standards and measures used by these agencies for each of the categories, features, and characteristics included in the study. Multiple measures often had to be listed because state practices varied in what measures they used, and some state DOTs used more than one measure to describe the need for maintenance on a given feature or characteristic (*Maintenance Quality Assurance—Synthesis of Measures* 2005, p. 21). The measures and standards data were also compared with the information presented at the 2000 Scottsdale workshop. "Measures" describe what conditions, qualities, or performance attributes will be used to rate a feature or its characteristics; however, they are not yet quantified or assigned numerical values. Performance-based measures that are quantified or assigned values are referred to as "thresholds," defined as "predetermined, system-wide maintenance levels for features and categories," in the nature of grading scales, indicators, or scores (*Maintenance Quality Assurance—Synthesis of Measures* 2005, p. 5). Thresholds identify the degree of deficiency (or conversely, the degree of satisfactory performance) of the highway system or portion thereof, and may reflect a customer perspective. The MRUTC synthesis did not include specific examples or tabulations of thresholds.

2008 Peer Exchange

A second MQA peer exchange was organized by the MRUTC in 2008. Following that event, updated data from 23 U.S. and Canadian transportation agencies were analyzed and compared with the 2004 results presented earlier (*Maintenance Quality Assurance Peer Exchange 2* Apr. 2009). The same definitions were used as in 2005, but some of the data (i.e., the specific categories, features, and characteristics) had changed, as had the population of state DOTs and Canadian provincial agencies surveyed. The 2009 information was tabulated in the same manner as in 2005 (categories, features, characteristics, standards, and measures). Information was also included on the popularity of features within each category (i.e., their frequency of use across the 23 agencies). Comparing the 2009 and 2005 findings, the report authors observed that fewer features were being measured within several maintenance categories, but agencies were moving toward concepts of overall highway performance in lieu of the former, more detailed, analytic measurements. Considering the example of traffic signs discussed earlier, analytic measures such as sign vertical alignment, lateral placement, and worn or missing characters that were reported in 2005 had by 2009 been replaced by the more qualitative and encompassing "anything preventing nighttime effectiveness of the sign."

Directory of State Program Information

Another product of the 2008 peer exchange was a directory of state program information posted by the University of Wisconsin–Madison in July 2009. This directory contains responses by the 50 state DOTs to the following inquiries:

- DOT identification and contact information.
- Overview of the MQA program: purpose, legislative mandate (if any), and history.
- Program status: length of time the program has been active; recent changes in the MQA program; and description of software used.
- Performance measures and rating systems: performance measures currently in use; description of how the rating system for measures was developed; and measurement scale that is used.
- Maintenance features and ratings: items that are rated; rating software used; and frequency of training on ratings.

- Data collection: frequency; sample size (or 100%); highway segment length; manner of collection; and use of automated surveys, if any.
- Reporting: uses of the data that have been collected; methods of reporting condition information; customers for reports; and information reported.
- Budgeting: how MQA data are related to the budget; how LOS characterizations are used; and effectiveness of program in influencing budgeting.

The *Directory* is a straightforward compilation of state DOT-provided information. It is made up of brief, qualitative statements that respond to open-ended questions about the items listed previously. It does not present any reviews, tallies, or analyses of the state DOT responses.

Maintenance Condition Assessment Guide

A Guide to Maintenance Condition Assessment Systems, although focused on the important functions to be addressed by objective and repeatable data on maintained highway features, devoted attention also to the LOS that are supported by good field data and the roles played by these service levels in maintenance management (Zimmerman and Stivers 2007a). Summaries of pertinent items on condition assessment systems and LOS follow:

- Condition assessment is the physical inspection and rating of roadway assets to determine their condition for description at the individual asset, roadway section, or overall network level. (This process will be referred to as road rating or similar terminology in chapter three.) The objective condition information that results from a good condition assessment contributes to several tasks in PBM (adapted from p. 8 of the *Guide*):
  - Establishing target levels for asset condition with respect to available funding.
  - Helping to relate maintenance costs or cost reductions to incremental changes (favorable or unfavorable) in the condition of maintained assets.
  - Establishing consistent conditions across the highway system; reallocating resources to underperforming assets; and setting maintenance priorities on a statewide basis.
  - Improving linkages between customer expectations and maintenance to be performed.

  Examples of some of these tasks are illustrated in the case examples in chapter three.
- The *Condition Assessment Guide* discusses the relationship between LOS and cost and provides examples of relationships determined by the North Carolina DOT for several drainage maintenance activities (pp. 43–45 of the *Guide*). (In the context of the case examples in chapter three, this type of relationship will be referred to as an asset condition relationship.) The *Guide* also illustrates methods of reporting results that have been found to be useful in PBM: report cards and dashboards (pp. 41–42 of the *Guide*).
- The *Guide* summarizes shifts in maintenance management techniques that have been brought about in part because of the increasing use of performance-based concepts and related methods such as condition assessment itself (adapted from p. 5 of the *Guide*):
  - Information on highway condition to support decisions: a shift from subjective condition assessments to more objective condition information.
  - Types of performance measures used: a shift from output-based measures that record work accomplishments (e.g., area of pavement patched and number of plow-miles driven) to outcome-based measures (e.g., reduction in pavement roughness and increase in ride comfort, and time to achieve bare pavement or time to restore normal operating speed).
  - Importance of customer expectations: a shift from performance targets that are more task-oriented to those that are more customer-oriented based on feedback regarding expectations of road users.
  - Maintenance planning: a shift from a more reactive to a more proactive perspective.
  - Budget preparation: a shift from "basing coming budget on adjustments to previous budget" to "basing coming budget on cost to move from existing service levels to projected service targets."

A companion document identified a research need to fill a gap in many agencies' current management capabilities: the need for a tool to relate maintenance LOS to its estimated cost. Based on the results of a survey they had conducted, the authors noted that few agencies had such automated tools in place (Zimmerman and Stivers 2007b).

Nationwide Survey of Maintenance Management Systems

A nationwide survey of current capabilities of highway MMS and desired future capabilities was reported as part of a study for the Idaho Transportation Department on its maintenance management and pavement management needs (Applied Pavement Technology, Inc. 2008). The survey was conducted as part of FHWA course development on MMS. Twenty-nine state DOTs responded to this survey. With a focus on only those MMS capabilities oriented toward PBM, selected results of this survey included:

- In response to a question on planned enhancements to existing MMS, 23 of 29 respondents (the highest response overall) selected interfaces with other systems; 21, updates to the asset inventory; 16, an LOS approach; 14, performance targets; and 8, incorporating customer input. The report authors noted that most of these selections are consistent with capabilities supporting performance-based budgeting.

- In a similar vein, desired characteristics that respondents associated with a new system included links to performance measures (13 of 29 respondents, the second-highest response overall), outcome-based measures (12), integration within an agency's decision process (12), and customer-oriented measure (6).
- The study also asked participants their views on specific features that could be associated with an MMS. Performance targets, or target LOS, constituted one of these features. Because such targets could be determined in several ways, the questionnaire asked what method each state DOT used (more than one method could be selected). The top choice was experienced maintenance personnel (17 responses). This selection was followed by historical trends (16), customer surveys or focus groups (8), and other data sources (6), which included the pavement International Roughness Index, funding levels, the legislature or transportation commission, management, existing management systems (e.g., pavement management), and daily work accomplishments. Several agencies reported using more than one method in combination. (The emphasis on experienced maintenance personnel is consistent with the results of interviews conducted for this synthesis as reported in chapter three.)

Performance Implications of Levels of Service

Agencies with mature performance-based approaches have developed methods to illustrate the relationships among M&O LOS, annual M&O investment levels, and performance-based implications. WSDOT and WisDOT, both of which employ graded LOS approaches in their M&O programs, have each produced a graphic showing these relationships. The two agency graphics are similar but include different performance-based implications or outcomes. For purposes of this study, the two graphics have been consolidated into a single, unified diagram as shown in Figure 1.

The upper part of Figure 1 relates the level of annual M&O investment to LOS. LOS A is the superior level of maintenance and entails a greater annual investment to achieve superior quality, coverage (e.g., percent of the total highway network assets), and frequency of maintenance. LOS F is the minimal level of maintenance, funded at a lower annual investment, with LOS B, C, and D as intermediate values.

The lower part of Figure 1 illustrates performance implications or outcomes resulting from the level of annual M&O investment and the resulting delivered LOS. Two sets of outcomes are shown: those relating to the M&O program itself and those related to impacts on the transportation system. A line is used to represent each type of outcome, representing a spectrum or continuum of possible values of that outcome. On each such line, moving to the left entails outcomes of greater investment and better quality M&O; moving to the right incurs outcomes of lesser investment and poorer quality M&O. The set of outcomes shown is not exhaustive, but is sufficient to get the idea across. Also, these outcomes must be viewed in the context of typical agency stewardship of a highway system and the technological limits of maintenance itself. Thus, in the M&O program outcomes, maintenance work can extend the lives of highway assets and enable them to perform acceptably for longer periods of time, but it cannot do so indefinitely. Eventually, the ravages of time, weather, continuous traffic loading, structural fatigue, and catastrophic events, among other factors, take their toll, and assets must be rehabilitated, reconstructed, or replaced. In the transportation system outcomes, both capital construction and M&O actions determine the overall performance of the transportation network. Therefore, with both types of performance implications, it is important that the values of outcomes discussed be interpreted in relative rather than absolute terms.

The outcomes related to the M&O program include not only matters of quality, coverage, and frequency discussed previously, but also the character of the maintenance that can be systematically performed (whether preventive/proactive or corrective/reactive), the relative cost-effectiveness of the M&O actions and services, and the range of priorities that can be addressed. For example, a level of investment gauged to LOS A enables an agency to address a fuller range of priorities encompassing critical work such as safety or maintenance of critical infrastructure, as well as less critical priorities such as roadside appearance. By contrast, lower LOS values and lower levels of annual investment imply budget constraints that limit the scope of work priorities to critical repairs, actions, and services.

Similarly, in the transportation performance implications, M&O investments and LOS influence a number of basic outcomes:

- Safety, which is promoted through properly functioning signals, signs, pavement markings, roadway lighting, advance warning devices, Intelligent Transportation System (ITS) devices, roadway and roadside safety hardware, and effective response to roadway incidents.
- State of highway assets, which corresponds directly to the frequency, coverage, and quality of needed preventive maintenance; and corrective repairs, which can extend the lives of assets and enable more reliable operation.
- Reliability of system mobility, which is promoted through well-maintained equipment that facilitates safe and efficient traffic movement.
- Road and roadside appearance, which can increase road user comfort and pleasure.
- Total life-cycle costs of highway transportation, which includes road user costs as well as agency expenditures for highway construction, rehabilitation, and M&O. Higher M&O LOS and related expenditures can help minimize overall life-cycle costs through reductions in road user costs (leading to better mobility and safety), and reductions in agency costs (leading to life-extension of highway assets).

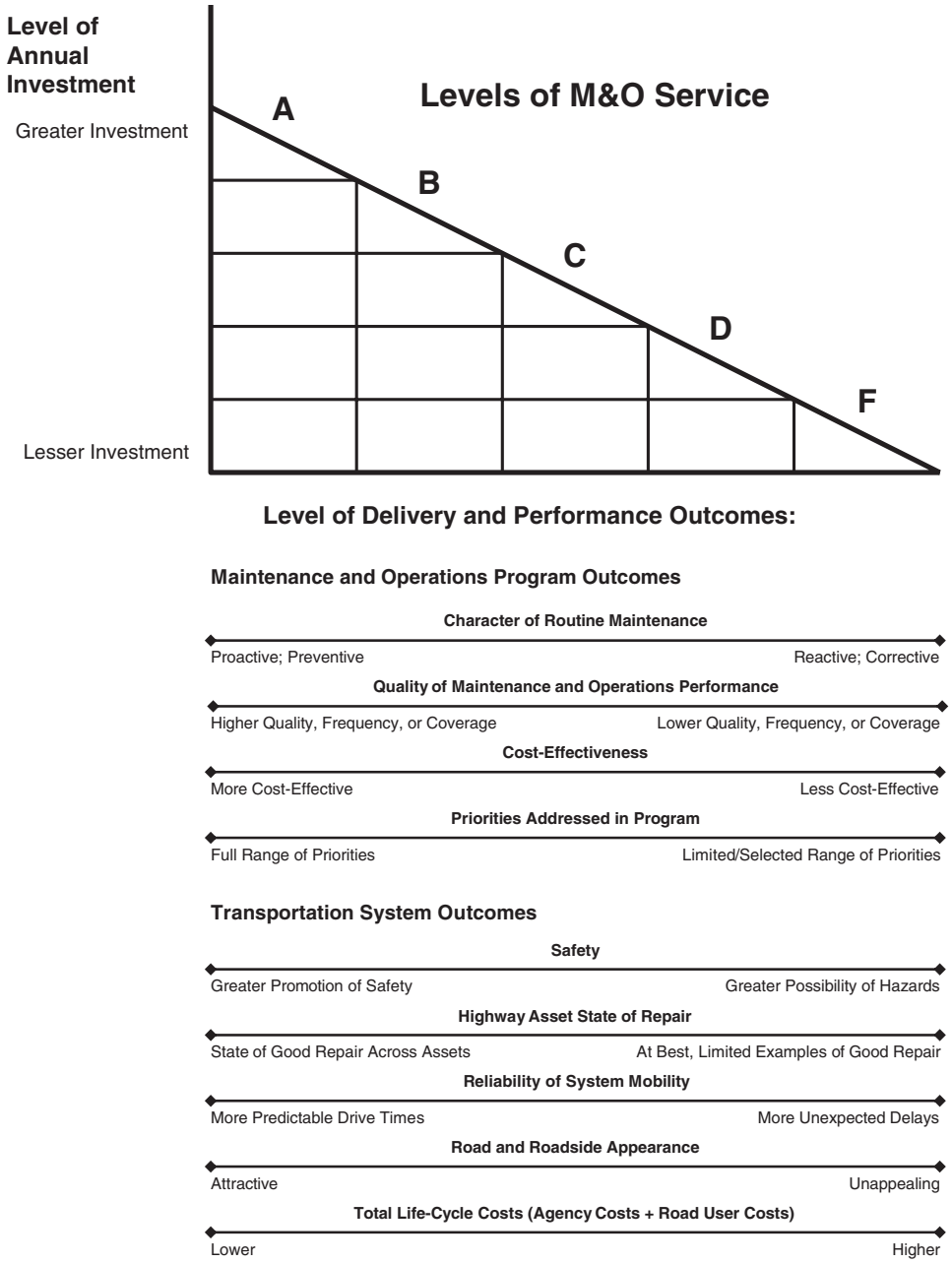


FIGURE 1 Maintenance LOS, level of investment, and performance impacts [adapted from WSDOT's *Maintenance Accountability Process Manual* (2008) and WisDOT's *Highway Operations* (2005)].

This graphic summarizes the kind of framework employed by M&O managers when considering current highway conditions, proposed budgets, and LOS targets as part of PBM planning. It may help to interpret findings of the survey that follow in this chapter, and the case examples in chapter three.

Levels of Service for Interstate Highways

Two NCHRP studies address development of performance-based LOS for the Interstate Highway System: *NCHRP Report 632: An Asset-Management Framework for the Interstate Highway System* (Cambridge Systematics Inc. et al. 2009) and *NCHRP Report 677: Development of Levels of Service for the Interstate Highway System* (Dye Management Group, Inc. et al. 2010). These studies were not focused solely on maintenance; rather, they encompassed a range of capital construction and maintenance programs. They are relevant to this synthesis in their structuring of the LOS measures, which is similar to that of graded LOS measures used in maintenance management. *NCHRP Report 677* provides a seven-tiered template for these measures encompassing Agency Goal/Outcome, Asset Class, Asset Element, Definition, Indicator, Measure, and LOS Thresholds. The report further proposes

LOS threshold values appropriate to the high-standard interstate system, drawn from a composite of state DOT systems and judgments by members of the research team.

SURVEY OF NATIONWIDE PRACTICE

As the preceding sections show, much of the research since the publication of *NCHRP Report 422* has centered on performance-based elements—measurement of condition, formulation of performance measures, different approaches to LOS, definitions of targets and thresholds, and the like—and their comparison among North American transportation agencies. The focus has been, as it were, on the tools in the performance-based toolbox and how they are manufactured. This synthesis looks instead at how the skilled craftsmen within highway M&O organizations apply these tools. This synthesis adopts as a premise that the "tools" used by state DOTs differ in their "materials and manufacture"—varying field data collection procedures and conventions, different constructions of performance measures, pass–fail versus graded measures of LOS, different thresholds and target values, and so forth. The synthesis acknowledges these differences, which are apparent in the four state DOT case examples in chapter three, but otherwise does not address them in any detail. Rather, the purpose of this synthesis is to understand how these tools are applied to build, operate, and sustain a successful performance-based M&O program to the benefit and satisfaction of both the agency and the customer.

The research that was described in preceding sections also addressed to some degree management concepts and techniques. Although these efforts developed useful information, findings, and insights, the results are either highly distilled and somewhat difficult to compare (as with the information in the *Directory of State Program Information*) or are adjuncts to broader topics that were the primary focus and motivation of the research projects (e.g., the studies of condition assessment systems and MMSs). This synthesis builds on this earlier work, but moves beyond it by dealing with performance-based M&O management as the primary topic of interest in its own right. Presentations are of two types:

- Subsequent sections of this chapter cover nationwide practice in performance-based M&O management as established through a synthesis survey of state DOT M&O managers. The survey questionnaire was designed to address the scope of work as described in chapter one, plus additional items suggested by panel members following review and trial use of draft questionnaires.
- Chapter three presents four case examples of current state DOT practice in performance-based M&O management. Criteria that guided selection of the four cases are discussed more thoroughly at the beginning of chapter three; but all the cases involve agencies that have either a preliminary or a mature performance-based approach based in LOS allowing them to provide meaningful descriptions and results. Candidates were initially identified through interviews with the synthesis topic panel members, recruiting discussions following presentations on this synthesis at the 2011 meeting of the TRB Maintenance and Operations Management Committee (AHD10), reviews of incoming survey responses, and initial discussions with potential contacts in candidate agencies. The topics of each case were initially proposed by the respective agency contact, identified in the acknowledgements at the beginning of this report. The validity of each case for meeting synthesis objectives was reviewed based on literature and descriptions provided by the agency representatives, supplemented by telephone interviews. The introductory section in chapter three describes the agreed on subject of each case.

OVERVIEW OF QUESTIONNAIRE AND RESPONSES

The survey conducted for this synthesis yielded 41 responses. Of these, 31 state DOTs reported using a performance-based approach for managing M&O; 10 reported not using a performance-based approach, as depicted in Figure 2. During the design of the survey questionnaire, a pre-test involving state DOT representatives on the topic panel had indicated that performance management might actually encompass a number of variants on performance-based approaches and different stages of development. These multiple possibilities were built into the survey questionnaire. For those agencies reporting that they did not use a performance-based approach for managing M&O, two questions addressed the method that was being used instead and the reasons for not currently adopting performance management.

Those agencies using a performance-based approach were categorized by the seven applications listed in Table 1. All of the survey respondents reported their current situation in terms of one of the first six choices. None selected

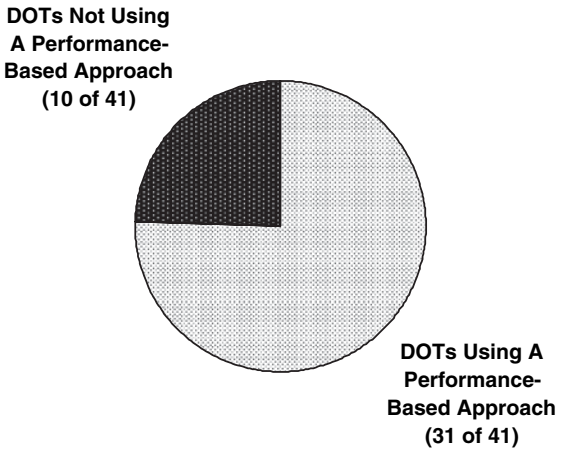


FIGURE 2 Breakdown of survey responses regarding use of a performance-based approach.

TABLE 1
CATEGORIES OF PERFORMANCE-BASED USE DEFINED IN THE SYNTHESIS SURVEY

Category	Description	Agency Responses
1. Primarily Condition and Performance Data Tracking	M&O-related condition or performance measures provide data to track performance trends, identify critical needs, and support tasks such as budget requests, but otherwise are not used in day-to-day management.	5
2. Strategic or Generalized Program Performance Measures	Our agency uses several generalized or strategic performance measures (capturing facility condition, congestion, crash data, etc.) to assess multiple highway investment programs: maintenance and operations as well as capital preservation, mobility, safety, and so forth.	3
3. Performance-Based Process Just Beginning	This agency has just begun investigating performance-based concepts, and is formulating its approach to M&O-related performance measures or levels of service.	3
4. Performance-Based Performance Measures	Performance measures have been defined for maintenance and operations specifically, and are used in M&O management tasks such as planning, budgeting, prioritization, regional allocations of funding, and accountability for results.	6
5. Preliminary M&O Levels of Service	The agency has defined M&O levels of service (including any underlying performance measures) for some or all activities/assets, but these are preliminary and likely to be revised in the near future.	6
6. Mature M&O Levels of Service	The agency has a mature program of M&O levels of service (including any underlying performance measures) that is well integrated in management procedures, assessments, decisions, and systems, and is used in reporting and communication.	8
7. Not Well Described Here	The performance-based, LOS, or performance-based practices used by this agency are not well described by any of the above statements.	0

the option to describe the application in his or her own words. The categories in Table 1 were designed to indicate the degree to which the state DOT had organized and developed a performance-based process on a programmatic basis to address a range of business procedures and management decisions. The responses received from the 31 agencies using a performance-based approach are distributed among these choices as indicated in Table 1 (the "Agency Responses" column) and illustrated in Figure 3.

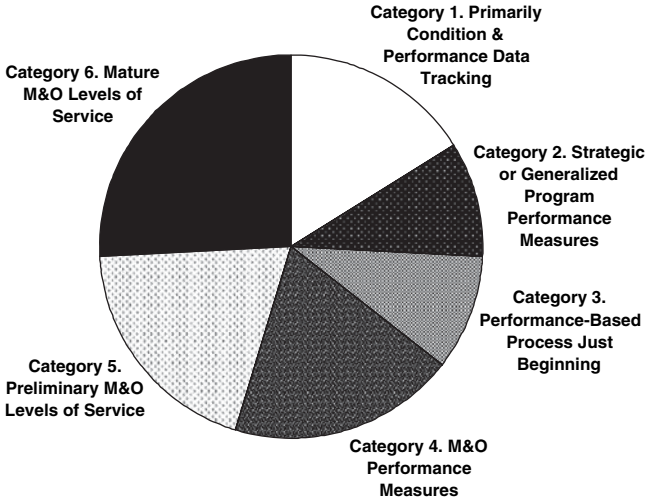


FIGURE 3 Stages of performance-based development among reporting agencies.

The responding agencies that use performance-based approaches are organized within groups because, even with most state DOTs responding to the survey, the results are diluted when distributed among the several possibilities in Figures 2 and 3; seeing the results in groups helps to provide a better perspective. As an example, there is no significant concentration of questionnaire responses in any single category. However, when categories 4 through 6 in Table 1 are viewed collectively, one perceives a critical mass of support for, and use of, a performance-based approach. This group represents agencies that already have a program of performance measures or LOS oriented specifically toward M&O. The perspective on this group is strengthened by adding those agencies that are just beginning a performance-based process (category 3 in Table 1). Figure 3 helps to visualize the impact of this grouping graphically. Moving between detailed and aggregate views of the survey results, wider implications of the categories of performance-based usage in Table 1 can be explored, based on the total of 31 agencies reporting the use of some type of performance-based approach.

- **Category 1—Primarily Condition and Performance Data Tracking:** The five agencies in this category collect performance-based information regarding M&O assets or actions. This information is used primarily to track conditions and performance and to inform various management decisions. However, these agencies have not implemented other performance-based elements (such as performance targets) required for a more comprehensive

and formalized management treatment of problems across a broad M&O program. Accordingly, the survey questions regarding this approach were not extensive; they addressed such topics as the types of assets and activities managed and the methods of field inspection.

- **Category 2—Strategic or Generalized Program Performance Measures:** The three agencies in this category subscribe to performance management at a broad level. Performance measures are strategic, applying to a range of agency programs and investments. For example, pavement and bridge conditions may be expressed by a generalized pavement-surface condition and bridge health index; safety by frequency of fatal and serious-injury collisions; and mobility by cumulative hours of passenger and freight delay. Although these performance measures may reflect the consequences of certain M&O actions and services, they are also affected by capital projects (e.g., for asset rehabilitation and operational improvements) as well as initiatives and investments by other transportation agencies and programs (for example, for law enforcement, driver education, etc.). The survey questions regarding this approach were likewise not extensive.
- **Category 3—Performance-Based Approach Just Beginning:** It could not be assumed that the three agencies in this category would yet have developed the information needed to complete the substance of the questionnaire. Accordingly, these respondents were asked instead for a brief description of their proposed effort.
- **Categories 4 through 6:** The 20 agencies in these three categories have an in-service performance-based program addressing a range of assets, activities, and services. These three categories are examined with the same set of questions in the survey, and receive the most detailed coverage. They are, however, distinct in the following ways:
  - **Category 4—Maintenance and Operations Performance Measures** (six agencies) refers to the reliance on performance measures rather than LOS as the basis for the performance element of performance-based management.
  - **Categories 5 and 6—Preliminary or Mature Maintenance and Operations Levels of Service** (six and eight agencies, respectively) have LOS as the performance element of performance-based. Category 5 describes those agencies whose LOS are preliminary and may be revised. Category 6 describes those agencies with a mature LOS program, implying more stable elements and values and potentially a greater tendency to explore more far-reaching research, more refined or sophisticated management capabilities, and a wider range of applications.

Some state DOTs in categories 4 through 6 submitted comments highlighting state-specific variations:

- Caltrans reported that its performance-based-capable IMMS has a budgeting model with advanced capabilities:
  - It gathers all maintenance-related expenditures, including those tracked by pavement management and bridge management systems.
  - It employs a diminishing-returns-on-efficiency cost model, rather than a more common linear model.
  - The budgeting procedure is able to perform what-if analyses regarding funding scenarios.

  These remarks are excerpts; Caltrans' full comments to this question and Question 6 are substantive and detailed; they are recorded in their entirety at the end of Appendix D. State DOTs that were the subjects of case examples also had views on current practices in cost estimation, and described methods they had recently instituted in their own performance-based systems (refer to chapter three).
- Iowa DOT has a maintenance performance measurement process in addition to data measures from other systems, including the pavement management system and bridge management system. The department's maintenance performance measures have defined LOS for nearly 10 years, but are not widely integrated into management, mostly because the data have not traditionally been timely to management decision making.
- Texas DOT (TxDOT) noted that although it applies performance measures that are specific to M&O in its Texas Maintenance Assessment Program (TxMAP), it also tracks data from its pavement management system and bridge inspection information. These measures and data influence district prioritization, but do not control the budget.

BASIC CHARACTERISTICS OF PROGRAMS SURVEYED

The survey questions addressed by the largest pool of respondents concerned basic characteristics of M&O programs: their composition, method of delivery, and method of inspection. Twenty-eight agencies had the opportunity to answer these questions, representing all categories in Table 1 except categories 3 and 7. Responses are summarized in the following sections. Because respondents were for the most part allowed to select as many multiple-choice items as were applicable, the total number of responses may total more than 100%. (Note: This qualification applies to all technical questions in the questionnaire.)

Program Composition

Program composition is described in terms of maintained assets or related actions, activities, or services. A check-box list was provided; respondents indicated those elements that were included in their respective programs. Assets and activities were not described in detail; for instance, the general description "Roadside and Median Vegetation" might apply to mowing, brush and tree care, noxious weed control, and landscaping. Similarly, "Drainage" included open elements (i.e., ditches) and closed elements (culvert pipes, manholes, inlets). Several respondents provided additional work

items in comments. The purpose of this question was not to describe every asset or activity in detail, because state DOTs differ considerably in the numbers of such elements in their management systems, but rather to get a sense of the general scope of the M&O program that is managed by the responding M&O organizations. The reported data are presented in Figure 4 in descending number of selected responses.

Several state agencies submitted "Other Assets/Activities" not listed in the questionnaire: safety investments and mobility/congestion improvements (California); mowing and crash attenuators (Tennessee); right-of-way fencing (Wisconsin); and noxious weeds, fencing, and cattle guards (Wyoming). The Wyoming DOT respondent also mentioned that some assets and activities that were not checked off in the questionnaire may currently be under development. Minnesota DOT (Mn/DOT) noted that the maturity of the performance measures for its activities varies. TxDOT reported that the assets included in its response are only those managed by TxMAP; bridges and operations-related assets are managed by other divisions.

Program Delivery

Program delivery results are shown in Table 2. In most cases the state DOT conducts the delivery of performance-based-related work under its own auspices through a variety of mechanisms, including force-account (or employee) labor and contracted M&O services. In three of the four instances in which other governmental agencies are involved in work delivery, they operate in concert with the state DOT. For example, a county or municipality may have responsibility for performing signal or roadway lighting maintenance on state highways within its boundary, whereas the state DOT handles other asset maintenance. The exception is Wisconsin, where WisDOT contracts all of its maintenance with county government (refer to the WisDOT case example in chapter three).

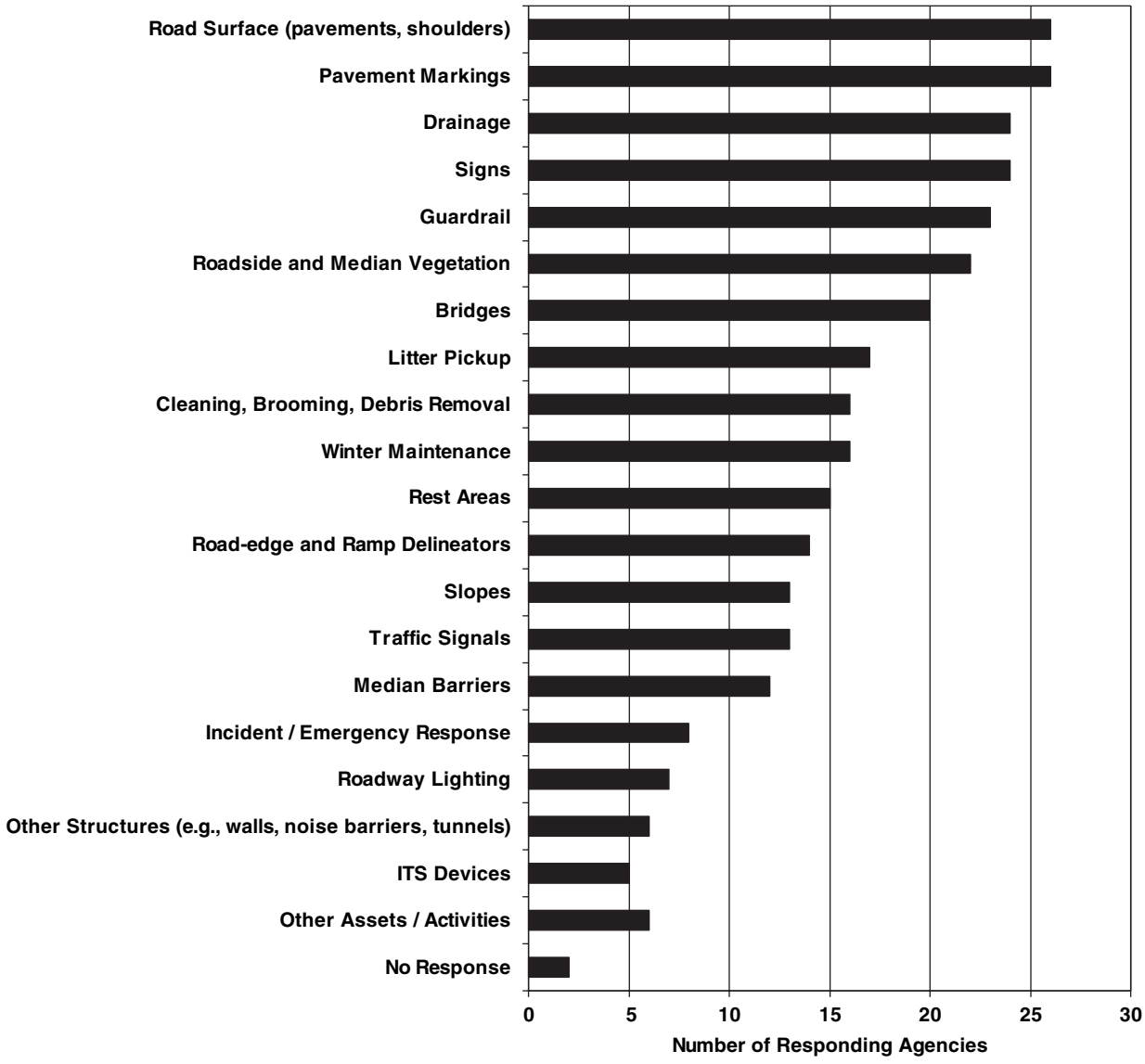


FIGURE 4 Program assets and activities addressed in performance-based programs.

TABLE 2
SURVEY RESULTS: PROGRAM DELIVERY

Method of Delivery	No. of Responses
Delivery under the auspices of the state DOT, whether using employees, contractors, volunteers, or prison labor	25
Delivery by other governmental levels (municipalities, counties, etc.), but the state DOT retains responsibility for monitoring LOS provided	3
Delivery by other governmental levels, with these other jurisdictions having responsibility for monitoring LOS provided	1
Other method(s)	1
No response	2

Note: Respondents could select more than one choice above.

Other variations in practice were described. Maryland State Highway Administration reported that in cases where other jurisdictions deliver maintenance work for the state, those jurisdictions have responsibility for monitoring the LOS provided. The Colorado DOT uses Sponsor-A-Highway to support litter control in heavily-trafficked areas that are unsuitable for use of Adopt-A-Highway.

Field Inspection

Field inspections to support performance-based programs are conducted in most instances using a combination of methods that may involve headquarters, district, and third-party teams, as noted in Table 3. Some state DOTs use only one of these methods, as shown in the first four entries in this table. Data gathered by others for agency-wide use refers to groups such as those performing pavement management and bridge management, who conduct their own data collection efforts and share results with M&O. "Other" methods and optional comments contributed by survey respondents include:

- Indiana DOT uses headquarters-based teams to gather data statewide, whereas the Iowa and Montana DOTs each use district-level teams to inspect their own state highways. Kansas DOT's districts are divided into areas, and inspections are conducted at the area level. Some areas inspect their own features, others do not, at the discretion of the district; however, all inspections are done by DOT personnel.
- The Iowa DOT described its data collection that supports performance measurement for its maintained assets. The process is based on a random sampling of 6,000 one-tenth-mile road segments from the state highway network. This method is designed to provide a statistically valid random sample of the overall network as well as to give significant information about the relative performance of Iowa's six districts. State highways in each district are inspected by personnel from that district. This approach applies to all of the assets listed in its response except rest areas, which have a different MQA process.
- TxDOT's central office team of four inspectors for TxMAP takes volunteers from districts on inspections of other districts. Pavement management inspections are conducted primarily by contractors.
- Performance data in Wisconsin are gathered by the WisDOT regional maintenance coordinator and the county patrol superintendent (refer also to the case example in chapter three).

TABLE 3
SURVEY RESULTS: FIELD INSPECTION

Method of Field Inspection	No. of Responses
Headquarters-based teams gather data statewide	4
District-level teams inspect other districts	1
District-level teams inspect own district	5
Independent third parties conduct inspections	1
Combination of above	14
Data are gathered for general agency-wide use (not limited to M&O) and are collected by a variety of efforts.	3
Other method(s)	3
No response	2

Note: Respondents could select more than one choice above.

A follow-up question inquired about QC mechanisms to validate field inspection results. More than two-thirds of the responding agencies indicated that they do perform QC checks, using a variety of techniques. These methods include application of measurement technology (such as retroreflectometer readings of pavement markings) to validate visual inspections on a sample of sites, use of headquarters-based teams or independent reviewers to verify findings of district-based teams, and use of teams from one district or region of a state to check a sampling of results from another region. Specific state practices were reported as follows:

- Arizona DOT noted that QC inspections are performed by headquarters staff on a random sample of the original sample segments.
- Caltrans reported that the district inspection is performed on a 20% random sample; a headquarters QA team reviews10% of district inspections.
- Indiana DOT has two teams, covering the north and south halves of the state. They occasionally survey each other's roads, with their supervisors, to ensure consistent measurement.
- Iowa DOT has annual training meetings to "calibrate" the teams. It also has a specialist in central maintenance who does spot re-reviews of segments for each team, conducts continuing education, and develops and refines the measurement process and tools.
- Kansas DOT reported that a fraction of the sample sites is re-inspected by experienced teams.
- New York DOT has clearly defined scoring criteria. It uses local scoring supplemented with regional and/or statewide scoring to verify results.
- North Carolina DOT has an independent team that does QA checks on the segments initially inspected by the MQA teams.
- South Carolina DOT has a management team conduct follow-up inspections on a random sample of segments to ensure that performance is being measured to set standards.
- Tennessee DOT uses third-party rating teams to conduct QA inspections on 10% of those initial inspections performed by in-house staff.
- TxDOT's QC efforts correspond to its two components of maintenance inspections visual and automated. The TxMAP inspection process is primarily visual. The four central office-based inspectors from time to time conduct inspections together to ensure consistent application. Regarding pavement management, all surveyors receive annual training and the automated pavement inspection equipment used to collect data is calibrated each year.
- Utah DOT reports that a headquarters-based team does a random follow-up on data collected by each district.
- Virginia DOT (VDOT) uses a third party to conduct automated measurements of pavement condition data. Extensive QC procedures are used by VDOT to check data values, including reference to historical information and data from comparable locations.
- In Washington State, region-level teams inspect other regions. Duplicate surveys are conducted on a percentage of locations in each region by personnel from headquarters as a quality check.
- Among Wisconsin's 72 counties, annual QA is performed in ten counties (two counties in each of five regions); six roadway segments are reviewed per county. These QA reviews provide the region and county rating teams with information on areas to emphasize in training and could suggest modifications to deficiency thresholds and/or measurement techniques. (Refer also to the WisDOT case example in chapter three.)
- Wyoming DOT reported that districts do the actual data gathering for their own state highways. Headquarters-based teams gather data statewide, which are used as a QA check to ensure that performance measures are being assessed consistently.

ATTRIBUTES OF PERFORMANCE-BASED MANAGEMENT ADDRESSING HIGHWAY MAINTENANCE AND OPERATIONS

The majority of survey questions addressed PBM that employs performance measures and/or LOS for M&O explicitly. In other words, these programs are not limited solely to tracking performance data, and they go beyond the use of strategic or generalized performance measures that are applied to capital as well as M&O programs. Even those approaches that agencies had identified as using "preliminary LOS" qualify for this section, because they often include elements, such as target LOS values, that also characterize more mature programs. For purposes of this survey, a preliminary performance-based program simply means that program elements such as performance measures, LOS thresholds, grading or scoring procedures, and targets are tentative in their definition and valuation. Revisions may be expected in the near future and these may be broadly based. It has been observed in the case examples, however, that even those performance-based programs that are considered to be mature are still evolving in their details, adjustments in M&O activity scope, and advances in analytic techniques. Twenty responding agencies had the opportunity to answer the set of questions associated with these more fully developed performance-based programs, with the option of skipping individual questions. Results are summarized in the following sections.

Geographic Application of Performance-Based Measures

All of the responding agencies begin with a base of uniform LOS or performance measure values statewide. A few impose regional variations on a subset of these measures. These results are tabulated in Table 4.

As an example of an "Other" method, Caltrans added that in addition to its districts and regions, it had defined

TABLE 4
SURVEY RESULTS: GEOGRAPHIC DEFINITION OF MEASURES

LOS or Performance Measures Are Defined:	No. of Responses
With uniform values statewide	19
With regional variations in values	4
Other ways	1
No response	1

Note: Respondents could select more than one choice above.

28 zones based on traffic volume and terrain, which allowed an additional dimension of variation in LOS values.

Several comments by state DOT respondents focused on the nature of statewide variability in performance-based measures:

- Missouri DOT remarked that while measures were for the most part uniform statewide, some M&O activities might be susceptible to variation between urban and rural areas.
- Tennessee DOT mentioned that only snow and ice removal activities have received a variation from the statewide standard values.
- In the county-oriented M&O program managed by WisDOT, measures are defined statewide, but with regional variations. However, the existing MQA program does not have an adequate sample size to be statistically valid at the county level.
- Wyoming DOT commented that it is considering regional variations in threshold values, but not in the overall performance measures.

Goals and Targets

Seventeen of the 20 state DOTs that responded to this question indicated that they define targets for their LOS or performance measures. Agencies considered one or a combination of factors (with four being the maximum) in setting the values of these targets. The factors are listed with corresponding numbers of responses in Table 5. Additional comments by survey participants follow:

- Caltrans reported that its budget model for field maintenance (excluding operations work) was capable of estimating a budget-constrained LOS target as a function of the particular assets or features involved the existing LOS, the asset inventory, and the average cost per inventory item to perform maintenance work. Unconstrained targets could also be estimated. Caltrans' full comments are reproduced at the end of Appendix D.
- At the Colorado DOT, the M&O branch manager makes recommendations to the transportation commission, which then sets the target LOS for M&O, as well as a budget to reach that target.
- Iowa DOT reported that a few selected measures are part of a "performance plan" that is submitted to the state's department of management. This plan process was established under the Iowa Accountable Government Act.
- Mn/DOT commented that its targets are generally needs-based; that is, they are set or based on market research or engineering judgment.
- TxDOT sets "realistic" targets on the basis of internal management or engineering analysis. TxDOT's goal is to keep 90% of pavements within a condition range of

TABLE 5
SURVEY RESULTS: SETTING TARGETS

Factors Considered by State DOTs in Setting Targets	No. of Responses
As a function of projected M&O budget	9
As a legislatively mandated agency commitment	2
As an agency commitment under a state government accountability initiative	2
Solely as a commitment to meet an agency-established objective or goal	7
As a result of internal management or engineering analysis indicating a realistic target for accomplishment	6
By another method	6
No response	1

Note: Respondents could select more than one choice above.

good to excellent. Although there has not been enough funding to achieve this goal, the department has come close to attaining it.
- WisDOT sets its targets (1) as a result of internal management or engineering analysis, (2) as a function of projected M&O budget, and (3) as a commitment to meet an agency-established objective or goal. WisDOT also performs a gap analysis between conditions and targets to track whether the targets are realistic given the existing conditions, priorities, and budget. (Refer to the WisDOT case example in chapter three.)

Management Tasks Supported by Performance-Based Approaches

From the list of management tasks in Table 6, most agencies selected from the first six options to describe their focus for applying performance-based techniques. Additional comments related to management tasks included the following:

- To reiterate an earlier comment submitted by Iowa DOT that is relevant to this question as well: Although maintenance performance measures and LOS are defined within the agency, they are not widely integrated into management tasks because supporting data are not sufficiently timely for decision making.
- TxDOT commented that managers are rated on the condition of their state highways in terms of both maintenance quality and pavement condition. These evaluations also identify where work is needed.
- Wyoming DOT is looking to use performance-based tools to prioritize M&O work; however, the efforts are in their infancy. Funding shortfalls limit the DOT's ability to allocate resources based entirely on MQA results.
- In separate discussions, two other state agencies remarked that previously developed performance-based capabilities were not used anymore. In one case this was the result of the difficulty of having a LOS-cost relationship work meaningfully given the uncertainties in funding. In the second case the shift was the result of an update in maintenance management software, where the new product would not be able to support the computational procedures that had previously been used to estimate a particular LOS-versus-cost analytic relationship.

Customer Input

Twelve of 20 respondents to this question reported obtaining customer input to inform their decisions on M&O performance and priority. The mechanisms used are identified in Table 7, resulting in an average number of methods used per agency of more than two. (The actual numbers of survey methods used by individual agencies ranged from one to six.) "Other" methods that were identified included the following:

- Two agencies described using web-based resources to obtain feedback from customers. Caltrans maintenance has a web-based "Maintenance Service Request" site for the public to identify service needs. Mn/DOT reported that given its strong market-research commitment, the department has recently initiated an "on-line community" to hear from customers.
- In addition to using several of the methods listed in Table 7, Missouri DOT also hears feedback from customers at road rallies.

WSDOT has instituted an online customer survey for highway maintenance, where the public is asked to "rate highway pavement conditions, emergency response to collisions and bad weather, and how WSDOT should prioritize

TABLE 6
SURVEY RESULTS: PERFORMANCE-BASED-SUPPORTED TASKS

Tasks Supported by Performance-Based Methods as Reported by Agencies	No. of Responses
Tracking of condition, performance, or quality of M&O assets/activities	18
Development of needs-based management estimates	13
Maintenance and operations prioritization	15
Budget development and justification	15
Resource allocation among districts/divisions/regions	11
Analytic relationships between LOS and cost	8
Anticipation of future management requirements in reauthorization Legislation	1
Innovative communications techniques	2
Other tasks	2
No response	0

Note: Respondents could select more than one choice above.

TABLE 7
SURVEY RESULTS: METHODS TO OBTAIN CUSTOMER INPUT

Methods of Obtaining Customer Input	No. of Responses
Telephone or mailed surveys	9
Survey cards (e.g., at rest areas)	4
Trouble and complaint calls	3
Written complaints	2
Focus groups, discussion groups	3
Formally organized citizensí panels	1
Website, social media announcements and responses	3
Other methods	2
No response	1

Note: Respondents could select more than one choice above.

future maintenance spending" ("WSDOT Launches . . ." Oct. 7, 2010). Additional comments by state DOTs were as follows:

- Iowa DOT has done a few large road-user surveys over the past 10 years; the last was completed in 2006.
- Although Ohio DOT does not obtain customer input directly, the department has four quality inspectors who drive all 43,000 lane-miles of state-maintained Interstates and roadways each year, recording maintenance deficiencies from a user's standpoint.
- TxDOT responds to customer concerns received mainly through trouble/complaint calls and written complaints. Many of these address litter, vegetation, and rest areas. Although TxDOT has in the past responded to as many of these complaints as possible as they have been received, under its current budget the department has had to cut back on these types of activities to concentrate more on promoting safety and maintaining the pavement.
- WisDOT has in the past surveyed riders concerning their relative priorities (i.e., asking how they would spend $1 on various maintenance activities); however, the department has not done this recently, and did not respond affirmatively to this question.
- The respondent from Wyoming DOT did respond affirmatively, but noted that the few surveys conducted by the agency are brief and very general, covering the entire span of interest of the DOT. Responses provide little foundation to prioritize efforts at a detailed level.

Industry Input

Most state DOTs do not solicit industry input to their performance-based M&O programs, although such input is actively sought in other contexts (for example, regarding design, contracting, and warranty practices). Some agencies automatically submit proposed changes in relevant policies and practices to local industry groups for review. Requests for such reviews are reflected in the results in Table 8.

TABLE 8
SURVEY RESULTS: METHODS TO OBTAIN INDUSTRY INPUT

Methods of Obtaining Industry Input	No. of Responses
Surveys of industry firms	0
General meetings, agency presentations	3
By-invitation meetings, invited industry presentations	2
Industry/association review and comment on relevant proposed policies and practices	4
Newsletter distribution	1
Website, social media announcements and responses	2
Focus groups, discussion groups on specific topics	1
Formally organized industry advisory panels	2
Other methods	0
No response	1

Note: Respondents could select more than one choice above.

TABLE 9
SURVEY RESULTS: APPLICATION OF PERFORMANCE-BASED MEASURES TO CONTRACTS

For Performance-Based Applications to Contracting, LOS or Performance Measure Values Are:	No. of Responses
The same as those used for agency employee or force account work	7
Defined specifically for contract work, completely separate from force account performance or LOS values	1
A combination of what is expected of force account performance and of contractor performance	4
Other approach	1
No response	1

Note: Respondents could select more than one choice above.

Application of Performance-Based Principles to Contracts

A slight majority of states responding to this question indicated that they do apply performance-based principles to contract work. The methods used are shown in Table 9.

Responding agencies provided the following comments:

- Iowa DOT commented that the performance measures used depend on the M&O function (activity) being performed. Most functions are measured according to the same agency specs that are applied to work by the DOT's own employees. However, sometimes there are additional requirements placed on contracting, and the performance measures or LOS values would be adjusted.
- Wyoming DOT's major contract maintenance work is not assessed in its MQA process. The agency uses other management systems (pavement, bridge, and eventually safety) to assess those needs and the work being done.

Communication of Performance-Based Information

Communication of performance-based information was addressed in two questions in the survey: to whom is information directed, and by what means. Results are presented in Tables 10 and 11. Regarding the intended audience for communications, several "Other" recipients were mentioned:

- Within the Iowa DOT, rest area results are reported in a rest area newsletter available to the general public.
- WisDOT provides this information to Wisconsin county agencies, the state's "contractors" for M&O work.

Other comments received for this question are as follows:

- Iowa DOT transmits a few specific performance measures to the Iowa Department of Management as part of the DOT's performance plan.
- Tennessee DOT reports performance information to the agency group that compiles information called for by Governmental Accounting Standards Board.
- Wyoming DOT observed that anyone with Internet access can access to the summaries of performance results.

Regarding the methods of communication listed in Table 11, "Other" measures used by agencies include internal memos (Arizona); presentations at the Transportation Commission and other meetings (Colorado); community meetings and industry meetings (Virginia); and the "Compass" MQA website (Wisconsin). Further information was provided as follows:

- Iowa DOT added its newsletter to communicate results for rest areas, and a dashboard for results communicated to the state's Department of Management. The department is looking into development of a dashboard or some BI (business intelligence) tools for all of the performance-measures data.
- In addition to its accountability reports, newsletters, and website articles, Wyoming DOT is working on dashboards to post its performance-based results.

Unique Operations-Related Measures

State DOTs were asked about innovative performance measures and LOS they may have defined specifically for operations activities: such as, winter maintenance, ITS devices, traffic signal systems, and incident response. Some of these examples of innovative features and characteristics that were reported include:

- Winter maintenance: for example, definitions of winter storm indexes or of "standard winter storms."
- Traffic signal measures that go beyond consideration of individual signal heads or single intersections to encompass link, corridor, and multijurisdictional effects. These could include measures of signal coordination that more closely relate to mobility improvements.

TABLE 10
SURVEY RESULTS: COMMUNICATION OF PERFORMANCE-BASED INFORMATION

To Whom Performance-Based Information Is Communicated	No. of Responses
Internally within the DOT organization, including bureaus or branches (e.g., motor vehicles)	19
State transportation commission or equivalent	11
Legislature, legislative staff	12
Governor's office, executive staff	9
Other state executive agencies (e.g., financial management, attorney general)	2
State-level task forces or groups (e.g., safety commissions, governmental public protection groups)	2
Other state DOTs, FHWA	5
Professional and industry groups	4
Non-governmental public advocacy groups	1
General public, including via news outlets, Internet postings, social media	8
Others	4
No response	1

Note: Respondents could select more than one choice above.

- ITS device maintenance that reflects performance and reliability; consideration of IntelliDrive devices.
- Performance measures for electronic and environmental sensing systems (as in tunnels) that capture system compatibility of component replacement or that gauge overall system reliability.
- Measures of incident or emergency response that capture safety, mobility, and preservation considerations.

Nine state DOTs responded affirmatively to this question, with responses tabulated in Table 12. Iowa DOT described current work to develop a winter performance measure using traffic speed and post-storm speed recovery time to evaluate maintenance performance. Washington State reported performance measures in two areas other than those listed previously: traveler information ("511" calls), and work zone and highway safety. Other agencies commented that existing performance measures were associated more with maintenance repair rather than operations.

AGENCIES JUST BEGINNING PERFORMANCE-MANAGEMENT DEVELOPMENT

Three agencies are just beginning to implement a performance-based approach for their M&O programs.

- One state has just begun field data collection. Its performance-based approach will deal with contracts as well as state-performed work.
- A second state has selected software to support its performance-based M&O management system, and is now working with the software vendor and a technical

TABLE 11
SURVEY RESULTS: METHODS OF COMMUNICATION

Method of Communicating Performance-Based Information	No. of Responses
Performance-accomplishment reports	15
Newsletters	6
Agency website articles	7
Dashboards, summaries of performance indicators or LOS values	11
Social media announcements	2
Emails, listserv distributions	3
Postal mailings	1
Other method.	4
No response	1

Note: Respondents could select more than one choice above.

TABLE 12
SURVEY RESULTS: INNOVATIVE OPERATIONS MEASURES

Innovative Operations Measures	No. of Responses
Winter maintenance indexes or measures	4
Traffic signal system measures	3
ITS device and other "intelligent" technology measures	1
Electronic system and environmental sensing system measures	1
Incident or emergency response measures	2
Other measures	3
Optional comments	2
No response	11

Note: Respondents could select more than one choice above.

consultant to formulate a performance-based approach and its elements, and to configure and customize the software.
- The third state has engaged a local university to recommend a performance-based approach to managing its M&O program. The project is still in its early stages.

AGENCIES THAT DO NOT NOW USE PERFORMANCE-BASED METHODS

Ten state DOTs responded in the survey that they do not now use performance-based methods to manage their maintenance and programs. Eight of these provided explanations of alternate management approaches they now use, selected from a list of possibilities provided in the questionnaire. These results are presented in Table 13. Responding agencies cited up to three methods used to manage their M&O programs; funding availability was included most often in the responses. The same eight agencies also listed what they perceive as reasons for not moving to a performance-based approach; these reasons are tallied in Table 14. Most agencies cited two or three reasons in combination for not having moved to performance-based M&O management, with an evolving management approach and insufficient resources being the most prevalent. The one agency that cited a single reason selected Insufficient Resources. No additional comments or other factors were provided by these respondents.

SUPPORTING DOCUMENTS

The survey questionnaire provided multiple opportunities for respondents to cite documents describing their M&O performance management process (or conversely, describing other management philosophies in lieu of a performance-based approach). In all, 19 of 41 agencies did so. More than one-third of these references were to existing documents already in MRUTC's the online MQA Document Library [www.mrutc.org/outreach/MQA/library/]. These documents were used as background during the process of identifying case example candidates. However, the great majority of these reports and papers did not directly address the facets of performance-based management applications that were the focus of this synthesis.

Several documents were submitted electronically. These provided a good sense of current agency activity in performance management for M&O, and most of these (with the respective agency's assent) will be forwarded to the Document

TABLE 13
SURVEY RESULTS: OTHER MANAGEMENT APPROACHES USED

Other Methods Used by Agencies in Lieu of Performance Management:	No. of Responses
Annual programs are based upon previous year plus specific adjustments	5
Annual programs are based primarily upon inventory quantities and percentage inventory maintained each year	2
Annual programs are tailored to funding availability, irrespective of inventory, condition, or performance	6
M&O work is being deferred, with a focus on critical items only	4
M&O needs are being met through other programs (e.g., capital repairs or replacement)	0
Other methods	0

Note: Respondents could select more than one choice above.

TABLE 14
SURVEY RESULTS: REASONS FOR NOT ADOPTING
A PERFORMANCE-BASED APPROACH

Reasons for Not Adopting a Performance-Based Approach to Maintenance and Operations	No. of Responses
Our state government has not yet adopted a performance-based philosophy	3
Our agency is satisfied with our current management approach, and does not see a need for a performance-based approach	1
Performance measures and LOS values are inconclusive and difficult to define now	0
Our M&O management approach is evolving, but final decisions have not yet been made	6
We do not have the resources (funding, staffing, equipment) to support a performance-based approach	6
Our current M&O management systems do not support performance measures or performance-based procedures	4
Other reasons	0

Note: Respondents could select more than one choice above.

Library to be made available to the highway maintenance community. To a large degree, these documents represented field data collection and entry manuals, performance measurement and accountability reports, and tables defining or describing elements used in highway maintenance-oriented performance management (condition measures, performance measures, measurable or recordable conditions, LOS, etc.).

As a practical matter, references needed to document applications of M&O performance management for the case examples in chapter three were obtained directly from the respective agency. The information in these documents was supplemented by interviews with agency managers cited in the author's acknowledgements. These state DOT representatives were extremely helpful in filling in the blanks, describing connections among data in various documents, and explaining the rationale behind agency business and decision processes.

SUMMARY OF FINDINGS: NATIONWIDE PRACTICE

Performance-based highway M&O management has been the subject of active research, peer exchanges, and workshops for more than 10 years. The focus of these efforts has been on the "tools of the trade": for example, condition assessment, measures of performance, definitions of LOS, establishment of LOS thresholds, and incorporation of these elements within existing, modified, or new MMSs. Studies of the concepts, methods, and applications of performance-based M&O management have also been performed and have yielded useful understandings of basic trends in management practices. It is also apparent from previous work that state DOTs understand the importance of such key elements in performance-based thinking as the roles of condition assessment data and inventory, establishment of performance standards, the setting of outcome-based performance targets, incorporating customer input, and integration within agency business processes, to name a few. While adopting a nationwide perspective, however, these past studies have been limited in scope and detail, conducted at a very general level or as adjuncts to other research objectives.

This chapter has approached the review of nationwide practice in terms of performance-based M&O management on its own merits. The primary source of data has been a survey of 51 state DOTs plus the District of Columbia, from which 41 responses were received. The responses indicate that at least three-fourths of participating agencies are using or actively developing performance-based M&O management in some way. Practices vary in terms of:

- The highway assets or features that are addressed by performance-based M&O management;
- The types of performance information used (for instance, strategic performance measures reflecting accomplishments of highway capital construction as well as M&O programs versus performance measures oriented specifically to M&O);
- The general purposes to which performance information and management functions are applied, whether solely to track current performance data, determine historical trends, and infer future needs; or to apply to a fuller complement of management needs and tasks; and
- The level of agency maturity/experience in applying and sustaining the systems that underlie performance-based management.

Adding to this overarching variability, past research has demonstrated differences in practice at a detailed level: for example, in the definitions of specific performance measures and LOS, and the quantification of LOS thresholds. Nonetheless, despite the diversity in management prac-

tices, survey results indicate general agreement on key aspects of management technique and supporting activities, among them:

- Performance measures and LOS thresholds currently tend to be defined on a uniform statewide basis. Some variability is allowed for in activities influenced by weather (e.g., winter maintenance) or by traffic volume and degree of urbanization. A unique approach has been adopted by Caltrans in defining zones within the state to account for varying traffic volumes and terrain combined. State DOTs may be willing to consider introducing additional variability in thresholds when the pool of accumulated performance data is deeper.
- The majority of respondents selected a cluster of factors that are important in setting LOS targets: the projected M&O budget, commitments to an agency-established goal or objective, and analytic estimates of LOS values that are realistic to attain and sustain.
- State DOTs tend to look to several management tasks in common to be supported by performance-based methods. These tasks include tracking of condition, performance, and quality; M&O prioritization; budget development and justification; development of needs-based management estimates; resource allocation among field offices; and an understanding of the relationship between LOS and cost. These findings were generally consistent with those of past research.

Survey results provide other examples of commonality in practice. The following chapter will consider another dimension of this, focusing on more in-depth investigations of PBM methods and applications within four state DOTs that have adopted a LOS-based approach.

CHAPTER THREE

CASE EXAMPLES

OVERVIEW OF CASE EXAMPLES

To add depth and detail to the synthesis of national practice in chapter two, this chapter describes four case examples of highway M&O performance management by state DOTs. The cases were selected to illustrate different aspects of performance-based approaches, and to represent different geographic regions to the extent possible. Apart from this desire to reflect diversity in practice, a key consideration in the selection of state DOT cases was the willingness of state DOT personnel to assist in case development and review, and the availability of supporting data and documentation to enable building the case.

The cases are developed in two broad groups: the first, comprising two cases for MDOT and WisDOT, focuses on process issues; the second, comprising FDOT and WSDOT, examines applications of M&O service levels to specific management tasks. Because the process-oriented cases deal with the various components of each performance-based system, they are lengthier than the management-oriented cases, which are focused on the particular issue at hand and which introduce only those aspects of each performance-based approach that are pertinent to the issue.

- MDOT has recently instituted a performance-based M&O management approach based on preliminary definitions of highway maintenance LOS. This work coincides with recent implementation of a new MMS. The case illustrates how the DOT went about defining the components of its performance-based system and strengthened organizational capability to undertake the new approach.
- WisDOT has employed its Compass system for performance-based M&O for almost ten years. WisDOT's approach to M&O is unique nationwide in that it contracts for all of its highway M&O services with the state's 72 counties, placing a premium on the strength of departmental management, communication, and coordination. The state and counties collaborate in updating and applying performance management techniques that meet departmental goals and priorities. Although Compass is considered a mature application, WisDOT systematically pursues business processes that maintain the currency of the system and ensure a high level of work quality. The case describes these business and decision processes with reference to key components of the Compass system.
- FDOT has applied its MRP to highway M&O since the 1980s, qualifying it as a mature performance-management approach employing quantitative LOS. The MRP provides a uniform and consistent method for evaluating the conditions of maintained features on Florida's highway system. This case illustrates the application of MRP data to the prioritization of maintenance work.
- WSDOT has applied its Maintenance Accountability Process (MAP) since the late 1990s, a process also considered to be a mature application of M&O service levels. WSDOT has found MAP to be an important tool in planning and managing its M&O program; communicating accomplishments and potential issues to the legislature, governor, and the public; and establishing credibility and accountability for its program. This case illustrates the application of MAP data to evaluating the implications of an updated WSDOT municipal stormwater permit that affects maintenance service levels for drainage features, a change that has required additional funding.

Although each case is different in its subject, organizational setting, and performance management system used, the descriptions and findings of the cases collectively suggest common themes in performance management practices that relate to specific items of the scope of work. Interviews were held with managers from the subject departments (identified in the author's acknowledgements) to obtain additional information related to these themes. This material is presented in a concluding section entitled "Cross-Cutting Themes."

MISSISSIPPI DEPARTMENT OF TRANSPORTATION

Introduction

MDOT has recently instituted a performance-based maintenance management approach based on preliminary definitions of LOS. This development coincides with implementation of a new MMS in 2010. This new way of managing maintenance is expected to serve a number of performance-related tasks; for example, to track highway system condition and performance; develop needs-based estimates; help prioritize M&O needs and actions; develop and support budget requests; allocate resources among districts; quantify relationships between LOS and cost; and support communication. The case illustrates an early stage of performance-management implementation for M&O. It also illustrates a method of relating LOS values to costs, as for budgeting.

Case Description

New Management System

Through the mid-2000s, MDOT employed a legacy management system based on pass–fail ratings for managing M&O needs. Threshold values of conditions had been defined for assets or deficiencies among several categories of maintained items: pavements, bridges, roadside, traffic services, drainage, and vegetation and aesthetics. Toward the latter part of the decade, MDOT looked to a more performance-based approach to coincide with adoption of a new management system. MDOT purchased the new management system software in 2008, referred to by the agency as Accountability in MDOT Maintenance Operations or AMMO.

AMMO comprises several modules: Work Planning, Work Order Management, Roadway Features, Inspections, Contract Management, Remote Processing, and a GIS capability. The Work Planning module is relevant to this synthesis: It compiles information to estimate needs and budgeted costs based on meeting LOS targets, as described in the following section. Other modules will support additional management tasks; for example, better M&O resource allocation, sharing, and use through the Work Scheduling module; greater standardization and consistency of data-gathering using the Inspections module; and integration of input data from several other departmental management systems, plus communication of output data and results to other agency management functions such as financial accounting ("User Spotlight/Case Study: Mississippi D.O.T." 2010).

System Implementation and Business Process Improvement

MDOT followed a multi-staged trial and evaluation process in acquiring the software and building in desired performance-based capabilities. (The information reported through the remainder of this section has been obtained from "User Spotlight/Case Study: Mississippi D.O.T." 2010, discussions with the MDOT staff member listed in the acknowledgements, and other references as cited here.)

- MDOT senior staff participated in sessions with representatives of the software vendor and technical consultants to review how matters of data, analytic capabilities, internal work-flow, operational decision making, and reporting could best be served by the new performance-based process and AMMO system software.
- A business process review was conducted to identify areas where the agency could improve on its internal business and decision processes with appropriate support from the AMMO modules. Business processes were discussed as existing or "as is" procedures, and desired future or "to be" procedures. As many MDOT needs and expectations as possible were included within these proposed improvements. Interactions with other systems (for example, input from pavement management and bridge management) were also discussed and included in the results.
- MDOT took advantage of AMMO software customization provided by its vendor to preserve the agency's current field data collection form and the familiarity of its staff with existing data recording conventions and procedures.
- The AMMO software was reviewed in stages: an initial software QA review; acceptance testing; and "live" pilot testing within a single district through a two-month period. This pilot-testing district received early training in the uses of AMMO modules as appropriate to various management, supervisory, and staff levels. For example, district management personnel were trained in the application of the performance-based elements important to this synthesis: work planning based on LOS values and targets. Other staff levels were trained in other functions such as maintenance scheduling and data gathering and recording.
- The benefits of pilot testing were assessed in three areas before full-scale implementation: (1) a check on the accuracy of information processed and produced by AMMO; (2) consistency of AMMO use with intended business processes and decisions; and (3) identification of further changes needed in the formal, agency-wide training. Once the pilot tests were completed, MDOT proceeded to department-wide implementation, which was completed by September 1, 2010.
- MDOT has employed a "Train the Trainers" approach in which selected agency employees, who are familiar with computer use and who have received training in AMMO, provide training to each district. This approach is believed by MDOT to ensure consistency in understanding AMMO methodology and its use among maintenance staff statewide.
- The implementation of performance-based concepts within the new AMMO management system will result in an annual work planning cycle based on performance-oriented levels of M&O service. This new approach is expected to help in standardizing business processes and improving MDOT's ability to develop, support, and influence budget requests.

AMMO Data Structure and Procedures

The initial version of the AMMO data structure and procedures is outlined in the *AMMO Data Collection Manual* (*AMMO: Accountability in MDOT Maintenance Operations* Aug. 2009). The *Manual* covers introductory material; specific data collection procedures for roadways, bridges, and rest areas; data management issues; and several appendices discussing data collection criteria for each maintained feature or deficiency, the field data sampling methodology, and specialized information (e.g., noxious weed data), among other topics. Pertinent information for this synthesis includes the high-level data structure shown in Table 15, and examples of the data collection criteria. Because almost 60 individual data collection criteria are defined in the Manual, only four have been selected as illustrations (see Exhibits 1 through 4).

TABLE 15
DATA SOURCES BY MDOT RATED-ASSET FEATURE

Asset Group	Rated Asset Features	Condition Assessment			Inventory		
		UOM	Exists	Source	UOM	Exists	Source
Asphalt Pavement	1. Potholes	No./Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	2. Rutting	Lin Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	3. Stripping	Sq Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	4. Alligator Cracking	Sq Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	5. Area Cracking	Sq Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	6. Linear Cracking	Lin Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	7. Edge Raveling	Lin Ft/Sh Mi	Yes	PMS	Sh Mi	Yes	Research Div.
	8. Shoving	Sq Ft/Ln Mi	No	Field Data	Ln Mi	Yes	Research Div.
	9. Sweeping	Lin Ft/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
Concrete Pavement	1. Spalling	No./Ln	Yes	PMS	Ln Mi	Yes	Research Div.
	2. Faulting	Lin Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	3. Joint Sealing	Lin Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	4. Crack Sealing	Lin Ft/Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	5. Punchouts	No./Ln Mi	Yes	PMS	Ln Mi	Yes	Research Div.
	6. Pumping	No. Slabs/Ln Mi	No	Field Data	Ln Mi	Yes	Research Div.
	7. Sweeping	Lin Ft/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
Paved Shoulders	1. Potholes	No./Sh Mi	No	Field Data	Sh Mi	Yes	Research Div.
	2. Edge Raveling	Lin Ft/Sh Mi	No	Field Data	Sh Mi	Yes	Research Div.
Non-Paved Shoulder	1. Drop Off	Lin Ft/Sh Mi	No	Field Data	Sh Mi	Yes	Research Div.
	2. High Shoulder	Lin Ft/Sh Mi	No	Field Data	Sh Mi	Yes	Research Div.
Drainage	1. Side Drains	Percent	No	Field Data	Number	No	Maint. Div.
	2. Cross Drains	Percent	No	Field Data	Number	No	Maint. Div.
	3. Edge Drains	Percent	No	Field Data	Number	No	Maint. Div.
	4. Unpaved Ditches	Lin Ft/Di Mi	No	Field Data	Di Mi	No	Maint. Div.
	5. Paved Ditches	Lin Ft/Di Mi	No	Field Data	Di Mi	No	Maint. Div.
	(blank)						
	7. Drop Inlets	Percent	No	Field Data	Number	No	Maint. Div.
Roadside	1. Erosion Control - Front Slopes	Lin Ft/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
	2. Erosion Control - Back Slopes	Lin Ft/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
	3. Unpaved Driveway & Street/Road Connection	Percent	No	Field Data	Number	No	Maint. Div.
	4. Mowing	Height (in.)	No	Field Data	Acres	No	Maint. Div.
	5. Brush Control	Lin Ft/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
	6. Dead/Diseased/Hazardous Tree Removal	Number/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
	7. Undesirable Vegetation	Lin Ft/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
	8. MDOT Fences	Percent	No	Field Data	Lin Ft	No	Maint. Div.
	9. Litter Control	Objects/Sh Mi	No	Field Data	Sh Mi	No	Maint. Div.
Traffic	1. Signals	Percent	No	Field Data	Number	Yes	Maint. Div.
	2. Signs - Warning & Regulatory	Percent	No	Field Data	No. Faces	Yes	Traffic Div.
	3. Signs - Other	Percent	No	Field Data	No. Faces	Yes	Traffic Div.
	4. Delineators	Percent	No	Field Data	Number	No	Maint. Div.
	5. Raised Pavement Markers	Percent	Yes	Maint. Div.	Number	Yes	Maint. Div.
	6. Pavement Striping	Lin Ft/Line Mi	No	Field Data	Line Mi	No	Maint. Div.
	7. Pavement Symbols & Legends	Percent	No	Field Data	Sq Ft	No	Maint. Div.
	8. Guardrails	Percent	No	Field Data	Lin Ft	Yes	Traffic Div.
	9. Barrier Walls	Percent	No		Lin Ft	No	Maint. Div.
	10. Impact Attenuators	Percent	Yes	Maint. Div.	Number	Yes	Maint. Div.
	11. Highway Lighting	Percent	No	Field Data	No. Lamps	No	Maint. Div.
Bridges	1. Painting	Percent	Yes	PONTIS	Lin Ft	Yes	Bridge Div.
	2. Approaches	Percent	No	Bridge Div.	No. Appr.	Yes	Bridge Div.
	3. Deck Holes & Spalls	No./Br Ln Mi	Yes	PONTIS	Br Ln Mi	Yes	Bridge Div.
	4. Deck Cracking	Lin Ft/Br Ln Mi	Yes	PONTIS	Br Ln Mi	Yes	Bridge Div.
	5. Deck Joints	No./Br Ln Mi	Yes	PONTIS	Lin Ft	Yes	Bridge Div.
	6. Drain Holes	Percent	No	Bridge Div.	Number	No	Bridge Div.
	7. Railings & Wheel Guards	Percent	Yes	PONTIS	Lin Ft	Yes	Bridge Div.
	8. Sweeping	Lin Ft/Br Mi	No	Bridge Div.	No. Br	Yes	Bridge Div.
	9. Undesirable Vegetation	Lin Ft/Br Mi	No	Bridge Div.	No. Br	Yes	Bridge Div.
Rest Areas	1. Janitorial Services	Condition Rating	No	Field Data	Number	Yes	Maint. Div.
	2. Buildings and Appurtenances	Condition Rating	No	Field Data	Number	Yes	Maint. Div.
	3. Landscaping	Condition Rating	No	Field Data	Number	Yes	Maint. Div.

Source: *AMMO: Accountability…* (Aug. 2009). *Notes*: UOM = unit of measure; Div. = Division; No. = number of…; Sh Mi = shoulder-mile. (Other units of measure employ commonly used abbreviations. "Line Mi" refers to the length of the pavement stripe in miles, and is not a typographical error for "Lane Mile.")

EXHIBIT 1
ASPHALT PAVEMENT, ALLIGATOR CRACKING

Asset Group: Asphalt Pavement	**Date:** June 2007
Maintenance Feature: Alligator Cracking	
Definition: Alligator cracking is the type of cracking that makes the surface look somewhat like an alligator's hide, with a mostly rectangular pattern of cracks. This type of cracking is usually associated with base failure.	
Measurement Unit: Inventory: Asphalt lane-miles Condition: Surface area with alligator cracking, expressed as square feet per asphalt lane-mile	
Inspection Procedure: The average square feet of alligator cracking per asphalt lane-mile will be obtained from PMS data from the MDOT Research Division, for each district and road class. Should PMS data not be available, the data will be collected at the sample sites in the field. For each sample on asphalt-surfaced pavements, inspect the paved surface for alligator cracking. Measure the total length and average width of each distressed area. Record the total square feet of alligator cracking for all lanes. It will be helpful to have a clipboard and notepad to jot down the size of each distressed area and calculate the total distressed area in the sample section.	

Source: *AMMO: Accountability in MDOT Maintenance Operations* Aug. 2009, Appendix A.

EXHIBIT 2
ROADSIDE, LITTER CONTROL

Asset Group: Roadside	**Date:** June 2007
Maintenance Feature: Litter Control	
Definition: Litter and debris consists of any unwanted objects on the highway right-of-way that are fist-size or larger, including trash, materials that have fallen off vehicles, and dead animals. (Note that rocks and tree limbs are not counted here, unless they are on the travel lanes or shoulders, but are included in the Erosion Control and Tree Removal categories.)	
Measurement Unit: Inventory: N/A Condition: Number of fist-size objects, as expressed in objects per shoulder-mile	
Inspection Procedure: Inspect the right-of-way in the sample area for litter and debris. Count and record the total number of fist-size or larger objects.	

Source: *AMMO: Accountability in MDOT Maintenance Operations* Aug. 2009, Appendix A.

EXHIBIT 3
TRAFFIC SERVICES, SIGNALS

Asset Group: Traffic Services	**Date:** June 2007
Maintenance Feature: Signals	
Definition: Traffic signals include all electronic devices that control or warn traffic, except variable message signs. Traffic signals include traffic control signals (stop lights), flashing beacons, and lane-use control signals.	
Measurement Unit: Inventory: Number of traffic signals Condition: Number of traffic signals not fully functional	
Inspection Procedure: Signal condition data will be collected at the sample sites in the field. For each sample with one or more traffic signals, inspect all signals within the sample area for proper functioning. A signal is considered to be nonfunctional when any of the following conditions exist: 1. Any one or a combination of lamps in the signal head are not lit during several cycles. 2. Signal missing or damaged to the extent that traffic is not being effectively controlled. 3. Signal phasing is not cycling properly (e.g., locked into one phase or displaying conflicting phases). 4. Controller cabinet is damaged to the extent that it affects signal functions. Record the total number of signals and the total number of nonfunctioning signals in the sample area. In the case of an intersection on a divided highway, count and rate all signals facing the sample area.	

Source: *AMMO: Accountability in MDOT Maintenance Operations* Aug. 2009, Appendix A.

EXHIBIT 4
TRAFFIC SERVICES, PAVEMENT STRIPING

Asset Group: Traffic Services	**Date:** June 2007
Maintenance Feature: Pavement Striping	
Definition: Pavement striping includes all linear markings on the travel lanes, including centerlines, lane stripes, no-passing stripes, and pavement edge lines. Materials may include paint and hot and cold tape applications.	
Measurement Unit: Inventory: Linear feet of pavement striping Condition: Linear feet of deficient striping	
Inspection Procedure: Striping data will be collected at the sample sites in the field. Inspect the pavement stripes within the sample area for deficiencies. Any length of stripe that is faded, worn, or missing is considered to be deficient. Measure and record the total length of all pavement stripes and the total length of deficient stripes in the sample area. If a retroreflectometer is available, take two measurements on each of the two edge lines and two measurements on the centerline or the left line of the right lane, if more than two lanes are present. It is ok to take a reading on a dew covered stripe, but not if it is really wet such as after a rain storm. Note that the sample area is 528 feet in length. In most two-lane samples, there will be two edge lines and one centerline, or a total inventory length of 1,584 feet (skip lines are considered to be continuous for condition rating purposes).	

Source: *AMMO: Accountability in MDOT Maintenance Operations* Aug. 2009, Appendix A.

- The data structure in Table 15 illustrates several points about the information base that will be used by the new management approach:
  - The table lists asset features and conditions to be encompassed by AMMO, with respective units of measure for condition and for inventory.
  - Notations indicate whether or not the information currently exists, suggesting future efforts to gather and build a new body of information on condition (and, ultimately, historical trends in condition) and inventory. (Since AMMO implementation is ongoing, some items labeled "No data currently existing" in Table 15 may now have such data.)
  - The table identifies sources of information on condition and inventory, including several systems and divisions outside of maintenance proper. AMMO has been designed to accommodate exchanges of information with other systems on both input and output. This point also indicates that data collection is a shared responsibility within MDOT as the result of system integration.
- The criteria in Exhibits 1 through 4 describe the procedures to be used to obtain quantitative information on feature condition or level of deficiency. The four exhibits illustrate different types of features and deficiencies: alligator cracking in asphalt pavements, pavement striping, traffic signals, and litter control. Analogous criteria have been defined for each of the rated asset features listed in Table 15, and are included in Appendix A of the *AMMO Data Collection Manual.* The LOS values that are obtained based on these criteria will be applied directly in the LOS procedures discussed in the next section.

Performance-Based Application

Relating LOS to Cost

MDOT has defined preliminary values of LOS to launch its performance-based approach to M&O: see Table 16 for LOS definitions for the four maintenance asset elements discussed earlier. (As before, analogous LOS definitions have been stated in preliminary form for all maintenance features or deficiencies listed in Table 15.) Since the AMMO system is new and still evolving, these values may be revised as the department gains experience with their use. Furthermore, because historical information is lacking on the application of the system and its LOS values to various management tasks, the topic that was discussed with the MDOT managerial contact concerned the relationship of LOS to cost, as would be used in budgeting, cost tracking, and estimates of remaining work realistically possible with remaining funds.

Central to this relationship between LOS and cost is the quantitative nature of the LOS values themselves: they all can be related to a numerically measureable amount of work accomplishment. MMSs can, in turn, relate work accomplishment to cost, using methods that have been understood and applied by maintenance managers for more than 40 years through legacy MMSs. The nature of these computations is summarized here. Associated management steps needed to fulfill these computations are as follows, as currently envisioned by MDOT:

- Each fiscal year, headquarters M&O management sets LOS target values and inserts them in AMMO. These targets are set statewide by letter-grade rating shown in Table 16; the targets may also account for the relative priority of a maintenance element (Table 16, column 1) or asset group (Table 15, column 1; e.g., pavements may have higher priority than roadside elements), as well as any extraordinary needs that may exist (e.g., owing to disasters and emergency repairs). In addition to these influences, target-setting is a function of internal management and engineering analyses that indicate what is realistic to accomplish given anticipated budget.
- Actual LOS values are determined from the condition ratings obtained through maintenance inspections

TABLE 16
EXAMPLES OF MDOT PRELIMINARY LOS DEFINITIONS

Maintenance Element	LOS Measure	Levels of Service				
		A	B	C	D	F
Asphalt Pavement						
Alligator cracking	% of surface area distressed	0	0–10	10–20	20–30	>30
Roadside						
Litter control	Number of fist-size objects per shoulder mile	0–50	50–100	100–300	300–500	>500
Traffic Services						
Signals	% of signals defective	0–1	1–5	5–10	10-15	>15
Striping	% of total length defective	0–2	2–5	5–15	15–30	>30

Source: Mississippi DOT.

each fiscal year. Processing of inspection data, which are drawn from a sample of highway segments, is as described in the criteria illustrated in Exhibits 1 through 4. Condition data can be compared with the threshold criteria in Table 16 to determine actual LOS for each feature or deficiency at the district and statewide levels. Where actual LOS values are below target, the respective district will be responsible for meeting the target.

- The gap between target and actual LOS reflects a quantitative amount of work that is needed to be accomplished. For the four illustrative examples used in this case, work needs would be measured as follows:
  - Alligator cracking: the area of alligator cracking in square feet per asphalt lane-mile is obtained from the pavement management system (Exhibit 1), which can be converted to percent of surface area distressed for use with data in Table 16.
  - Litter control: number of fist-size objects per shoulder-mile. (MDOT assumes a shoulder at each pavement edge; a two-lane road would therefore have two shoulders, implying two-shoulder-miles per centerline mile. A divided highway with median would have four-shoulder-miles per centerline mile.)
  - Traffic signals: percent of signals that are defective.
  - Pavement striping: lineal feet of stripe per line-mile that is defective, which is easily converted to percent of stripe length defective.
  - For brevity, the remainder of the example is described for only the first work example, asphalt pavement alligator cracking.
- The percent area distressed enables LOS to be determined as A, B, C, D, or F, using the criteria in Table 16.
- MDOT applies performance standards (which are different from performance measures) to calculate resources needed to perform the work to bring asphalt pavements up to the LOS target for alligator cracking. Performance standards identify the resource usage or inputs needed to repair (fill or patch) one square foot of alligator cracking in terms of total labor-hours or labor-days, equipment hours, and materials consumed; and (2) the hourly or daily production rate (e.g., square feet per day), which enables a calculation of total hours onsite. Performance standards are defined on an average statewide basis based on historical data, and are assumed to hold across all LOS.
- Unit prices of each class of labor, equipment, and materials are applied to the respective resource usages to calculate total cost of the maintenance action. Unit prices are determined based on average statewide price data, and are assumed to hold across all LOS. The total cost of this work identifies the cost of bringing the asphalt pavement up to the LOS target.
- The LOS–cost relationship will be helpful in the future in developing and defending the proposed M&O budget. Given the newness of AMMO, MDOT is in a transition period in which budget discussions with upper management are based on a combination of planned maintenance work production (lane-miles to be paved, grass to be mowed, etc.), and target LOS to indicate the directions and priorities toward which the maintenance program is headed. Discussions are held with the MDOT budget director, chief engineer, and the executive office, as well as the transporta-tion commission and the legislature. Currently, high-way revenues are flat, so the budget director is constrained in his or her latitude in addressing LOS targets; to date, however, communication has worked well.

Additional Performance-Based Aspects

In its survey responses, MDOT reported other aspects of its operations that contribute to an effective performance-based program:

- MDOT identified a number of tasks that it anticipates will be served by AMMO when fully implemented. These tasks include tracking condition and performance, developing needs-based estimates, prioritizing M&O actions, developing and justifying budget proposals, allocating resources among districts, relating LOS to the cost of M&O, and anticipating performance-oriented business procedures that may be included in future federal transportation reauthorization.
- MDOT surveys its customers on their perceptions of how well Mississippi highways are being maintained. Customer information is gathered through telephone or mailed surveys and in focus groups or discussion groups. A copy of MDOT's customer survey form for telephone use is included in Appendix C.
- Reporting of performance accountability is still in the early stages with respect to the new AMMO system. Performance-related communications are planned both within the agency and from the agency to the transportation commission. Performance-accomplishment reports and MDOT website articles are two proposed mechanisms.
- Communications to agency district and field staff regarding implementation and use of AMMO have been ongoing, using quick reference guides, and additional booklets are planned.

Concluding Remarks

- MDOT has made the decision to incorporate performance management and performance-based elements directly and immediately within its M&O business

process redevelopment and its adoption of AMMO, a modern, enhanced MMS. It is now beginning to use these new elements as part of its updated business and decision processes.

- MDOT employed an implementation process involving planning, testing, and verification steps for merging business and software requirements.
  - It balanced business process needs against software functionality, focusing on both what is needed immediately and what enhancements might be possible in the future.
  - It preserved existing capabilities that worked well, customizing AMMO's features accordingly.
  - It explicitly considered opportunities to improve the existing business process, with ideas from performance management contributing to an expanded view of what new approaches were possible.
  - From the business side, a number of issues were identified ahead of time that could be incorporated directly into the new AMMO architecture such as desired performance-based elements, highway asset features, deficiencies, data needs, LOS criteria, and system functionality.
  - From the systems side, a step-by-step process of system review, pilot testing, and implementation ensured a reliable product that was responsive to the updated business cycle and MDOT's decision-making needs.
  - Other activities were integrated into the AMMO and performance-management development cycle: early training prior to pilot testing, a more formal full training program based on a "Train the Trainer" concept, and employee-developed quick reference guides to aid in AMMO implementation.
- The pilot-testing approach helped in ensuring that AMMO operation was consistent with MDOT's business processes, verifying data handling and computations, and validating and improving the training curriculum.
- As implementation of performance management and AMMO proceeds, LOS are beginning to become part of the conversations regarding the M&O budget. However, given the current level funding environment, MDOT is constrained in the degree to which it can adjust funding amounts to achieve desired improvements in LOS.
- MDOT has recognized the importance of good communication internally and externally, in both sending and receiving information. During the transition period to the new AMMO system and performance-based business process, it has targeted the need for effective performance reporting and management accountability, and the need to transmit accurate, helpful, and consistent guidance on implementing the new AMMO system and performance-based capabilities. It has also continued to solicit information from its customers on the quality of maintenance services that it provides.

WISCONSIN DEPARTMENT OF TRANSPORTATION

Introduction

WisDOT's performance-based approach is called Compass. Work on Compass began in 2001 based on the findings and recommendations in *NCHRP Report 422* (Stivers et al. 1999). The Compass effort was put through a pilot program for six months, and the system has been operational since 2002 (Lebwohl 2003). The WisDOT managers of Compass have continually sought to improve its analytic features and its application to a number of management topics in evaluating system performance, establishing maintenance policy (in terms of targets) and budget, and program monitoring and accountability. Several of these business applications are covered here, particularly with respect to target-setting, communication and use of targets, reflection of maintenance priority within LOS, and relationship of LOS to cost. This case illustrates a mature application of LOS concepts and methods that continues to evolve toward more sophisticated implementation of performance-management principles. The case is unique also because WisDOT contracts with Wisconsin's 72 counties for 100% of its highway maintenance—the only state DOT with such a contracting arrangement.

The Compass features and capabilities described in the following sections are the products of primarily the WisDOT staff from central and field offices. This culture, which values internal leadership and accomplishment extends back to the initiation of Compass, when WisDOT decided to dedicate a full-time manager to the program in lieu of contracting with a consultant. Internal leadership increased program credibility, improved relationships with field managers, and promoted greater organizational knowledge (given the large number of players involved) among central office staff. (WisDOT also worked to avoid pitfalls in this approach, including inflated expectations resulting from early successes.) Consultants have been brought in to address specific tasks within the overall Compass framework; for example, training design and data modeling (Lebwohl 2003).

Case Description

Compass Ratings Overview

The Compass program addresses 27 maintainable features related to shoulders, drainage, roadsides, and traffic control and safety devices. Condition data on these features are obtained annually on a sample of 1,200 randomly selected, one-tenth mile road segments. Guidelines on field data col-

lection are contained in the *Compass Rating Manual* (*Rating Manual—Compass* Sum. 2010); the associated Rating Sheet is displayed in Figure 5. The *Rating Manual* and Rating Sheet together identify the measurement techniques and deficiency thresholds that drive the ratings process. To provide a sense of this guidance, Table 17 shows selected information from the *Rating Manual* and Sheet for four of the 27 Compass features. The *Rating Manual* also describes methods of measurement, which are not shown in this table.

The rating guidelines in Table 17 provide the basis for identifying deficient segments backlogged for maintenance. These guidelines are reviewed and updated periodically by a WisDOT ratings team drawn from two departmental units: the Division of Transportation System Development and the Bureau of Highway Maintenance (formerly the Bureau of Operations), and spearheaded by the compass program manager. Before proceeding to the analytic aspects of LOS valuation, however, it is helpful to review the concepts and guidelines underlying M&O service levels as perceived by WisDOT.

LOS Concepts

WisDOT M&O LOS are ultimately expressed in letter grades A-B-C-D-F. Conceptual interpretations have been assigned to each of these grades to assist in applying them across a diverse set of highway features, conditions, and M&O actions. These qualitative descriptions, which express several general characteristics of each LOS letter grade, can then be translated into quantitative representations of LOS for each road feature that build on the field data in Table 17. For brevity, three such sets of characteristics are presented here, for LOS A, C, and F respectively. The complete list for all LOS values, as well as photographs that illustrate different LOS grades for several road features, are contained in WisDOT's "highway maintenance and operations story" document (*Highway Operations* 2005).

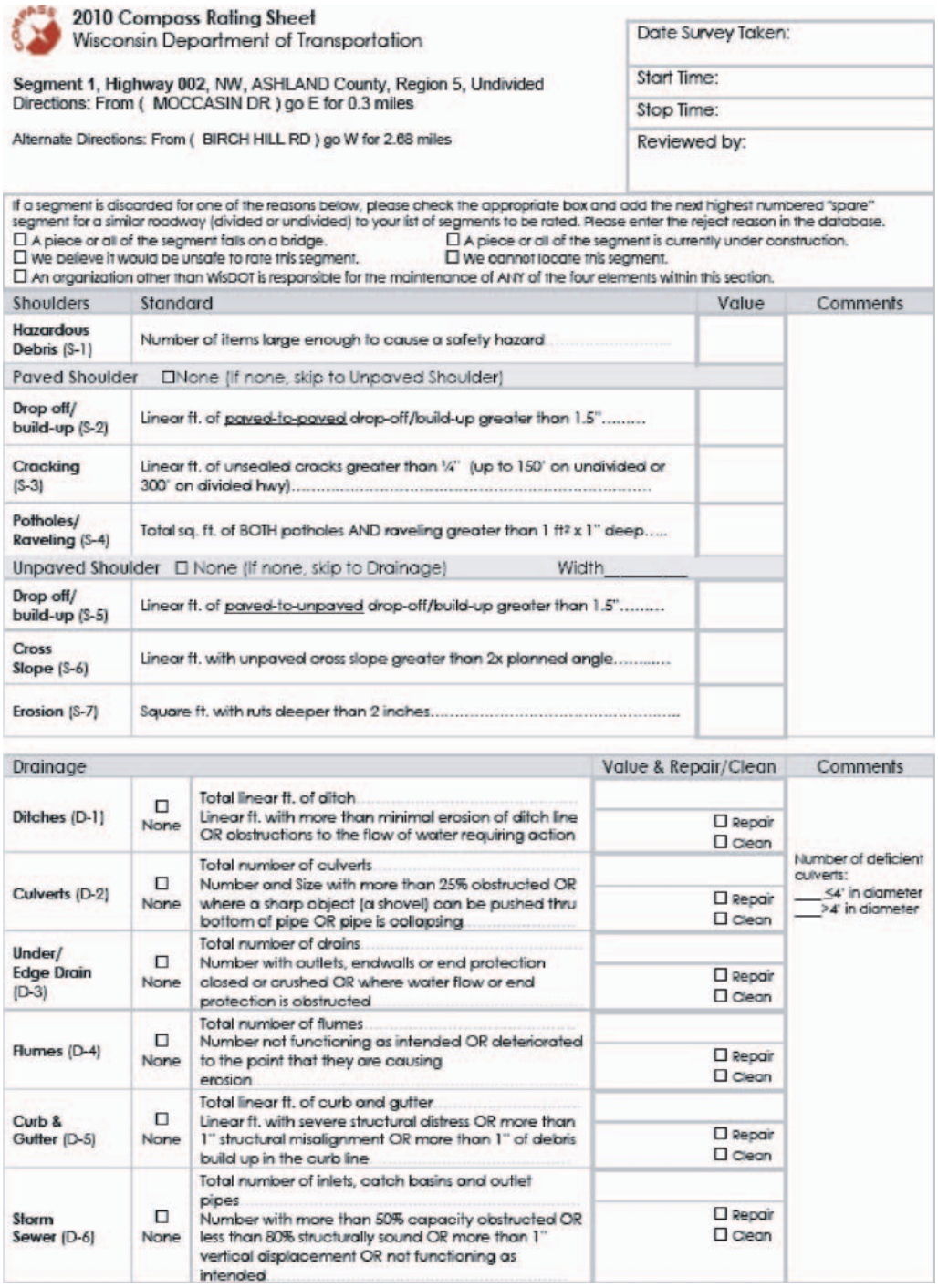
- Service level A is the highest service level in which the roadway and associated features are in excellent condition.
  - Systems are operational and users experience almost no unexpected delays.
  - At this maintenance service level, very few deficiencies are present and the overall appearance is pleasing.
  - Preventive and routine maintenance is practiced on a regular basis, requiring minimal corrective maintenance.
- Service level C is a medium service level in which the roadway and associated features are in fair condition.
  - Highway features may occasionally be inoperable or unavailable to users.
  - Short, unexpected delays are more frequent, resulting in minor safety impacts.
  - Some deficiencies are present in safety-related activities, moderate deficiencies for investment protection activities, and significant deficiencies in highway appearance and roadside aesthetics.
  - Preventive maintenance is deferred for most activities, except safety-critical work.
  - More emphasis is placed on routine maintenance activities, with corrective maintenance as necessary.
  - A backlog of deficiencies begins to build.
  - Some structural problems begin to appear as a result of long-term deterioration of the system.
- Service level F is the lowest maintenance service level in which the roadway and associated features are in poor and failing condition.
  - Unexpected delays occur regularly.
  - Significant deficiencies are present in all maintenance activities.
  - The overall appearance is extremely poor.
  - Preventive maintenance is not practiced for any maintenance activities.
  - Maintenance is reactive, correcting problems after they occur.
  - Excessive safety problems persist.
  - Road conditions have deteriorated until maintenance treatments are not enough to correct deficiencies, necessitating high-cost remedial construction preservation projects in the future.

Defining LOS Thresholds and Grading Curves

LOS threshold values and grading curves depend on how critical a feature is judged to be, particularly regarding consequences to road users and preservation of investment, an issue important to both the agency and road users. WisDOT has defined five levels of criticality, referred to as *contribution categories:*

- *Critical Safety:* Features that would necessitate immediate action—with overtime pay if necessary—to remedy if not properly functioning.
- *Safety/Mobility:* Highway features and characteristics that protect users against—and provide them with a clear sense of freedom from—danger, injury, or damage.
- *Ride/Comfort:* Highway features and characteristics, such as ride quality, proper signing, or lack of obstructions, that provide a state of ease and quiet enjoyment for highway users.
- *Stewardship:* Actions taken to help a highway element reach its full potential service life.
- *Aesthetics:* The beautification of a highway corridor, including landscaping or decorative structures; the absence of things such as litter and graffiti or other elements that detract from the sightlines of the road.

Each road element and feature is assigned to a single contribution category as shown in Table 18. Based on this assignment, and considering the LOS information discussed previously, WisDOT managers have developed LOS threshold



2010 Compass Rating Sheet
Wisconsin Department of Transportation

Date Survey Taken:
Start Time:
Stop Time:
Reviewed by:

Segment 1, Highway 002, NW, ASHLAND County, Region 5, Undivided
Directions: From (MOCCASIN DR) go E for 0.3 miles

Alternate Directions: From (BIRCH HILL RD) go W for 2.68 miles

If a segment is discarded for one of the reasons below, please check the appropriate box and add the next highest numbered "spare" segment for a similar roadway (divided or undivided) to your list of segments to be rated. Please enter the reject reason in the database.
☐ A piece or all of the segment falls on a bridge.
☐ A piece or all of the segment is currently under construction.
☐ We believe it would be unsafe to rate this segment.
☐ We cannot locate this segment.
☐ An organization other than WisDOT is responsible for the maintenance of ANY of the four elements within this section.

Shoulders	Standard	Value	Comments
Hazardous Debris (S-1)	Number of items large enough to cause a safety hazard		
Paved Shoulder	☐None (If none, skip to Unpaved Shoulder)		
Drop off/ build-up (S-2)	Linear ft. of paved-to-paved drop-off/build-up greater than 1.5"		
Cracking (S-3)	Linear ft. of unsealed cracks greater than ¼" (up to 150' on undivided or 300' on divided hwy)		
Potholes/ Raveling (S-4)	Total sq. ft. of BOTH potholes AND raveling greater than 1 ft² x 1" deep		
Unpaved Shoulder	☐ None (If none, skip to Drainage) Width_____		
Drop off/ build-up (S-5)	Linear ft. of paved-to-unpaved drop-off/build-up greater than 1.5"		
Cross Slope (S-6)	Linear ft. with unpaved cross slope greater than 2x planned angle		
Erosion (S-7)	Square ft. with ruts deeper than 2 inches		

Drainage			Value & Repair/Clean	Comments
Ditches (D-1)	☐ None	Total linear ft. of ditch Linear ft. with more than minimal erosion of ditch line OR obstructions to the flow of water requiring action	☐ Repair ☐ Clean	Number of deficient culverts: ___≤4" in diameter ___>4" in diameter
Culverts (D-2)	☐ None	Total number of culverts Number and Size with more than 25% obstructed OR where a sharp object (a shovel) can be pushed thru bottom of pipe OR pipe is collapsing	☐ Repair ☐ Clean	
Under/ Edge Drain (D-3)	☐ None	Total number of drains Number with outlets, endwalls or end protection closed or crushed OR where water flow or end protection is obstructed	☐ Repair ☐ Clean	
Flumes (D-4)	☐ None	Total number of flumes Number not functioning as intended OR deteriorated to the point that they are causing erosion	☐ Repair ☐ Clean	
Curb & Gutter (D-5)	☐ None	Total linear ft. of curb and gutter Linear ft. with severe structural distress OR more than 1" structural misalignment OR more than 1" of debris build up in the curb line	☐ Repair ☐ Clean	
Storm Sewer (D-6)	☐ None	Total number of inlets, catch basins and outlet pipes Number with more than 50% capacity obstructed OR less than 80% structurally sound OR more than 1" vertical displacement OR not functioning as intended	☐ Repair ☐ Clean	

FIGURE 5 Compass rating form (page 1 of 2). *Source*: Wisconsin DOT.

values and grading curves that reflect the consequences of a level of deficiency in a road feature, the relative importance of the feature to the driving public, and the contribution of the feature to the roadway network (i.e., the contribution category in Table 18).

The grading curves have numerical values. The curves are presented in descending order of importance: Critical Safety, Safety/Mobility, Ride/Comfort, Stewardship, and Aesthetics. The five percentages in each curve correspond to the upper value of the threshold interval for each LOS grade A, B, C, D, or F. (These numerical values will be explained further.)

- Critical Safety: 2%, 5%, 9%, 15%, and >15%.
- Safety/Mobility: 4%, 9%, 18%, 30%, >30%; also 5%, 12%, 23%, 40%, >40%.
- Ride/Comfort: 6%, 15%, 29%, 50%, >50%; also 7%, 18%, 35%, 60%, >60%.

Roadsides			Value	Comments
Litter (R-1)		Number of pieces (up to 15) of litter & non-natural encroachments on shoulders & roadside visible at posted speed, but not causing a safety threat		☐ Canada Thistle ☐ Field Bindweed ☐ Leafy Spurge
Mowing (R-2)		Mowing meets standard If NO, grass is mowed: ☐ too wide ☐ too short ☐ too tall ☐ in a no mow zone If NO, why: ☐ safety/equipment ☐ mowed by property owner ☐ woody vegetation control ☐ maintenance decision	☐yes ☐no	
Mowing Vision (R-2)	☐ None	Grass blocks a vision triangle or sightlines	☐yes ☐no	
Noxious Weeds (R-3)		Visible clumps of noxious weeds are present and type(s) of noxious weeds present	☐yes ☐no	
Woody Vegetation (R-4)		Number of instances in which a tree > 4" in diameter is present in the clear zone OR trees and/or branches overhang the roadway or shoulder creating a clearance problem		
Woody Vegetation Vision (R-4)		Woody vegetation causes a vision problem	☐yes ☐no	
Fences (R-5)	☐ None	Total linear ft. of right-of-way fence Linear ft. missing OR not functioning as intended		

Traffic Control and Safety			Value	Comments
Centerline Markings (T-1)	☐ None	Over total segment, > 20% centerline material missing	☐yes ☐no	
Edgeline Markings (T-1)	☐ None	Over total segment, > 20% edgeline material missing	☐yes ☐no	
Special Pavement Markings (T-2)	☐ None	Total number of special pavement markings Number missing OR not functioning as intended		
Regulatory/ Warning Signs (T-3)	☐ None	Total number of regulatory/warning signs Number missing OR damaged		
Other Signs (T-4)	☐ None	Total number of other signs Number missing OR damaged		
Delineators (T-5)	☐ None	Total number of delineators Number missing OR damaged		
Protective Barriers (T-6)	☐ None	Total linear ft. of beam guard, concrete barrier, and cable guard Linear ft. of protective barriers not functioning as intended and type of deficient protective barrier(s)	☐ Beam Guard ☐ Damaged Terminal ☐ Concrete Barrier ☐ Cable Guard	

Indicates some or all of feature rating must be completed while driving at posted speed OR rated through the eyes of a driver traveling at posted speed.

1/10-mile	528 ft
X2	1056 ft
X3	1584 ft
X4	2112 ft

Rating Sheets should be entered into the LAN database **by October 15, 2010.** Please send the hardcopy Rating Sheets Inter-D to Scott Bush, Hill Farms, Room 501 **by October 15, 2010.**

Questions? Please call Scott Bush, Compass Program Manager at 608-266-8666 or email him at Scott.Bush@dot.wi.gov

FIGURE 5 Compass rating form (page 2 of 2). *Source*: Wisconsin DOT.

- Stewardship: 7%, 18%, 35%, 60%, and >60%; also 9%, 22%, 41%, 70%, >70%.
- Aesthetics: 10%, 25%, 47%, 80%, >80%.

For example, consider the Critical Safety category. The thresholds defining the intervals of each LOS grade would be as follows, using the information cited previously: A = 0% to 2%; B ≥ 2% to 5%; C ≥ 5% to 9%; D ≥ 9% to 15%; and F ≥ 15%. Again, a grading curve provides the percentages that are at the top of the interval covered by each letter grade A, B, C, D, and F. Several contribution categories have two grading curves, allowing additional latitude in distinguishing between more and less critical items within those categories. The most important features—those related to Critical Safety—have a stricter grading curve than the other four categories.

Bringing all the concepts in this section together yields the threshold values and grade ranges for Compass road features shown in Table 19. This table guides the Compass system in determining the current LOS of highway features, the calculation of which will be illustrated shortly. The term "percent backlogged" used in the table header refers to the relative number of one-tenth-mile segments that require maintenance work on a feature. The setting of target values is described in the next section.

Target Setting

WisDOT develops maintenance targets annually based on existing conditions, department policies and priorities, and available funding. The Compass program manager develops

TABLE 17
RATINGS INFORMATION FOR FOUR COMPASS HIGHWAY FEATURES

Feature: Condition	Definition of Condition	Compass Standard	Reporting Measure	Comments
Shoulders: Cracking	A stress fracture in rigid or flexible pavement. Includes alligator cracking	All unsealed cracking greater than ¼ inch in width	Linear feet of cracking	Use for paved shoulders only. Helpful tools include ruler and measuring wheel.
Roadsides: Litter	Any objects that should not be there, including illegal signs. This includes litter on the shoulder that is not a safety threat. It also includes dead animals on the roadside.	Visible at posted speed	Number of instances (up to 15) of litter	"Visible at posted speed" is used as the standard to accurately reflect the experience of drivers. So something you can see walking, but not driving, should not be counted.
Drainage: Ditches	Channels that are parallel to the roadway for the purpose of carrying runoff and that have an inslope and a back slope on the right-of-way.	Greater than minimal erosion of ditch line *or* Obstructions to the flow of water that require action.	-Total linear feet of ditches. -Linear feet of deficient ditches. -Deficient ditches needing "Repair," "Clean," or both.	Private entrance culverts should be evaluated while rating this element. They may be the obstruction requiring action. Helpful tools include: measuring wheel.
Traffic: Centerline and Edge Line Markings	*Centerline*—Yellow lines, solid or dashed, dividing opposing travel directions on roads. Also includes white dashed lines on multi-lane roads used to divide lanes traveling in the same direction. *Edge line*—White solid lines used to indicate the edge of the traveled roadway. On multi-lane roadways, yellow solid line on left of traveled roadway is included.	>20% of total material missing.	Absence of >20% of total material (yes/no)	Roads with curb and gutter may not have edge line. Roads without curb and gutter should have edge line. A road without curb and gutter *and* without edge line on either side would have deficient edge line. Check "None": For edge line, only if curb and gutter are present and there is no edge line.

Source: *Compass Rating Manual.*

draft targets with the maintenance supervisors in the WisDOT regions; the operations managers (who supervise the maintenance supervisors) finalize the targets. To help develop realistic targets, managers and supervisors review the existing maintenance budget, conditions over the past 5 years, existing conditions across the five WisDOT regions, and targets from the past 5 years. A "targets history" spreadsheet is prepared that compiles this information for this review. Entries in the targets history spreadsheet are of the form "*nn* = *g*" where *nn* is the percent backlogged and *g* is the feature grade on the A through F scale. Thus, "30 = *C*" would translate to 30% backlogged on a feature that is rated *C*. This type of information is entered in the matrix for every feature and for both target and actual results for the past 5 years. The target values for the coming year are also shown. For example, the matrix prepared in 2010 shows target and actual entries for 2005 through 2009, plus the targets for 2011. A "targets memo" supplements the quantitative targets with qualitative information on the department's maintenance priorities. The central office distributes the target information with the budget information each fall, to help the WisDOT region offices negotiate the annual work plans and Routine Maintenance Agreements with counties for the following year (recall that WisDOT contracts all winter and non-winter maintenance with the 72 counties in the state).

The spreadsheet with the 5-year historical information has helped the maintenance supervisors develop more reasonable target levels, given current highway condition and funding availability. The inclusion of previous targets together with historical condition data have helped create an objective picture of the implications of past target settings. Breakouts of existing conditions by region have also helped managers and supervisors to assess more accurately what is can be accomplished in the next year. WisDOT's experience is that targets have become more realistic and therefore more attainable because of the information distributed by means of the spreadsheet.

The maintenance priorities in the targets memo provide a further context to the target-setting exercise by assessing the

TABLE 18
COMPASS FEATURE CONTRIBUTION CATEGORIES

		This Feature Contributes Primarily To:				
Element	Feature	Critical Safety	Safety/ Mobility	Ride/ Comfort	Stewardship	Aesthetics
Traffic and Safety	Centerline markings	✓				
	Delineators		✓			
	Edge line markings		✓			
	Detour/object marker/ recreation/guide signs (emergency repair)		✓			
	Detour/ object marker/recreation/ guide signs (routine repair)			✓		
	Protective barriers		✓			
	Reg./warning signs (emergency)	✓				
	Reg./warning signs (routine)		✓			
	Special pavement markings		✓			
Shoulders	Hazardous debris	✓				
	Cracking (paved)				✓	
	Potholes/raveling (paved)			✓		
	Cross-slope (unpaved)			✓		
	Drop-off/build-up (unpaved)	✓				
	Erosion (unpaved)				✓	
Drainage	Culverts				✓	
	Curb and gutter				✓	
	Ditches				✓	
	Flumes				✓	
	Storm sewer system				✓	
	Underdrains/edge-drains				✓	
Roadside	Fences		✓			
	Litter					✓
	Mowing		✓*			‘---*
	Mowing for vision		✓			
	Noxious weeds				✓	
	Woody vegetation		✓			
	Woody vegetation control for vision		✓			

Source: Wisconsin DOT.
**Note*: A Safety contribution category is shown for mowing. If a mowed area does not present a safety hazard, the grading curve for aesthetics is used.

TABLE 19
COMPASS THRESHOLDS AND GRADE RANGES BY FEATURE

Element	Feature	Threshold	Ranges for System Grades *Grade determined by percent backlogged* Shown: top of range				
			A	B	C	D	F
Traffic Control and Safety Devices (selected)	Centerline markings	Line with >20% paint missing (by mile)	2%	5%	9%	15%	>15%
	Edge line markings	Line with >20% paint missing (by mile)	4%	9%	18%	30%	>30%
	Delineators	Missing *or* not visible at posted speed *or* damaged (by delineator)	5%	12%	23%	40%	>40%
	Detour/object marker/recreation/guide signs (emergency repair)	Missing *or* not visible at posted speed (by sign)	4%	9%	18%	30%	>30%
	Detour/object marker/recreation/guide signs (routine)		7%	18%	35%	60%	>60%
	Protective barriers	Not functioning as intended (linear feet of barrier)	4%	9%	18%	30%	>30%
	Regulatory/warning signs (emergency repair)	Missing *or* not visible at posted speed (by sign)	2%	5%	9%	15%	>15%
	Regulatory/warning signs (routine)	Beyond recommended service life (by sign)	5%	12%	23%	40%	>40%
	Special pavement markings	Missing *or* not functioning as intended (by marking)	5%	12%	23%	40%	>40%
Shoulders	Hazardous debris	Any items large enough to cause a safety hazard (by mile)	2%	5%	9%	15%	>15%
	Cracking on paved shoulder	200 linear feet or more of unsealed cracks > ¼ inch (by mile)	7%	18%	35%	60%	>60%
	Potholes/raveling on paved shoulder	Any potholes *or* raveling > 1 square foot by 1 inch deep (by mile)	6%	15%	29%	50%	>50%
	Cross-slope on unpaved shoulder	200 linear feet or more of cross-slope at least 2x planned slope with the maximum cross slope of 8% (by mile)	7%	18%	35%	60%	>60%
	Drop-off/build-up on unpaved shoulder	200 linear feet or more with drop-off or build-up > 1.5 inches (by mile)	2%	5%	9%	15%	>15%
	Erosion on unpaved shoulder	200 linear feet or more with erosion >2 inches deep (by mile)	7%	18%	35%	60%	>60%
Drainage	Culverts	Culverts that are >25% obstructed *or* where a sharp object—e.g., a shovel can be pushed through the bottom of the pipe *or* pipe is collapsed or separated (by culvert)	7%	18%	35%	60%	>60%
	Curb and gutter	Curb and gutter with severe structural distress *or* >1 inch structural misalignment *or* >1 inch of debris build-up in the curb line (by linear feet of curb and gutter)	9%	22%	41%	70%	>70%
	Ditches	Ditch with greater than minimal erosion of ditch line *or* obstructions to flow of water requiring action (by linear feet of ditch)	7%	18%	35%	60%	>60%
	Flumes	Not functioning as intended *or* deteriorated to the point that they are causing erosion (by flume)	7%	18%	35%	60%	>60%

(*continued on next page*)

TABLE 19
(*continued*)

Element	Feature	Threshold	Ranges for System Grades *Grade determined by percent backlogged* Shown: top of range				
			A	B	C	D	F
	Storm sewer system	Inlets, catch basins, and outlet pipes with ?50% capacity obstructed *or* <80% structurally sound *or* >1 inch vertical displacement or heaving *or* not functioning as intended (by inlet, catch basin and outlet pipes)	7%	18%	35%	60%	>60%
	Underdrains/edge-drains	Under- and edge-drains with outlets, endwalls or end protection closed or crushed *or* water flow or end protection is obstructed (by drain)	9%	22%	41%	70%	>70%
Roadsides	Fences	Fence missing *or* not functioning as intended (by LF of fence)	4%	9%	18%	30%	>30%
	Litter	Any pieces of litter on shoulders and roadside visible at posted speed, but not causing a safety threat (by mile)	10%	25%	47%	80%	>80%
	Mowing	Any roadside has mowed grass that is too short, too wide or is mowed in a no-mow zone (by mile)	10%	25%	47%	80%	>80%
	Mowing for vision	Any instances in which grass is too high or blocks a vision triangle (by mile)	4%	9%	18%	30%	>30%
	Noxious weeds	Any visible clumps (by mile)	7%	18%	35%	60%	>60%
	Woody vegetation control	Any instances in which a tree is present in the clear zone *or* trees and/or branches overhang the roadway or shoulder creating a clearance problem (by mile)	4%	9%	18%	30%	>30%
	Woody vegetation control for vision	Any instances in which woody vegetation blocks a vision triangle (by mile)	4%	9%	18%	30%	>30%

Source: Wisconsin DOT.

implications of budget constraints on the M&O program in the following ways (applicable to 2011):

- **Focus areas:** These are areas that will receive priority in continuing to promote safety on the highway system. Shoulder patching, removal of hazardous debris, repair of damaged safety appurtenances, correction of paved shoulder drop-off and unpaved shoulder cross-slope problems, and correction of problems with delineators and protective barriers are some of the priority activities.
- **Reduced activities:** Activities such as mowing and litter pickup will be reduced in scope or frequency to save costs.
- **Suspended activities:** Certain activities such as pavement preventive maintenance will not be performed as routine maintenance, but rather through other programs such as improvements to leverage that source of funding.

Communication of Targets

In Wisconsin, counties maintain the state highway system under contract with WisDOT through routine maintenance agreements. With 72 county highway departments and five WisDOT region offices, effective communication of maintenance targets throughout county and state organizations is critical. The information must reach and be understood not only at the managerial level, but also the front-line maintenance coordinators. Targets distributed to the WisDOT region offices are accompanied by budget information for the same year, to underscore the relationship between the targets and the development of the routine maintenance agreements and work plans with counties.

The Compass program manager observed that WisDOT, perhaps like other state DOTs, sets targets year to year with a relatively short-term perspective. It is an annual, iterative

process based primarily on the current fiscal environment. There tends to be no long-range vision or goal for these targets. The process could perhaps be strengthened by a road map indicating the long-term goal that an agency would like the M&O program ultimately to meet.

Performance-Based Application

Computing Current LOS

The current LOS regarding one of the features identified in Table 19 is computed as follows:

- The condition of the feature in each one-tenth-mile segment is rated according to the criteria shown on the rating form (Figure 5), applying the guidance illustrated in Table 17. The rating may be a numerical quantity (e.g., number of objects or linear feet of cracking) or a pass–fail assessment against a standard.
- The field data are processed according to the thresholds and grading curves in Table 19. If a segment exceeds the threshold, it is considered a backlog segment. The percent of backlog segments (within a region or statewide) is evaluated using the grading curve to determine the LOS for that road feature.
- A report card on existing highway condition is produced each year from these processed field data, showing grades A through F for 27 highway features at a statewide and regional level.
- A peer group analysis is also produced to compare condition levels across the five regions for similar road classes. Maintenance expenditures are also presented for each region at the aggregate road element level (i.e., corresponding to the first column in Table 19).

Gap Analysis

For each roadway feature, actual conditions are compared with maintenance targets annually. A feature is "on target" if the existing condition is within ±5 percentage points of the target. (The gap analysis is done in both a positive and a negative direction, showing the percentage of sections above target as well as the percentage below target.) The gap analysis is performed at both the statewide and region levels. The analysis highlights the level of compliance with the maintenance priorities and also is an indication of how realistic the targets were based on existing conditions and available maintenance funds.

The Compass program manager is proposing to add a trend analysis of these annually computed gaps to the historical spreadsheet. These gap-related data would complement the trends in existing conditions and targets for each year in the historical tracking, providing managers with an additional set of data by which to assess forward-looking strategies.

Relating LOS to Cost

The Compass program manager has developed unit costs to maintain each roadway feature based on the direct and indirect costs of performing M&O (labor, equipment, material and administrative fees paid by WisDOT to the counties). These unit costs are applied at the state level to the following purposes:

- The unit costs are applied to expenditures by activity as reported by each county to estimate each county's activity-based M&O productivity.
- Unit costs have been applied to the several Compass grading curves for the various roadway features to estimate the costs of reducing maintenance backlogs and improving LOS to higher levels for each feature.
- These cost relationships are used to support budget proposals, various M&O initiatives, long-range plans, and other purposes requiring projected cost data.

The unit costs are referred to as "price tags" in the context of their use by counties. These unit costs help counties to understand in a quantitative way the magnitude of their maintenance programs and to "size" proposed initiatives.

Cost relationships are now in draft form for statewide-average unit costs. Future work may seek to quantify regional unit cost differences and cost differentials based on road class. Also, the current method of cost calculation is a "one-way" analysis assuming additional dollars to increase the level of M&O service. Lacking good deterioration curves for road features other than pavements and bridges, Compass does not yet calculate increased maintenance backlogs resulting from less funding. Furthermore, counties do not now report either the quantities of work accomplished or the locations where work was performed on each activity. Such data would improve program monitoring and reporting, the analysis of M&O productivity, and identification of potential highway network "trouble spots" having recurring maintenance problems. These gaps in knowledge suggest potential analytic improvements that are currently being explored by the Compass program manager.

Tabulations of M&O expenditures are included in annual reports distributed to the regions. These expenditures are aggregated at the road element level (corresponding to the first column in Table 19).

Organizational Support and Partnership

WisDOT supports and reinforces the Compass program through ongoing systematic actions to maintain a level of skill and consistency in the performance of Compass tasks. Some of these actions, such as annual coordination by state and county personnel to review and set program targets for the coming maintenance year, are discussed in previous sections. Other examples of important support activities include the following (interview with the Compass program manager; Adams and Bush 2007).

- **Training.** Training is conducted annually for all state and county personnel involved in Compass field data collection: a two-day introductory course for new personnel and a one-day refresher course for experienced staff. The training is conducted by state and county instructors, and includes both classroom and field work. Seventy-two two-person teams are involved, consisting of one state DOT employee, the regional maintenance coordinator; and a county employee, the county patrol superintendent.
- **QA.** Each year the Compass program manager works with selected rating teams to ensure consistency in ratings and to review changes in the ratings procedures in a response to, for example, revised deficiency thresholds (refer to Table 19), or adjustments in the features to be rated. QA reviews are conducted for two counties in each region, and on six highway segments in each county. Both state and county raters participate in the review with the Compass program manager. The success of the QA program is indicated because the variations in field ratings observed during these reviews has declined over time. Also, the Compass program manager has adopted a practice of sharing his own ratings with the rating teams, so that they understand better how their practices can be improved toward the statewide guidelines.
- **Organizational Buy-In.** WisDOT has the unique task of establishing and maintaining internal and external support among the DOT central office Compass staff, five DOT regions, and 72 counties that perform its M&O services. It has done this through consistent, deliberate, and positive outreach to its partners within each component of the Compass program. Coordination and engagement of all partners in Compass have been described in the earlier examples. A more broadly based illustration is the formation of standards teams that involve the WisDOT central and regional offices, counties, and the local University of Wisconsin–Madison. These teams review technical standards within the full scope of Compass highway assets—not only those subject to field evaluation that have been described in the previous sections. That is, in addition to the four highway features that are subject to field inspections and ratings (shoulders, roadsides, traffic, and drainage—refer to Table 17), Compass includes ratings from other data systems on pavements, bridges, signs, and winter maintenance. An annual report on condition of all these assets is issued by Compass to promote better data-driven decision making. As a final example, the guidance of the Compass program is also a shared responsibility among representatives of the counties, the WisDOT regions, and the central office.

Concluding Remarks

- This section has described WisDOT's Compass program for performance-based M&O management, with a focus on setting targets and integrating condition measures, LOS, LOS targets, maintenance priority, and available funding.
- Although other DOTs no doubt engage these same issues in their M&O performance management programs, the attributes of this case study include the detailed, systematic methods by which Compass business processes address particular elements of performance management; and the relative transparency of these processes, including the availability of internal documents that help explain various policy and business issues within a unified framework.
- A further advantage is that Compass is continuing to evolve, looking at more sophisticated ways of treating costs, for example, which may yield new ways of looking at the LOS–cost relationship and point the way to research explorations by other agencies.
- Compass assists a number of departmental business areas:
  - Evaluating system performance; for example, field inspections leading to calculations of current condition for 27 highway features, and an annual report card on existing conditions.
  - Supporting policy and budget development: setting annual targets for M&O LOS attainment based on existing conditions, historical trends, available funding, and agency priorities; conducting a gap analysis comparing stated targets with actual conditions for each roadway feature; and application of M&O unit costs to support cost-based tasks and analyses, as in budget preparation and analysis of the estimated cost to reduce existing work backlogs.
  - Program monitoring and accountability, including a time-trend analysis showing a 5-year history of highway conditions and LOS targets (which also assists in target-setting for the coming year), and compliance with departmental policies and directives regarding M&O work priorities to respond to limited budgets.

FLORIDA DEPARTMENT OF TRANSPORTATION

Introduction

The previous two case examples illustrated some of the steps involved in launching a new performance management effort and in defining the components of an agency performance-based approach. This case and the next illustrate the application of a performance-based methodology to management tasks that arise in M&O. This case concerns the use of performance information for maintenance prioritization. It uses data in reports from FDOT's MRP to illustrate how information on projected versus actual condition of highway features can set the stage for an assessment of the priority for further maintenance investment.

Case Description

Only a brief overview of the MRP is provided here for context. Information on MRP and copies of relevant documents, including the *MRP Handbook* and the MRP Procedure

memorandum, are available on FDOT's MRP website: http://www.dot.state.fl.us/statemaintenanceoffice/MaintRatingProgram.shtm. Another source of information used in the MRP description has been provided by FDOT in a webinar on asset management and performance-based maintenance (Sprayberry 2008).

Florida's MRP provides a uniform and consistent method for evaluating conditions of maintained features on Florida's highway system. This evaluation may be used to schedule and prioritize routine maintenance activities. It also helps ensure that resulting maintained highway conditions meet departmental objectives.

The MRP breaks the highway system down and processes condition rating data in the following way:

- Roadway classifications or facility types (e.g., urban limited access, urban arterial, rural limited access, and rural arterial).
- Each roadway classification is made up of five categories or elements, with each element comprising a number of characteristics.
  - The five elements are Roadway, Roadside, Traffic Services, Drainage, and Vegetation and Aesthetics.
  - The Roadway element has nine characteristics, which essentially define different possible conditions. For example, for flexible pavements the characteristics are: pothole, edge raveling, shoving, depression/bump, and paved shoulder/turnout; and for rigid pavements: pothole, depression/bump, joint cracking, and paved shoulder/turnout.
  - Regarding the other elements, Roadside has five characteristics; Traffic Services, nine; Drainage, six; and Vegetation and Aesthetics, seven.
- For MRP ratings, each characteristic is evaluated against a performance standard contained in the *MRP Handbook* (*Maintenance Rating Program Handbook* 2011). For example, for a flexible pothole, no defect may be larger than ½ ft^2 in area; no measurement may exceed 1.5 in. in depth; and no pervious base may be exposed in any hole. (Observe that this comparison parallels the comparison of highway features to defined thresholds in the Compass case example.)
- If the characteristic passes the performance standard, it is rated Yes. Otherwise, it is rated No (does not meet the desired maintenance conditions). The total number of Yes-rated characteristics within a facility and element is then compared with the total number of that characteristic, yielding a raw percentage. For example, if there are 79 characteristics in a facility and element, and 66 of them are rated Yes, the raw percentage is 84.
- The MRP analytic framework also includes two sets of priority factors: the relative importance of each characteristic by facility type, and the LOS- weight of each element by facility type. These factors are incorporated, together with the raw percentages discussed earlier, within the computation of the MRP ratings across all facility types, elements, and characteristics. The MRP ratings are used to judge whether a state highway meets the accepted maintenance standard.
- The accepted maintenance standard is defined in terms of the MRP ratings as an overall district score of at least 80; an element score of at least 75; and a characteristic score of at least 70. FDOT's goal is to achieve the accepted maintenance standard for 100% of state highways.

Additional information can be found in FDOT's *MRP Handbook* (*Maintenance Rating Program Handbook* 2011).

Performance-Based Application

Prioritization of maintenance activities by FDOT needs to be understood in the context of its highway budgeting process. As required by statute, the maintenance program is funded first by the legislature when considering highway programs. It is funded to the level needed for 100% of state highways to meet the accepted maintenance standard; as noted in the previous section, this standard requires that MRP equal or exceed a threshold of 80 for roadways statewide. Maintenance funding to this level is therefore not subject to competition with other highway programs. Prioritization decisions by district and field managers using MRP focus on options and decisions within the maintenance program itself, particularly on those facility types, elements, and characteristics that do not meet the threshold criteria for satisfying the accepted statewide maintenance standard.

Ratings are conducted and reported in each of three rating periods per year, with each rating period having a four-month duration. FDOT produces a report showing MRP ratings for each characteristic, for the element, and for the facility. Reports are available by geographic area and statewide. Managers may review these reports to identify where characteristic scores are low. Maintenance work will need to be directed to these characteristics to raise their scores before the next MRP rating period.

In assessing maintenance priorities, managers also have access to an MRP planned versus completed report that shows total planned workload for each maintenance activity that year, the total completed to date (as of each period), the difference (which is essentially budgeted workload remaining and available for use), and the percentage completed. Managers may use this information to see if work to date reflects the objective of performing those maintenance activities that would be expected to improve scores that had been low in the previous period; and to help plan the assignment of activities needed to improve MRP scores that are currently low before the next MRP reporting period.

If total district scores fall short of district goals, the district would be regarded as noncompliant during the MRP QA review. A report of this would be sent to the district secretary. It is therefore important that managers within the district try

to increase the MRP score before the next MRP reporting period by increasing the priority of work on currently deficient elements and characteristics.

Concluding Remarks

It is important to bear in mind that while the FDOT example concerned a single characteristic and a single maintenance activity to correct defects and increase the characteristic rating, agency managers might need to deal with competing demands for available budgeted workload, and would need to balance the assignment of maintenance resources against the relative importance of the demands throughout the road network for those resources. For this reason, it is important that both types of reports discussed previously (the report of MRP ratings and the planned versus completed report) are available for management use in reaching these judgments. It is also important that the analytic aspect of performance, represented by the MRP rating, be understood as working in combination with the business process aspect—the managerial review of MRP ratings, the identification of maintenance needs, the meeting of those needs through work assignments, and the checks and balances provided by the QA review. The MRP ratings indicate where additional funds could enable deficient elements/characteristics to meet the accepted maintenance standard, but the QA review seeks to ensure that the funding is actually redirected with positive performance results.

The FDOT maintenance office also considers the larger budgeting context and the standing of maintenance with respect to MRP-rated performance and funding needs. For example, in the current economic climate, bids for maintenance work have been coming in below estimate, and the current MRP rating is about 87, exceeding the statewide threshold. The maintenance office did therefore reduce program funding in FY 2012 and 2013 as part of its due diligence in program management. In FDOT's view, this reduction demonstrates departmental credibility and accountability.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Introduction

WSDOT's Maintenance Accountability Process (MAP) has been in place since the late 1990s. Through its easily understandable letter grades, its successful use of photographs to communicate the meaning of different LOS A through F, and its success in gaining credibility for the maintenance program in the state legislature, MAP has continued to be an influential example of a performance-based application. As now configured, MAP encompasses 31 M&O activities organized within seven groups: Roadway Maintenance and Operations, Drainage Maintenance and Slope Repair, Roadside and Vegetation Management, Bridge and Urban Tunnel Maintenance and Operations, Snow and Ice Control Operations, Traffic Control Maintenance and Operations, and Rest Area Operations. This case example will focus on two aspects of MAP: the addition of a second performance-based metric to characterize the current status of the M&O program; and the use of MAP data in connection with WSDOT's Phase II municipal stormwater permit, with implications for maintenance of stormwater drainage structures.

Performance Metric

Through 2009, MAP employed LOS defined on a letter grading scale A-B-C-D-F as its performance-based metric. The LOS are determined through field inspections in which data collectors compare the condition of a feature with technical threshold values. For example, for drainage catch basins and inlets, the applicable threshold measure is the percent of inlets blocked or of catch basins with silt build-up greater than 50% of depth (*Maintenance Accountability Process Manual* 2008, pp. 4–5). When data gathering is completed, the LOS can be determined according to the grading curve for the maintenance activity to maintain catch basins and inlets. In this case, LOS A would be assigned if 0% to 3% of catch basins had the indicated depth of silt; LOS B for 3.1% to 7%; and so forth. These LOS are referred to as *asset condition metrics*.

Asset condition measures are lagging indicators; they report annually what has already happened. Because of a recent issue involving a growing backlog of essential maintenance work on its highway system, WSDOT has decided to add a second type of metric, *task completion*. Task completion is a leading indicator in that it measures the percentage of needed tasks completed each year, pointing to what work remains to be done. The difference between work that should have been done and work that actually was done is the maintenance backlog. Depending on context, "task completion" can refer to maintenance work or a list of existing deficiencies. In both cases, the goal over time is to have all items on the list crossed off. A task completion perspective is particularly well suited to managing backlogged work and to demonstrating the performance of preventive maintenance (*The Gray Notebook* Feb. 18, 2011).

WSDOT is increasingly using the two types of metrics in concert, because they tell a more complete story from two different perspectives:

> Task completion measures will be the primary tool used to measure program performance and develop performance-based budgets. Asset condition performance measures will serve as a quality assurance tool used to verify or support changes in the task completion measures. (Source: *The Gray Notebook* Feb. 19, 2010.)

Stormwater Permit Implications

Overview of Permit Requirements

WSDOT's Phase II National Pollutant Discharge Elimination System stormwater drainage permit imposes greater maintenance requirements on WSDOT's drainage structures

(*Washington State* . . . Feb. 2009). The permit notes that the legislature currently funds drainage maintenance to an LOS of C+. The permit requires annual inspections of catch basins and other stormwater facilities such as detention and retention ponds or basins, grassy bio-swales, and underground stormwater vaults. (The permit refers to these facilities as best management practices, or BMPs.) It also specifies the required maintenance of these facilities. In essence, the permit has imposed a new LOS target on these drainage structures within affected jurisdictions. From a performance-based perspective, a higher LOS target implies a need for additional funding to cover costs that are above and beyond current operations. MAP was therefore used to assist WSDOT in preparing a budget request to the legislature to finance this additional work. MAP will also be used in monitoring and reporting the delivery of inspections and maintenance work required by the Phase II permit.

Application of MAP Data

The application of MAP data is illustrated for the two drainage maintenance activities with LOS targets affected by requirements of the stormwater permit:

- Activity 2A3—Maintain Catch Basins and Inlets, which under the updated permit will be inspected annually, with maintenance to be performed on inlets that are blocked and catch basins that have a silt build-up greater than 50% of depth (measured from the bottom of the basin to the invert of the outflow pipe).
- Activity 2A4—Stormwater Facility Maintenance, which encompasses the silt ponds, grassy swales, tanks, underground vaults, and other facilities mentioned earlier. These facilities will be inspected annually, with maintenance to be performed on those that can no longer perform according to design.

Pertinent MAP information used in this case includes performance measures and outcome thresholds that relate observed condition to service levels, current performance data obtained through field inspections, and comparisons of current performance with target LOS values.

Performance Measures Key information contained in performance measures for activities 2A3 and 2A4 is presented in Exhibit 5. For each activity the exhibit includes the definition of the performance measure, the threshold performance values that define each service level A through F, and the source of information used to quantify the performance measure. Performance measures are the basis for the asset condition metric discussed earlier. They enable the outcomes of different LOS to be expressed and understood quantitatively. For example, the current LOS = C+ implies that 7.1% to 9.7% of catch basins and inlets require maintenance. Improving the service level to B would reduce the deficiency range to 4.5% to 5.7% of these drainage features. In other words, the system-wide performance of catch basins and drainage inlets would improve from an average of 92% to almost 95%. Activity 2A4 has recently been expanded in scope to address a wider set of facilities described previously that are also important to managing the quality of stormwater discharge. The information for this activity in Exhibit 5 is therefore illustrative and due to be revised.

MAP Accountability Reporting A major component of accountability reporting for WSDOT M&O is the comparison of service-level targets to LOS actually achieved in the field. The format of this report is illustrated schematically in Table 20 for three hypothetical activities. The five-point letter grade scale is converted to a 15-point scale to allow finer distinctions in both LOS reporting (using intermediate values such as B– or C+) and in the underlying performance metrics (subdividing numerical ranges shown in Exhibit 5 into three subsidiary ranges). MAP targets are reviewed and updated, if needed, in each legislative biennium ("MAP Activity Service Level Targets 2009–2011" n.d.). LOS levels achieved in the field are developed from the most recent field inspections in each calendar year.

- Activity Example 1 shows actual performance exceeding the target LOS: in this case, an achieved service level of C+ versus a LOS target of D+.
- Activity Example 2 shows that actual performance has met the target of C, likewise a successful outcome.
- Activity Example 3 shows attained performance (LOS D+) missing the target (LOS B). In this case, a different symbol [**o**] is used to denote the missed target.

Performance History WSDOT provides annual reports for all M&O activities by region and statewide, which conform to the presentation in Table 20. Statewide data for Activities 2A3 and 2A4 have been compiled from these reports for calendar years (CY) 2005–2010 and are displayed in Table 21. These data provide historical context for the impact of the increased service levels specified in the Phase II stormwater permit. The proposed LOS targets through the end of fiscal year 2011 (June 30, 2011) are also given in Table 21.

Delivered service levels for Activity 2A3 declined from their relatively high (B+) grades in 2005–2006 to LOS D in 2007 and D+ in 2008. This decline was part of a pattern that reflected missed targets for almost half of the reported LOS values in 2008, owing to several causes: increased inventory of assets requiring M&O resulting from system expansion, impacts of inflation on M&O costs, and increased backlog of needed work as a result of asset deterioration and greater regulatory requirements (*The Gray Notebook* Feb. 27, 2009). Since 2008, attained performance has regained lost ground, in part as a result of anticipation of the Phase II permit requirements. Targets for years 2009–2011 were adjusted to reflect more realistic expectations each year, with the 2011 value of LOS B again reflecting the anticipated impact of the Phase II permit.

EXHIBIT 5
PERFORMANCE MEASURES FOR PERMIT-RELATED DRAINAGE ACTIVITIES

Activity	2A3—Maintain Catch Basins and Inlets				
Indicator	Catch basins and inlets that are blocked or have sediment build-up.				
Outcome Measure	Percent of inlets blocked or catch basins with silt build-up greater than 50%.				
Outcome Thresholds	Service Level				
	A	B	C	D	F
	0 to 3.0%	3.1 to 7.0%	7.1 to 15.0%	15.1 to 30.0%	>30%
Data Source	Field surveys				
Activity	2A4—Stormwater Facility Maintenance (formerly Maintain Detention/Retention Basins)				
Indicator	Facilities unable to perform to design capacity.				
Outcome Measure	Percent of silt basins that are more than 25% filled with sediment.*				
Outcome Thresholds	Service Level*				
	A	B	C	D	F
	0 to 1.0%	1.1 to 5.0%	5.1 to 10.0%	10.1 to 15.0%	>15%
Data Source: Remarks	Service level is estimated. Performance measure development is in progress, in conjunction with implementation of the municipal stormwater permit.				

Source: *WSDOT MAP Manual* (2008), Section 5.
*Illustrative information is provided for silt basins, the former focus of this activity. Updated information to be developed will reflect (1) a broadened activity scope that also includes grassy swales, open concrete tanks, and underground storage vaults; and (2) potential revisions to the numerical thresholds shown above, reflecting changed practice as a result of stormwater permit requirements.

TABLE 20
EXAMPLE WSDOT REPORT FOR MAINTENANCE ACCOUNTABILITY

Activity	Maintenance LOS Targets and LOS Delivered									
	+	A	–	+	B	–	+	C	–	+	D	–	+	F	–
Example Activity Group															
Activity Example 1								☑			⊙				
Activity Example 2								☑ ⊙							
Activity Example 3					⊚						☑				

Notes: ⊙ = LOS target achieved; ⊚ = LOS target missed; ☑ = LOS delivered.

TABLE 21
RECENT HISTORY OF LOS TARGETS AND LOS DELIVERED FOR DRAINAGE ACTIVITIES COVERED BY STORMWATER PERMIT

Activity by Calendar Year	Maintenance LOS Targets and LOS Delivered									
	+	A	–	+	B	–	+	C	–	+	D	–	+	F	–
Group 2 Drainage Maintenance Affected by Stormwater Permit															
2A3 Maintain Catch Basins and Inlets															
CY 2005				☑	⊙										
CY 2006				☑	⊙										
CY 2007					O						☑				
CY 2008					O					☑					
CY 2009								☑		⊙					
CY 2010							☑			⊙					
Target: 2009–2011 Biennium					⊙										
2A4 Stormwater Facility Maintenance*															
CY 2005								☑ ⊙							
CY 2006								☑ ⊙							
CY 2007								☑ ⊙							
CY 2008								☑ ⊙							
CY 2009								☑ ⊙							
CY 2010								☑ ⊙							
Target: 2009–2011 Biennium								⊙							

Source: WSDOT MAP reports.
Notes: ⊙ = LOS target achieved; O = LOS target missed; ☑ = LOS delivered.
*Facilities addressed by Activity 2A4 include detention and retention ponds or basins, grassy bio-swales, and underground stormwater vaults .

By comparison, Activity 2A4 targets and service levels have remained stable at LOS C throughout this period.

Working with the Phase II Permit Requirements

The new task completion component of MAP was used to identify the additional cost of the stormwater maintenance program under the Phase II permit. A formal request for additional funding (referred to as a decision package) was submitted to the Washington State legislature; to date a $4.5 million additional budget has been approved. Task completion capability will also be used to monitor and communicate program delivery. Measures to be used will be the percentage of catch basins and other stormwater facilities inspected annually and maintained to standards. The asset condition component of MAP will serve as a QA tool to measure the overall condition of these drainage features as a check on the effectiveness of the completed work tasks. WSDOT anticipates that with the greater, more frequent attention given to these drainage features, LOS may increase from the current C+ for inlets and catch basins to a grade approaching LOS B or A. If this turns out not to be the case, the unexpectedly low LOS will alert WSDOT to review the effectiveness of its work plan and identify any potential weaknesses. It is also possible that the drainage structures may be worn and deteriorated to a degree that they can no longer be maintained effectively, in which case, a capital project would be needed to rehabilitate or replace the drainage structures.

Concluding Remarks

The credibility of MAP in support of WSDOT's implementation of the Phase II permit is demonstrated in several ways.

Data from MAP are incorporated directly within the permit descriptions that cite current drainage LOS levels and associated allowable percentage ranges of deficient drainage features (these data correspond to entries in Exhibit 5 and Table 21). The permit also explicitly acknowledges the maintenance training received by WSDOT employees regarding water quality protection and proper maintenance of drainage facilities relevant to permit requirements. With its task completion capability, MAP has been or will be used for several purposes in analyzing the implications of the new stormwater permit requirements: identification of the cost of a new target LOS, communication to the legislature of the need for additional funding (a portion of which has already been approved), monitoring of program delivery, and production of reports for accountability purposes. The performance data will also support legal compliance reporting to the state's Department of Ecology, which issued the permit.

Apart from the stormwater drainage aspect, the development of the task completion capability within MAP adds another dimension to the subject of cost estimation and calculation within performance-based analyses. The dual approach used by WSDOT, combining asset condition and task completion, may have applications to other areas of maintenance expenditure.

In a broader context, WSDOT has seen the credibility of MAP continue to be sustained in the eyes of the legislature and the public, and has taken steps to maintain its currency, credibility, and usefulness. The adoption of the task completion capability is one example. Another is the continuing improvement process and response to new management needs that has led to the redefinition of Activity 2A4 addressing a broader range of drainage facilities. A third is the initiation of an online customer survey for highway maintenance, as mentioned in chapter two. The public is asked to rate highway pavement conditions and response to road emergencies, and offer opinion on priorities for future maintenance spending ("WSDOT Launches . . ." Oct. 7, 2010).

In addition to the references cited earlier, information on the application of MAP data to WSDOT's implementation of its Phase II stormwater permit can be found on the WSDOT website (www.wsdot.wa.gov/Environment/WaterQuality/StormwaterPermitQandA.htm) and in a separate analysis of options for permit implementation (*Stormwater Permit Requirements* . . . Jan. 5, 2011).

CROSS-CUTTING THEMES

Each of the case examples has focused on a particular topic appropriate to M&O management in that agency. The descriptions and findings of the cases, however, collectively suggest common themes that characterize effective performance management practices. Follow-up interviews were held with managers from the case example agencies to obtain their perspectives on these themes, in particular to expand on two items in the scope of work in greater depth than was possible in the synthesis survey. These items concern methods used by state DOTs to prioritize their M&O activities, and methods used to determine the numerical threshold values and LOS ranges that constitute guidance for rating and reporting M&O performance and targets.

Prioritization of Maintenance and Operations Activities

The survey identified factors that were considered in setting M&O priorities, and the case example for FDOT illustrated how the results of the MRP process are applied to prioritization of needed work. Maintenance prioritization in FDOT takes place in the context of full funding for 100% of state highways to meet the accepted maintenance standard of MRP = 80 or above. As a general principle, funds are allocated to ensure that the target MRP level can be sustained across all state highway elements and characteristics. In more immediate or short-term time frames, decisions on the priority of work focus on those highway elements and characteristics that are not meeting the statewide standard. These features and conditions need maintenance work to bring them up to the acceptable MRP threshold. Moreover, the MRP score itself is influenced by priority considerations. Within the MRP analytic framework are factors that express the relative importance of each characteristic by facility type, and the LOS weight of each element by facility type. These factors influence the computation of the MRP ratings among all facility types, elements, and characteristics.

MDOT is pursuing a similar principle, although its LOS are defined and quantified differently from the MRP score. MDOT communicates guidance for prioritization through its LOS targets for each asset feature. Targets are set by the assistant chief engineer and used by districts during maintenance planning to set priorities for the coming year. Variations in target values can be considered; for example, the target LOS for warning or regulatory signs could be set higher than that for other signs. Issues regarding target values can be taken up with the assistant chief on a case-by-case basis.

WisDOT and WSDOT have formally defined prioritization tables. The WisDOT table is organized by road feature and indicates to which of five policy-related attributes each feature contributes (refer to Table 18). Recall from the case example that the contribution category associated with a road feature determines its LOS grading curve. WisDOT can also perform sensitivity analyses by adjusting the grading curve applied to a feature. (Note that in the case example, several contribution categories have two grading curves that can be used.) As another example, the Mowing activity may take on one of two contribution categories: Safety (shown in Table 18) or Aesthetics (if the mowed area presents no Safety hazards). A choice between these two options based on the

specific site conditions directly affects the selection of the grading curve for this activity, which influences the relative priority that it will receive. Also note that the separate activity of Vision Mowing is always assumed to have a Safety contribution category.

The current WSDOT priority matrix can be obtained on its maintenance performance measures website ("2009–2011 Maintenance Activities Priority and Level of Service Matrix" n.d.). WSDOT also takes into account the contribution (in this case, of each maintenance activity) to policy objectives, but does so quantitatively and allows an activity to have an impact on more than one policy objective.

The quantification occurs in two steps. The first step is associated with the policy objectives themselves, in a way that can be regarded as weights. The policy objectives and their respective weights (in square brackets) are:

- Safety of Travelling Public and Employees [10].
- Operate the Highway System and Keep the Road Open [9].
- Meet Environmental Responsibilities [7].
- Maintaining the Infrastructure [7].
- Address Legal Mandates Other than Environmental (including torts) [7].
- Contribute to Comfort, Aesthetics, or Convenience [2].

The second step in quantification is associated with each maintenance activity. Each activity is assigned a weight indicating its relative contribution to each policy objective. Activity weights are assigned values on the following scale:

- 9: Critical impact on a policy objective
- 6: Significant impact on a policy objective
- 3: A contributing impact on a policy objective
- 0: No impact on a policy objective.

For each activity and policy objective, the two weights are multiplied; the resulting values across all objectives are tallied to estimate a total priority score of each activity. In contrast with WisDOT's contribution table, the WSDOT activities are rank-ordered as the result of the prioritization.

This priority matrix generated by WSDOT provides higher-level guidance when strategic decisions need to be made across competing activities, such as funding, or for high-priority activity performance following an emergency. It also communicates WSDOT's perspective on maintenance priorities to the legislature and other stakeholders. For example, in the face of a proposed budget reduction, the matrix provides a rationale, together with other input, for considering and communicating which group of activities can be protected versus which group may be vulnerable to reductions. With respect to the continual, cyclic process of performance-based planning and budgeting, WSDOT applies the MAP-generated LOS-target-versus-delivered reports, together with the priority matrix and other relevant information, to identify what work needs to be done and how much it will cost. When the biennial budget is approved, it balances estimates of needs, priorities, and available funding to implement the maintenance program. The reporting cycle is undertaken for the new biennium. As the next biennial budget process approaches, WSDOT begins the planning and budgeting processes again. In more near-term or tactical situations where a nimble response may be needed to a particular needs-based or financial situation, WSDOT can also turn to its data on task completion to compare the accumulated work backlog across activities, and make decisions on the basis of reducing the work backlog.

Defining Numerical Service-Level Values

The case example agencies were asked about their process for establishing numerical thresholds (e.g., for pass–fail) and ranges that define performance-measure and service-level values (for example, grading curves). The state DOT managers all mentioned relying on the experienced judgment of their M&O staff in arriving at these values. In general, the values were determined in meetings between central office and field personnel. Data from other state DOTs were not used by any of the agencies interviewed WisDOT uses standards teams comprising WisDOT staff from its regions and central office, county representatives, and university staff to meet annually on this type of matter. Separate teams are organized by selected Compass elements: Pavement, Drainage, Roadsides, Traffic Control and Safety, Bridge, and Winter Maintenance.

CHAPTER FOUR

CONCLUSIONS

BACKGROUND AND CONTEXT

Performance-based highway maintenance and operations (M&O) management has been the subject of active research and industry exchanges for more than 10 years. The focus of these efforts has tended to emphasize peformance-based elements, or the "tools of the trade": for example, condition assessment, measures of performance, definitions of levels of service (LOS), establishment of LOS thresholds, and incorporation of these elements within existing, modified, or new maintenance management systems (MMSs). Studies of performance-based management (PBM) itself—its concepts, methods, and applications—have also been performed, but to a lesser degree than the element-oriented studies. Nonetheless, the work that has been done has yielded better understandings of basic trends in management practices. For example, performance-based concepts and methods have been credited with changing agencies' thinking about how highway M&O programs are planned and managed, promoting the following attributes:

- More objective information on highway condition
- Greater emphasis on outcome-based performance measures rather than output measures
- Performance measures that are more customer-oriented, reflecting road-user expectations
- A shift toward more proactive maintenance planning
- A greater influence of performance-based measures in prioritization and budgeting

Previous work has also shown that state departments of transportation (DOTs) understand the importance of key elements in performance-based thinking: the roles of condition assessment data and inventory data, establishment of performance standards, the setting of outcome-based performance targets, incorporating customer input, and integration within agency business processes, to name a few. While adopting a nationwide perspective, however, these past studies have been limited in scope and detail, conducted at a very general level or as adjuncts to other research objectives. It is therefore difficult to infer from them a comprehensive description of current nationwide practice in performance-based M&O management techniques and applications.

OBJECTIVE AND FRAMEWORK OF STUDY

The objective of this synthesis has been to compile current practices in PBM as applied to highway M&O, and supplement this nationwide profile with four examples of specific applications. The scope of work identified several specific items to address, which were reflected in responses to the survey questions and findings of the case examples: for example, the use of performance measures within M&O management, the ways in which state DOTs quantify LOS threshold values and grading curves, the consequences of not meeting (or of exceeding) targeted M&O service levels, and other tasks listed in chapter one. With previous research, conferences, peer exchanges, and other sources having already focused on the elements of a performance-based M&O approach that are used by state DOTs, this study would look at how these elements are combined and applied in management techniques, processes, and decisions. Also, because significant work had recently been conducted by NCHRP on performance-based maintenance contracting, that topic would not be a major component of this synthesis.

Performance-based maintenance management has been influenced throughout the past decade by maintenance quality assurance (MQA). MQA has provided an overarching framework for a number of management implementations by state DOTs that continue to refer to their LOS-based programs as MQA programs. MQA has also been the subject of M&O peer exchanges, the online document library organized by the Midwest Regional University Transportation Center, and research efforts. The MQA implementation process anticipated many program management features and procedures that are still in use. This synthesis, however, has adopted the concepts, methods, and nomenclature of *performance-based management* as its organizing framework. PBM is a more current usage that incorporates the elements and procedures envisioned in MQA, but emphasizes additional capabilities as well (listed later). A performance-based approach provides a more recognizable fit to the considerable work now underway at the federal, national, and state levels regarding performance measurement and accountability. A performance-based approach anticipates provisions in the future reauthorization of the federal surface transportation act. Beyond consistency with these other developments, a performance-based approach to highway M&O gives more explicit recognition and emphasis to several capabilities that state DOTs are applying: for example, management (or performance) accountability reporting, a renewed focus on customer-satisfaction input to M&O priorities and assessments, more comprehensive processes for updating the components of a performance-based approach, inclusion of mobility and operations-related features and activities, and

more comprehensive accounting of highway performance and cost. As a counterpoint to the previous observation, the study activities on this synthesis have identified several state DOTs that refer to their M&O management in terms of performance and accountability rather than MQA, signaling at least a blend of usages and perhaps a transition in management perspective that is underway.

FINDINGS

Nationwide Practice

Current nationwide practice in performance-based M&O management was developed through a survey of DOTs in 50 states and the District of Columbia. The survey yielded 41 responses. Of these, 31 DOTs, or 76%, reported that they use some form of PBM. The specifics of any particular management approach can vary; for example, whether performance measures or LOS are used, whether performance measures are strategic or tactical, whether LOS are value-based or pass–fail, and whether the performance-based approach is preliminary or mature. Despite these differences, all of the various approaches developed by state DOTs to date tend to share a common set of practices, perceptions, or characteristics at an overall level. It is important that these commonalities be understood as agency agreement on a cluster of factors, rather than on a single, paramount consideration. This is not a surprising result. Participants in the survey were allowed to select more than one choice on most multiple-choice questions. That they often did so indicated a perception of having to deal with multiple, sometimes conflicting, factors influencing a process or decision. Examples of topics in which this agreement on groups of factors occurred are given in the following bulleted list. (Refer to chapter two to see the overall tally of responses to each survey question, and to Appendix D to see the responses by state DOT across multiple-choice selections.)

The synthesis survey has highlighted the following characteristics of performance-based highway M&O management among state DOTs:

- A performance-based approach is used to address a wide range of highway features. Prevalent among these are road surfaces, bridges, pavement markings, drainage features, road signs, guardrails, and roadside and median vegetation. Other items are represented to a lesser degree: Intelligent Transportation System (ITS) devices, structures other than bridges, and roadway lighting, among others. In addition to highway features or assets, M&O services— for example, incident or emergency response and winter maintenance—may also be addressed through a performance-based approach.
- In most cases M&O services are delivered under the auspices of the state DOT using its own employee work forces, contractors, volunteers, or prison labor. In only a few instances are other governmental levels (e.g., municipalities or counties) used for service delivery. In most cases where other jurisdictions are involved, overall program delivery is performed by a combination of state and local forces, and the state retains the responsibility for monitoring the level of service that is delivered. The Wisconsin DOT (WisDOT) is unique in contracting all of its M&O activities with Wisconsin counties, although WisDOT monitors the LOS delivered.
- Performance measures and LOS thresholds currently tend to be defined on a uniform statewide basis. Some variability is allowed for in activities influenced by weather (e.g., winter maintenance) or by traffic volume and degree of urbanization. A unique approach has been adopted by the California DOT in defining zones within the state to account for varying traffic volumes and terrain combined. State DOTs may be willing to consider introducing additional variability in thresholds when the pool of accumulated performance data is deeper.
- Inspections to determine field conditions that support the performance-based approach are conducted in various ways with no particular method predominating. Most state DOTs use a combination of central office, district, and third-party teams to accomplish data gathering.
- Setting performance-based targets is accomplished as a matter of professional judgment considering several factors. In order of decreasing number of responses, these factors include the projected M&O budget, a commitment to meet an agency-established objective, and an internal management or engineering analysis indicating a realistic target for accomplishment. In some cases other factors may drive goal-setting, for example, legislative mandates and agency commitments under a state government accountability initiative.
- State DOTs tend to look to several management tasks in common to be supported by performance-based methods. These tasks include tracking of condition, performance, and quality; M&O prioritization; budget development and justification; development of needs-based management estimates; resource allocation among field offices; and an understanding of the relationship between LOS and cost. These findings were generally consistent with those of past research.
- Twelve of 20 responding agencies solicit feedback from customers through a variety of ways, with telephone or mailed surveys being the primary methods. Although some survey efforts are relatively broad and infrequent, others are directed specifically to M&O issues, and agencies on average employ more than a single method to obtain this information. Several agencies report soliciting customer assessments and opinions online. Only a few agencies solicit input from industry groups.
- Just over half of the responding agencies apply performance-based measures to contracts, often using the same LOS or performance measures as those applied to in-house forces doing comparable work.
- Agencies view communication of performance-based information as important, whether it concerns information prior to a decision or the consequences that may

result following a decision. Most respondents identified five entities most often involved in communications of performance-based accomplishments or accountability: personnel within the DOT itself, the transportation commission or equivalent, the legislature, the governor, and the general public. Other recipients are involved less often; for example, other state agencies, industry groups, the FHWA, and so forth. Several mechanisms are used for communication, but the two reportedly used the most are performance accomplishment reports and dashboards presenting conveniently summarized information.

- To a question regarding development of innovative performance measures for operations activities specifically, fewer than half of the state DOTs responded affirmatively. Most responses identified winter maintenance and traffic signal systems as the subjects of innovative performance measure development. Other operations activities received one or two responses each: ITS devices, electronic/environmental sensing systems, and incident/emergency response.

Agency Case Examples

The case examples reinforced and built on the findings of the survey to illustrate how the individual performance-based elements come together and are applied by different agencies to management needs and tasks. Four cases were studied: two dealing with processes and procedures to build and sustain the performance-based approach itself, and two dealing with the application of the approach to M&O program management. Mississippi DOT (MDOT) and WisDOT were the subjects of the process-oriented cases; Florida DOT (FDOT) and Washington State DOT (WSDOT), the subjects of the program-oriented tasks.

The MDOT case illustrated the process used to implement a new performance-based approach including use of a new MMS, Accountability in MDOT Maintenance Operations (AMMO). Since data were also available on WisDOT's implementation of its performance-based approach, Compass, the two examples showed how agencies followed different implementation paths each tailored to the respective agency's needs and circumstances and the nature of their M&O program.

- MDOT employed consultants and vendors to guide the two prongs of its new performance-based approach: identifying and instituting new business processes, and customizing, developing, testing, and implementing new AMMO software. Pilot testing was useful in merging these two efforts correctly, verifying AMMO accuracy, familiarizing MDOT personnel with the system, and identifying training needs. This approach to implementation represented a process that was thought out ahead of time to ensure that all pieces fit together properly.
- WisDOT faced a situation in which Compass would need to work successfully among department central office and region staff plus 72 performing counties. Initial development of the system relied on strong internal leadership in lieu of consultant engagement; relationship-building among all parties; and a six-month pilot program to ensure proper coordination, communication, and use of Compass among state and county personnel. This approach was felt to be important to demonstrating Compass credibility early on, encouraging all parties to work together, improving central office knowledge of the highly decentralized work performance, and properly managing expectations following early successes.

The cases for WisDOT, FDOT, and WSDOT all represent agencies with mature LOS-based management systems for M&O.

- The WisDOT case focused on processes and procedures undertaken to keep Compass current and prepared to address program-management tasks. The case covered an overview of field rating procedures, LOS concepts, the method of assigning internal priorities to highway features, quantifying LOS thresholds and grading curves, target setting and communication of targets, preparation of annual "report cards" and conduct of a gap analysis to compare actual conditions with target values, relating LOS to cost through "price tags," and other support activities. In part because WisDOT and its five regions deal with 72 counties who are the performing organizations for state highway maintenance in Wisconsin, WisDOT places a premium on good communication, coordination, effective data to support decisions, and shared responsibilities between the state and county participants.
- The FDOT case looked at how maintenance activities are prioritized for accomplishment throughout the year to ensure that the statewide maintenance standard is met on all state highways. FDOT applies its maintenance rating program (MRP) to determine condition-based scores for each characteristic of its highway elements. MRP reports for each period assist field managers in prioritizing work through the following period to improve any MRP scores that are currently low. The department combines this objective, analytic basis for determining the status of planned versus actual condition with a managerial check, the QA review, which seeks to ensure that funding is actually redirected to those activities that will produce positive performance results in the following period.
- The WSDOT case illustrated the application of its Maintenance Accountability Process (MAP) data to support meeting the requirements of WSDOT's Phase II stormwater permit. This permit essentially elevated the LOS targets for two drainage maintenance activities. MAP

data were incorporated directly within the permit's language to discuss the performance and maintenance level-of-effort implications of the permit requirements, to indicate how compliance with the permit would be monitored through MAP inspections and reports, and to establish the basis for a request to the legislature for additional funding to comply with permit requirements.
- Two items identified in the scope of work were also addressed in more detail through cross-cutting themes among the findings for the case example states: a more broad-based review of prioritization of maintenance activities (going beyond the FDOT example), and procedures agencies use to quantify factors such as LOS threshold values and grading curves. The results showed that agencies use a variety of methods to communicate priorities and incorporate them within the analytic processes of their MMSs; and that quantification of performance-based elements by all the agencies interviewed relied primarily on the professional judgments of their experienced M&O personnel.

Barriers to More Widespread Implementation

The synthesis findings also revealed barriers to more widespread use of performance-based M&O management. Sources of information included survey responses by the ten agencies that do not currently use performance-based methods; comments on the survey questionnaire from agency managers who do use performance-based methods, but who also identified impediments that could occur; and discussions with state DOT personnel.

The primary reasons cited for non-use of performance-based methods by ten agencies were the following, in order of decreasing numbers of responses:

- The agency was evolving in its management approach, but no decisions had been made yet.
- The agency does not have the resources to support a performance-based approach.
- The agency's current management systems do not support a performance-based approach.
- The state government has not yet adopted a performance-based philosophy.
- One other respondent noted that his or her agency was satisfied with their current management approach and did not see a need to consider moving to performance-based methods.

Among agencies that currently do use performance-based methods, a theme that was voiced by agency personnel was that uncertainty in funding could impede the effective use of performance-based methods. Two agencies also mentioned limitations of MMS to deal with insufficient or unpredictable levels of funding, and loss of specific analytic capabilities caused by upgrades to new products, which could limit the use of formerly used performance-based computations.

RECOMMENDATIONS FOR FURTHER RESEARCH

Work on this synthesis has identified several gaps in current knowledge that could be addressed by the following recommended research.

Comparative Descriptions of Performance-Based Maintenance and Operations Management

Gaps in Current Knowledge

Past research has developed fairly detailed, nationwide compilations of basic elements of performance-based M&O management (refer to sections at the start of chapter two). Comparable information has not been developed for the management practices, communication of information, and decision-making that drive M&O programs. The case studies in this synthesis provide a point of departure for understanding the types of information and descriptions of business processes, organizational relationships, and decision support that the proposed research could capture. However, each of the four cases had as its objective the investigation of a particular management function or task, not the comprehensive description of the performance-based process in its entirety. The directory of program information compiled by the University of Wisconsin–Madison (*Directory of State Program Information* July 2009) illustrates more broadly based categories of information, but greater detail, comparisons among different methods, and explanations of the inner workings of key management functions and tasks would be helpful. Two related research projects are proposed: one focusing on a comparative analysis of performance-based M&O management approaches in different agencies; the second, focusing on factors important to successful implementations. Note that the treatment of cost within PBM is a separate effort discussed in the next project recommendation.

Research Recommendations

- Comparative studies of performance-based M&O management. This research would obtain detailed information and assessments from state DOTs on what they perceive as strengths in their performance-based approaches, and areas where they believe improvements could result in more effective applications. (They might also be asked to comment on preferred ways to exchange information on current management approaches and proposed improvements; for example, through peer exchanges, domestic scans, workshops or webinars, conference sessions, further research projects, or state-DOT user-group or cooperative-arrangement research efforts.) Key questions for each state DOT to address regarding its own PBM could be defined and distributed before the research is conducted. With limited time and budget, this synthesis surveyed only the highway maintenance units represented on AASHTO's Subcommittee on Maintenance. A broader research program could engage operations units as well. Examples suggested

by findings of this current synthesis include the following, although this list is by no means exhaustive: How would one describe the current PBM approach? How are field data that are currently collected used in supporting PBM functions or tasks? How are performance measures defined to represent the needs, interests, and concerns of the state highway agency and its customers? How are current performance measures used to inform business processes and decisions? How are maintenance priorities represented within the performance-based approach, and how are they used in business processes and decision support? What mechanisms of internal and external communication are most effective for different situations? What mechanisms of customer input appear to work the best? If resources were available to improve the current performance-based approach and supporting procedures/systems, what would be the top three priorities in descending order? What factors currently impede, or threaten to impede, proper operation of performance-based M&O management? It is recommended that this research be completed before undertaking the proposed project on cost-effectiveness of performance-based approaches described in a later section.

- Success factors in effective performance-based M&O management. The findings of this project could provide a better understanding of the effectiveness of various performance-based methods, and of the circumstances under which the different available approaches are best used. This research could either be a separate effort or a component of the previously described project. Success factors encompass those forces associated with organizational change generally (e.g., importance of champions, good communication, and stakeholder involvement), and with performance-based M&O management specifically. The latter topic could consider for example the importance of the professional judgments of experienced maintenance personnel in quantifying elements of PBM and the process by which changes in agency policies, priorities, inspection methods, and performance measures are translated into updates to existing performance-based approaches. Past research and this synthesis have suggested candidate success factors. What is needed is a larger sample size of existing approaches, a more broad-based understanding of each state DOT's approach, and more in-depth discussions with agency personnel to explain the value-added contributions of different success factors within the context of their own agency's programs, priorities, management culture, and expectations of the M&O program.

Relating Maintenance and Operations Level of Service to Cost

Gaps in Current Knowledge

The analytic relationship between LOS and cost is beset by a lack of clear agreement on practice and use. Past research discussed at the beginning of chapter two has indicated that few states now employ such a relationship. The one example cited there was of the form of an asset condition relationship developed by the North Carolina DOT (refer to the WSDOT case in chapter three for an explanation of this nomenclature). In the past few years, WSDOT itself has transitioned from an asset condition approach to a task completion approach for its backlog and cost calculations. Comments submitted as part of synthesis survey responses indicated that the California DOT has developed a budget model with nonlinear cost curves and automated what-if scenarios of LOS versus cost; Colorado DOT has a procedure to translate LOS targets to a proposed budget. In its recently developed system, MDOT has analytically defined its performance measures and M&O resource requirements for each asset/activity such that proposed changes in LOS can be related directly to positive or negative changes in work required, which in turn can be related to increases or decreases in cost. Within WisDOT's Compass system, unit costs have been applied to the several Compass grading curves for the various roadway features to estimate the statewide average costs to reduce maintenance backlogs and improve LOS. The Compass program manager sees research needs to quantify regional unit cost differences and cost differentials based on road class. Also, the current method of cost calculation is a one-way analysis assuming additional dollars to increase the level of M&O service. Lacking good deterioration curves for road features other than pavements and bridges, Compass does not yet calculate increased maintenance backlogs (therefore, reduced service levels) owing to less funding. A two-way analysis would address both increased and decreased LOS, corresponding to reduced and increased backlog. The LOS–cost relationship is important to several tasks; for example, scenario-testing of alternative maintenance program targets, budget preparation and revision, and—as the WSDOT case in chapter three has shown—addressing M&O responses to requirements imposed by external events such as state or federal mandates. Greater knowledge of practical, feasible cost models could assist agencies in building the analytic capability to perform these tasks more efficiently and effectively.

Research Suggestions

Research on LOS–cost relationships could be structured as a synthesis or a technical report. The bulk of the research might focus on those state DOTs that use LOS–cost relationships or that have conducted substantial research on them. Several objectives could be addressed in describing each state DOT's method:

- To document analytic assumptions, formulas, data requirements, and outputs related to the method;
- To describe the derivation of the method (e.g., the pool of data and the mathematical procedures used to develop and test the relationships), and the length of time the method has been in use;

- To obtain available information, if any, on the initial cost savings of deferring maintenance work versus the costs to get the deferred work caught up at a later date. (This issue of deferred maintenance could also be framed in terms of backlog calculations—refer to the research ideas discussed by the WisDOT program manager);
- To identify unique or innovative features and capabilities within the method;
- To document further research or development work anticipated by each state DOT regarding its method; and
- To identify particular characteristics or requirements inherent in the method; for example, specialized data within MMSs or links to other agency data (e.g., in financial management or accounting systems and payroll systems), or specific definitions of performance measures, service levels, or other factors needed for the method's calculations to work correctly.

Paths to Implementation

Gaps in Current Knowledge

At least ten agencies that do not now use performance-based methods for highway M&O could benefit from past lessons learned in how to install such a system in their agencies. Additional candidates for these insights would include agencies that now use performance-based methods, but wish to move toward a more broader approach or one designed specifically for highway M&O. The experience of both MDOT in implementing AMMO and WisDOT in implementing Compass is that the installation of a new performance-based approach could encompass two major developments simultaneously: agreement on the new business processes and management capabilities needed immediately and a vision of longer-term possibilities; and the design, development, pilot testing, and implementation of supporting software. A lesson of the AMMO and Compass installations, however, is the need to tailor development and implementation to the objectives, characteristics, and culture of the agency, and to the type of M&O program envisioned and its intended operation. Some individual implementation efforts have been documented (e.g., Lebwohl 2003 for Compass); however, information for several different cases has not been brought together in a single guide to illustrate tried-and-tested methods appropriate to different circumstances. Two separate research projects are proposed: one focusing on processes of development and implementation; the second, focusing on how to demonstrate the cost-effectiveness of implementing a performance-based M&O approach.

Research Recommendations

- Implementation paths to a performance-based M&O approach. Although Mississippi's and Wisconsin's efforts have both been successful, each followed a different path as described earlier. It is recommended that up to three additional state DOTs be studied, selecting case example subjects from those agencies that have recently implemented new performance-based business processes and/or software. These could be combined with updated versions of the AMMO and Compass cases.
- Cost-effectiveness of performance-based M&O management. Demonstrating the cost-effectiveness of performance-based M&O management could help an M&O business unit justify the resources required for initial development. Longer term, cost-effectiveness could be used to buttress requests for continuing operational expenditures (e.g., for data collection and management system operation) or significant updates and upgrades. Access to supporting data on cost-effectiveness is important in light of comments by several survey respondents citing the lack of resources and the lack of MMS capabilities as reasons for not moving ahead on a performance-based M&O capability. Development of cost-effectiveness findings requires collaboration with state DOTs that already have operational performance-based M&O management programs. Agencies with a track record and historical information on their respective performance-based systems could provide more accurate estimates of the costs of system development, implementation, and operation, and more accurate assessment of the benefits and other impacts of performance-based system use. Some benefits and other impacts may be nonmonetary (or not easily monetized) and even qualitative. A cost-effectiveness analysis, which could include a benefit–cost component, is therefore recommended to capture the widest possible set of all benefits and impacts. It is recommended that this research be started after the completion of the comparative studies of performance-based M&O management described earlier.

ACRONYMS AND ABBREVIATIONS

AMMO	Accountability in MDOT Maintenance Operations
BI	business intelligence
Caltrans	California Department of Transportation
FDOT	Florida Department of Transportation
LOS	level(s) of service; service level(s)
M&O	maintenance and operations
MAP	Maintenance Accountability Process (WSDOT)
MDOT	Mississippi Department of Transportation
Mn/DOT	Minnesota Department of Transportation
MQA	maintenance quality assurance
MRP	Maintenance Rating Program (FDOT)
MRUTC	Midwest Regional University Transportation Center
PBM	performance-based management
QA	quality assurance
QC	quality control
TxDOT	Texas Department of Transportation
TxMAP	Texas Maintenance Assessment Program
WisDOT	Wisconsin Department of Transportation
WSDOT	Washington State Department of Transportation

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APPENDIX A

Survey Questionnaire

**SYNTHESIS 42-06 WEB-BASED
SURVEY QUESTIONNAIRE**

**NCHRP 42-06: PERFORMANCE-BASED HIGHWAY MAINTENANCE AND OPERATIONS MANAGEMENT
DISTRIBUTED JAN 2011**

Cover Letter

Dear State Highway Maintenance Manager:

The Transportation Research Board (TRB) through its National Cooperative Highway Research Program (NCHRP) is preparing a synthesis on Performance-Based Highway Maintenance and Operations Management. This is being done under the sponsorship of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration (FHWA).

The objectives of this synthesis are two-fold: (1) compile and synthesize current information on performance measures, levels of service (LOS), and related work as applied to highway maintenance and operations (M&O), and (2) develop state DOT case studies of performance-based techniques in highway M&O management. By meeting these objectives, the synthesis can contribute to improved information and practices available to state DOTs for managing highway maintenance and operations. The results of the synthesis will be distributed through AASHTO, TRB, and FHWA.

This survey is being sent to state DOT representatives on the AASHTO Subcommittee on Maintenance (SCOM). Your cooperation in completing the questionnaire will ensure the success of this effort. If you are not the appropriate person at your agency to complete this survey, please forward it to the correct person by following the guidelines below.

Please complete and submit this survey by Friday, February 11th. We estimate that it should take no more than 30 minutes, and in many cases less than 20 minutes, to complete. Most questions are multiple-choice or selection-of-closest-description, and can be completed relatively quickly. "Text boxes" are provided throughout the questionnaire if you need to provide additional information or examples. If you have questions, please contact our principal investigator, Mike Markow, mjmarkow@comcast.net (508) 540-5966. Any supporting documents, spreadsheets, slide presentations, etc. can be uploaded directly into the questionnaire response. Or, you may send them by e-mail to Mike Markow or provide him the appropriate document links in the text boxes.

Thank you very much for participating in this research.

DEFINITIONS

For purposes of this synthesis, "performance-based management" means the use of performance measures or levels of service (LOS) as an integral part of managing the maintenance and operations program. Maintenance Quality Assurance (MQA) is described "as the planned and systematic actions needed to provide adequate confidence that highway facilities meet specified requirements. Such requirements are usually defined by the highway agency but are intended to reflect the needs and expectations of the [road] user" [*NCHRP Synthesis Report 422,* p. 9]

Contact Information

Please enter your contact information.

First Name: _____

Last Name: _____

Title: _____

Agency/Organization: _____

Street Address:_____

Suite:_____

City:_____

State:_____

Zip Code:_____

Country:_____

E-mail Address:_____

Phone Number:_____

Q1 and Branch to Appropriate Part of Survey

1. Does your maintenance and operations (M&O) management approach rely on performance-based or Maintenance Quality Assurance concepts?

( ) Yes (proceed to Question 2 and the remainder of the survey)

( ) No (proceed to Question 16 and the remainder of the survey)

Q2

2. Select the statement that best describes your agency's use of performance-based or maintenance-quality-assurance concepts. (You will be automatically redirected to other parts of the survey based upon your response.)

( ) M&O-related condition or performance measures provide data to track performance trends, identify critical needs, and support tasks such as budget requests, but otherwise are not used in day-to-day management.

( ) Our agency uses several generalized or strategic performance measures (capturing facility condition, congestion, crash data, etc.) to assess multiple highway investment programs: maintenance and operations as well as capital preservation, mobility, safety, and so forth.

( ) This agency has just begun investigating MQA concepts, and is formulating its approach to M&O-related performance measures or levels of service.

( ) Performance measures have been defined for maintenance and operations specifically, and are used in M&O management tasks such as planning, budgeting, prioritization, regional allocations of funding, and accountability for results

( ) The agency has defined M&O levels of service (including any underlying performance measures) for some or all activities/assets, but these are preliminary and likely to be revised in the near future.

( ) The agency has a mature program of M&O levels of service (including any underlying performance measures) that is well integrated in management procedures, assessments, decisions, and systems, and is used in reporting and communication.

( ) The MQA, LOS, or performance-based practices used by this agency are not well described by any of the above statements.

Optional comment:

_____

_____

Q3 (Branch 1)

3. To which assets or activities listed below do you apply the performance-based or MQA concepts described in Question 2? (Check all that apply.)

( ) Road Surface (pavement or other travel way surface, shoulders)

( ) Bridges

( ) Other Structures (e.g., retaining walls, noise barriers, tunnels, reinforced earth)

( ) Drainage (ditches, culverts, inlets, box culverts, etc.)

( ) Roadside and Median Vegetation

( ) Slopes

( ) Pavement Markings

( ) Traffic Signals

( ) Roadway Lighting

( ) Signs

( ) Guardrail

( ) ITS Devices

( ) Cleaning, Brooming, Debris Removal

( ) Litter Pickup

( ) Incident/Emergency Response (e.g., regarding crashes, hazardous spills, emergency highway repairs)

( ) Rest Areas

( ) Winter Maintenance

( ) Median barriers

( ) Road-edge and ramp delineators

( ) Other significant assets/activities: please identify in text box below.

Other assets/activities: _____

Considering only the assets/activities you have selected above, how is this work delivered? (Check all that apply.)

( ) It is delivered under the auspices of the state DOT, whether using agency employees, contractors, volunteers, or prison labor.

( ) It is delivered by other governmental levels (e.g., municipalities, counties, etc.), but the state DOT retains responsibility for monitoring level of service provided.

( ) It is delivered by other governmental levels, with these other jurisdictions having responsibility for monitoring the levels of service provided.

( ) Other: please describe in text box below.

Other method of delivery: _____

Optional comment: _____

_____

Q4 (= Q3 Branch 2)

4. To which assets or activities listed below do you apply the performance-based or MQA concepts described in Question 2? (Check all that apply.)

( ) Road Surface (pavement or other travel way surface, shoulders)

( ) Bridges

( ) Other Structures (e.g., retaining walls, noise barriers, tunnels, reinforced earth)

( ) Drainage (ditches, culverts, inlets, box culverts, etc.)

( ) Roadside and Median Vegetation

( ) Slopes

( ) Pavement Markings

( ) Traffic Signals

( ) Roadway Lighting

( ) Signs

( ) Guardrail

( ) ITS Devices

( ) Cleaning, Brooming, Debris Removal

( ) Litter Pickup

( ) Incident/Emergency Response (e.g., regarding crashes, hazardous spills, emergency highway repairs)

( ) Rest Areas

( ) Winter Maintenance

( ) Median barriers

( ) Road-edge and ramp delineators

( ) Other significant assets/activities: please identify in text box below.

Other assets/activities: _____

Considering only the assets/activities you have selected above, how is this work delivered? (Check all that apply.)

( ) It is delivered under the auspices of the state DOT, whether using agency employees, contractors, volunteers, or prison labor.

( ) It is delivered by other governmental levels (e.g., municipalities, counties, etc.), but the state DOT retains responsibility for monitoring level of service provided.

( ) It is delivered by other governmental levels, with these other jurisdictions having responsibility for monitoring the levels of service provided.

( ) Other method of delivery: please identify in text box below.

Other method of delivery: _____

Optional comment: _____

_____

Q5

5. Performance measures and/or levels of service are defined: (Check all that apply.)

( ) With uniform values statewide

( ) With regional variations in values

( ) Other: please describe briefly in text box below.

Other method of defining performance measures or LOS: _____

Optional comment: _____

_____

Q6

6. Do you set goals or targets for anticipated levels of future performance?—e.g., a target LOS value or a target performance level that you intend to achieve within a certain time?

( ) Yes

( ) No

If Yes, please indicate how these targets are determined: (Check all that apply.)

( ) As a function of projected M&O budget

( ) As a legislatively mandated agency commitment

( ) As an agency commitment under a state government accountability initiative

( ) Solely as a commitment to meet an agency-established objective or goal

( ) As a result of internal management or engineering analysis indicating a realistic target for accomplishment

( ) By another method: please describe in text box below.

Other method: _____

Q7

7. Please indicate whether your agency uses a performance-based or MQA approach for the following tasks: (Check all that apply.)

( ) Tracking of condition, performance, or quality of M&O assets/activities

( ) Development of needs-based management estimates

( ) Maintenance and operations prioritization

( ) Budget development and justification

( ) Resource allocation among districts/divisions/regions

( ) Analytic relationships between LOS and cost

( ) Anticipation of future management requirements in reauthorization legislation

( ) Innovative communications techniques

( ) Other task(s): please describe in text box below.

Other task(s): _____

Optional comment: _____

_____

Q8

8. Do you use customer (road user) input in your performance-based or MQA approach; e.g., to assess current or planned M&O services, priorities, or quality of work?

( ) Yes

( ) No

If Yes, how is this information obtained? (Check all that apply.)

( ) Telephone or mailed surveys

( ) Survey cards (e.g., at rest areas)

( ) Trouble and complaint calls

( ) Written complaints

( ) Focus groups, discussion groups

( ) Formally organized citizens' panels

( ) Website, social media announcements and responses

( ) Other method(s): please describe in text box below.

Other method(s): _____

Optional comment: _____

_____

Q9

9. Does your agency solicit input from industry (e.g., shippers, truckers, engineering and construction firms, vendors and suppliers, professional and trade associations) in your performance-based or MQA approach; e.g., to assess current or planned M&O services, priorities, or quality of work?

( ) Yes

( ) No

If Yes, how is that information obtained? (Check all that apply.)

( ) Surveys of industry firms

( ) General meetings, agency presentations

( ) By-invitation meetings, invited industry presentations

( ) Industry/association review and comment on relevant proposed policies and practices

( ) Newsletter distribution

( ) Website, social media announcements and responses

( ) Focus groups, discussion groups on specific topics

( ) Formally organized industry advisory panels

( ) Other method(s): please describe in text box below.

Other method(s): _____

Optional comment: _____

_____

Q10

10. If you contract for maintenance and operations services, are levels of service or performance thresholds applied to contractor performance?

( ) Yes

( ) No

If Yes, these performance or LOS values are: (Check all that apply to the contracted work.)

( ) The same as those used for agency employee or force account work

( ) Defined specifically for contract work, completely separate from force account performance or LOS values

( ) A combination of what is expected of force account performance and of contractor performance

( ) Other approach: please describe in text box below.

Other approach: _____

Optional comment: _____

_____

Q11

11. This synthesis seeks to identify innovative performance measures and levels of service that are defined for operations activities/assets; e.g., winter maintenance, ITS devices, traffic signal systems, and incident response. Please select the examples below where you feel your agency has taken innovative approaches.

( ) Winter maintenance; e.g., definitions of winter storm indexes, or of "standard winter storms."

( ) Traffic signal measures that go beyond consideration of individual signal heads or single intersections to encompass link, corridor, and multijurisdictional effects. These could include measures of signal coordination that more closely relate to mobility improvements.

( ) ITS device maintenance that reflects performance and reliability; consideration of IntelliDrive devices.

( ) Performance measures for electronic and environmental sensing systems (in tunnels) that capture system compatibility of component replacement, or that gauge overall system reliability.

( ) Measures of incident or emergency response that capture safety, mobility, and preservation considerations.

( ) Other example(s): please describe in text box below.

Other example(s): _____

Optional comment: _____

_____

Q12

12. To whom do you communicate performance-based results (e.g., LOS target vs. attained; M&O accomplishments and resulting outcomes)? (Check all that apply.)

( ) Internally within the DOT organization, including bureaus or branches (e.g., motor vehicles)

( ) State transportation commission or equivalent

( ) Legislature, legislative staff

( ) Governor's office, executive staff

( ) Other state executive agencies (e.g., financial management, attorney general)

( ) State-level task forces or groups (e.g., safety commissions, governmental public protection groups)

( ) Other state DOTs, FHWA

( ) Professional and industry groups

( ) Non-governmental public advocacy groups

( ) General public, including via news outlets, Internet postings, social media

( ) Others: please describe in the text box below.

Others: _____

Optional comment: _____

_____

Q13

13. How is the communication in Question 12 accomplished—what media are used by your agency?

( ) Performance-accomplishment reports

( ) Newsletters

( ) Agency website articles

( ) Dashboards, summaries of performance indicators or LOS values

( ) Social media announcements

( ) E-mails, list-serve distributions

( ) Postal mailings

( ) Other methods: please describe in the text box below.

Other methods: _____

Optional comment: _____

_____

Q14

14. In your periodic field inspections of road conditions related to M&O, how are the data that are used in quantifying current performance measures or LOS obtained? (Check all that apply.)

( ) Headquarters-based teams gather data statewide

( ) District-level teams inspect other districts

( ) District-level teams inspect own district

( ) Independent third parties conduct inspections

( ) Combination of above

( ) Data are gathered for general agency-wide use (not limited to M&O) and are collected by a variety of efforts

( ) Other method(s): please describe in text box below.

Other method(s): _____

Does your agency use a quality control method to ensure consistency and repeatability in these field inspections?

( ) Yes

( ) No

( ) Inspections are handled by other agency offices and multiple efforts may be involved—cannot provide a definite answer

If Yes, please describe briefly:_____

Optional comment: _____

_____

Q15

15. The synthesis would benefit greatly from documents describing your management approach and list of LOS definitions and/or performance measures. Reports, papers, slide presentations, and other descriptions are welcome. If you are willing, please indicate below the way in which you will refer or transmit documents to the Principal Investigator, M.J. Markow (contact information at end of survey).

( ) Current documents are already in the MQA database maintained by the Midwest Research University Transportation Consortium (MRUTC) at the University of Wisconsin (P.I. can access these directly)

( ) Documents are available at the link(s) given in the text box below

( ) Up to 2 documents may be uploaded as part of this questionnaire response (use the Browse buttons below)

( ) Documents will be sent as e-mail attachments to mjmarkow@comcast.net

( ) A CD with document files will be mailed to M.J. Markow at the address at end of questionnaire

( ) Hard-copy reports will be mailed to M.J. Markow at the address at end of questionnaire

( ) Documents to be posted on FTP site; logon and password instructions will be sent to mjmarkow@comcast.net

( ) Sorry, no documents are able to be provided

( ) Other method(s): please describe in the text box below

Other method(s): _____

Document link(s) as follows:_____

It would benefit other state DOTs and transportation professionals to have access to these documents. May a copy of uploaded documents be provided for posting in the public domain on the MRUTC MQA database established at the University of Wisconsin?

( ) Yes

( ) No

Q16

16. You have indicated that your agency does not use performance-based methods for maintenance and operations. The method that your agency does use is based upon the following: (Check all that apply.)

( ) Annual programs are based upon previous year plus specific adjustments

( ) Annual programs are based primarily upon inventory quantities and percentage inventory maintained each year

( ) Annual programs are tailored to funding availability, irrespective of inventory, condition, or performance

( ) M&O work is being deferred, with a focus on critical items only

( ) M&O needs are being met through other programs (e.g., capital repairs or replacement)

( ) Other method(s): please describe in the text box below.

Other method(s): _____

If you have a report, paper, or other document that describes your current management approach and would be willing to provide it, please transmit it by one of the following: (1) provide a link in the textbox following this question, (2) attach it to an e-mail to M.J. Markow at the address given at the end of the survey, or (3) upload it directly to this questionnaire using the Browse button at the bottom of the page.

_____

Q17

17. The reasons that your agency has not adopted a performance-based approach include the following: (Check all that apply.)

( ) Our state government has not yet adopted a performance-based philosophy

( ) Our agency is satisfied with our current management approach, and does not see a need for an MQA or performance-based approach

( ) Performance measures and LOS values are inconclusive and difficult to define now

( ) Our M&O management approach is evolving, but final decisions have not yet been made

( ) We do not have the resources (funding, staffing, equipment) to support a performance-based or MQA approach

( ) Our current M&O management systems do not support performance measures or MQA procedures

( ) Other reasons: please describe in the text box below.

Other reasons: _____

Q18

18. Please describe briefly your performance-based or MQA-related approach to maintenance and operations management, even if its development is still in preliminary stages. Please include reference documents if possible. You can enter a link in the text box with your description. You can also upload a document to this questionnaire using the Browse button below, or take advantage of other transmittal options using the contact information for the Principal Investigator, M.J. Markow, at the end of this questionnaire.

_____

_____

Thank You!

Thank you for taking our survey. Your response is very important to us. If you have any questions or comments, please feel free to contact our principal investigator, Mike Markow, at:

E-mail: mjmarkow@comcast.net

Post: 43 Rivers End Rd, Teaticket, MA 02536-5858

Phone: (508) 540-5966

APPENDIX B

Survey Participants

Alabama DOT
Alaska DOT&PF
Arizona DOT
Arkansas H&TD
California DOT
Colorado DOT
Connecticut DOT
Delaware DOT
District of Columbia DOT
Florida DOT
Idaho Transportation Department
Indiana DOT
Iowa DOT
Kansas DOT
Kentucky Transportation Cabinet
Louisiana DOTD
Maryland SHA
Michigan DOT
Minnesota DOT
Missouri DOT
Mississippi DOT
Montana DOT
Nebraska DOT
Nevada DOT
New Hampshire DOT
New Mexico DOT
New York DOT
North Carolina DOT
Ohio DOT
Rhode Island DOT
South Carolina DOT
South Dakota DOT
Tennessee DOT
Texas DOT
Utah DOT
Vermont AOT
Virginia DOT
Washington State DOT
West Virginia DOT
Wisconsin DOT
Wyoming DOT

APPENDIX C

Mississippi Department of Transportation Customer Survey Form

Mississippi Department of Transportation
Maintenance Survey

Hello, my name is _____and I am calling on behalf of the Mississippi Department of Transportation. We are conducting a study to learn more about public attitudes on how well the Mississippi highways are being maintained.

A. Do you travel at least 20 miles a week in motor vehicles on the state highways in Mississippi? State highways include the interstate, U.S. and state routes but not the arterials and streets maintained by cities and counties.

IF YES CONTINUE	IF NO --- ASK TO SPEAK WITH OTHER PERSON IN HOUSEHOLD WHO DOES; IF NOT AVAILABLE, ARRANGE CALLBACK; IF NONE, THANK & TERMINATE

1. To begin, roadway maintenance involves activities such as patching potholes, mowing and picking up litter along the roadway. Thinking about Mississippi highways in general, how would you rate the level of maintenance of the highways on a scale of 1 to 5, where 1 means very poorly maintained and 5 means very well maintained?

	1
	2
	3
	4
	5
(DON'T READ) Not sure	6

2. Now I am going to read through a list of categories concerning the level of maintenance on the highways. For each category, I would like you to rank the current level of maintenance as you see it from a 1, which is very poorly maintained to a 5, which is very well maintained. Then, I would like you to tell me the level of maintenance that you believe is appropriate using this same scale, recognizing that higher levels of maintenance are more costly.

First, on a scale of 1 to 5, how would you rate the level of maintenance for <u>paved roadway surfaces</u> where 5 means the ride quality is smooth and the roadway is nearly free of potholes and other flaws?

2a.. And recognizing that higher levels of maintenance are more costly, what do you believe the level of maintenance for paved roadway surfaces should be on a 1 to 5 scale?

	Question 2	**Question 2a**
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
Not sure	6	6

3. Next, on a scale of 1 to 5, how would you rate the level of maintenance for shoulders, where a 5 means shoulders are smooth with no potholes and are level with the roadway without a dropoff from the road to the shoulder so that it is totally safe for pulling off the highway?

3a. And what do you believe the level of maintenance for shoulders should be on a 1 to 5 scale?

	Question 3	**Question 3a**
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

4. On a 1 to 5 scale, how would you rate the level of maintenance for drainage where 5 means that water is efficiently drained off the highway so that no puddles form?

4a. And what do you believe the level of maintenance for drainage should be on a 1 to 5 scale?

	Question 4	**Question 4a**
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

5. On a 1 to 5 scale, how would you rate the level of maintenance for mowing where 5 means the grass is consistently neat and trimmed?

5a. And what do you believe the level of maintenance for mowing should be on a 1 to 5 scale?

	Question 5	**Question 5a**
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

6. On a 1 to 5 scale, how would you rate the level of maintenance for litter pick-up where 5 means the roadside is free of litter and other debris?

6a. And what do you believe the level of maintenance for litter pick-up should be on a 1 to 5 scale?

	Question 6	**Question 6a**
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

7. On a 1 to 5 scale, how would you rate the level of maintenance for signs where 5 means that signs are highly visible and easily read?

7a. And what do you believe the level of maintenance for signs should be on a 1 to 5 scale?

	Question 7	Question 7a
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

8. On a 1 to 5 scale, how would you rate the level of maintenance for pavement center lines and edge lines where 5 means these markings are present and highly reflective?

8a. And what do you believe the level of maintenance for pavement center lines and edge lines should be on a 1 to 5 scale?

	Question 8	Question 8a
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

9. On a 1 to 5 scale, how would you rate the level of maintenance for bridges where 5 means bridges are in excellent condition with no bumps or dips as they are approached and no cracks can be seen?

9a. And what do you believe the level of maintenance for bridges should be on a 1 to 5 scale?

	Question 9	Question 9a
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

10. On a 1 to 5 scale, how would you rate the level of maintenance for rest areas where 5 means that they are clean and well-kept?

10a. And what do you believe the level of maintenance for rest areas should be on a 1 to 5 scale?

	Question 10	Question 10a
	1	1
	2	2
	3	3
	4	4
	5	5
	(DON'T READ)	(DON'T READ)
	Not sure 6	Not sure 6

LOOKING AT THE LIST OF NINE ITEMS, NOTE THE TWO WHICH HAVE THE LOWEST RATINGS. IF MORE THAN TWO, SELECT THE FIRST TWO, THEN ROTATE EACH TIME THIS OCCURS. IF EVERYTHING IS RANKED 5, SKIP TO QUESTION 13

11. I notice you gave (SELECTED ITEM) one of the lower ratings. What needs to be improved?

Paved roadway surfaces...1
Shoulders...2
Drainage...3
Mowing...4
Litter pick-up...5
Signs...6
Pavement center lines and edge lines...7
Bridges...8
Rest Areas…9

_____
_____
_____

12. And what about (SELECTED ITEM)? What needs to be improved?

Paved roadway surfaces...1
Shoulders...2
Drainage...3
Mowing...4
Litter pick-up...5
Signs...6
Pavement center lines and edge lines...7
Bridges...8
Rest Areas…9

_____
_____

13. Compared to the maintenance of city or county roads in Mississippi, would you say the maintenance of the Mississippi state highways is... (READ EACH)

Considerably better...1
Somewhat better...2
About the same...3
Not quite as good...4
Much worse...5
(DO NOT READ) Not sure...6

14. How would you rate the level of highway maintenance for Mississippi in comparison to highways in other states in which you have traveled? Would you say the Mississippi highways are...(READ EACH)

Considerably better...1
Somewhat better...2
About the same...3
Not quite as good...4
Much worse...5
(DO NOT READ) Not sure...6

15. Next, I would like your opinion on spending priorities. For each of the following maintenance services I read, please tell me if you feel it warrants a high priority, medium priority, or low priority when planning expenditures of the Mississippi Department of Transportation? (READ EACH; ROTATE)

		High	Medium	Low	Not Sure
A.	Paved roadway surfaces	1	2	3	4
B.	Shoulders	1	2	3	4
C.	Drainage	1	2	3	4
D.	Mowing	1	2	3	4
E.	Litter pick-up	1	2	3	4
F	Signs	1	2	3	4
G	Pavement center lines and edge lines	1	2	3	4
H	Bridges	1	2	3	4
I	Rest areas	1	2	3	4

16. Now I am going to read several goals for the highway maintenance program. As I read each one, please just tell me how important this should be on a 5-point scale where 1 is the lowest level of importance and 5 is the highest level? (READ LIST, ROTATE - CODE NOT SURE 6).

		Rating
A.	Safety	/___/
B.	Preservation, protecting our investment in the roadway and facility assets	/___/
C.	Comfort, a smooth ride	/___/
D.	Lowest cost	/___/
E.	Visually pleasing experience	/___/

17. And finally, how many miles do you drive on the Mississippi highways in a typical week?

Under 20...1
20–49…2
50–99...3
100 or over...4

Thank you very much, that completes this interview. Your input will be critical in helping the Mississippi Department of Transportation to establish priorities for its roadway and facilities maintenance function. My supervisor may want to call you to verify that I conducted this interview so may I have your first name so that they may do so? (VERIFY PHONE NUMBER)

NAME: ___ PHONE #: _____

FROM SAMPLE:
COUNTY:

APPENDIX D

STATE DEPARTMENT OF TRANSPORTATION SURVEY RESPONSES

Tabulated Responses to Questions

Responses by state departments of transportation (DOTs) to each of the survey questions are recorded in Tables D1–D8. Concise descriptions of each numbered question and choices for selection are stated in the column headers. State DOTs are identified in the row headers. It is strongly recommended that these results be reviewed in conjunction with the full questionnaire in Appendix A, so that the context and exact wording of each question can be fully understood.

In most cases survey responses are indicated by the digit "1." In some cases zero ("0") is used for the following purposes:

- To indicate a negative response (as in a Yes/No part of Question 15).
- To indicate a response that had been made on the questionnaire, but subsequently revised or vacated based on review of other responses or receipt of additional information. For example, a respondent may have checked an option to provide "Other" information in a Comment field, but then left the Comment field blank.

California DOT (Caltrans) submitted substantive and relatively lengthy comments to Questions 2 and 6. These comments are reproduced in their entirety following the tabulated results.

Survey Comments by California Department of Transportation

Caltrans' responses and optional comments to Questions 2 and 6 on the synthesis survey are reproduced fully below.

2. Select the statement that best describes your agency's use of performance-based or maintenance-quality-assurance concepts. (You will be automatically redirected to other parts of the survey based upon your response.)

The agency has defined M&O levels of service (including any underlying performance measures) for some or all activities/assets, but these are preliminary and likely to be revised in the near future.

Optional comment:

- Operations uses general production units compared to expenditures to determine a workload standard in a spreadsheet summary for each of the 12 districts statewide.
- Field maintenance has a more defined asset management. The asset management system called Integrated Maintenance Management System (IMMS) captures detailed inventory, expenditures, workload, and utilizes work orders for our crews and is more than 10 years old. The current version is a Hansen product that runs with an Oracle database. Field maintenance also utilizes a performance measurement system called Level of Services (LOS). LOS measures field maintenance elements using a criteria survey to determine performance on a random sample throughout the state. The LOS measures the percent of performance and compares that to the target or goal. The maintenance budget determines the available funding level based on asset management data from IMMS and LOS to determine funding to zones across the state. Zones are determined by 5 average daily traffic and 6 terrain levels for a total of 28 zones across California that allows Caltrans to measure beyond general areas or urban versus rural. The zones are used by Caltrans to determine performance, allocations, and goals. Note that the budget model also captures all maintenance allocations including field maintenance, bridge maintenance, pavement maintenance, and other various activities in maintenance. The budget model also captures field maintenance allocations using diminishing-return efficiency curves instead of previous straight line projections. One more feature added to the budget model is the ability to address what-if scenarios for modeling additional or reduced funding.
- Bridge Maintenance: The Bridge Preservation Program in California consists of three main components: state operations (maintenance crews), major maintenance contract projects, and State Highway Operation and Protection Plan (SHOPP) projects. The bridge needs are identified through inspection, structural analysis, safety standards, and goods movement plans. All three [program] components are managed utilizing an established bridge management system based on the AASHTO Pontis software. Together these three main components provide for the majority of all preservation work being performed on bridges in California. Funding targets are established based on projections of deterioration and expected accomplishments over a defined time period.
- Pavement Maintenance: Currently, the Pavement Program provides an annual district target allocation for the pavement maintenance projects based on the districts' pavement condition survey for inventory and performance. The district maintenance engineers update their Five-Year Pavement Maintenance Plan, prioritize their annual district candidate pavement projects, and submit their pavement maintenance projects based on their target allocation using spreadsheets. The goal of the Pavement Maintenance Program is to accomplish 2,700 lane-miles of pavement maintenance work annually based on our current budget. The majority of the Pavement Maintenance budget is focused on pavement preservation that will keep the good roads in good to excellent condition. These are preventive maintenance treatments such as thin lift overlays, seal coats, and concrete profile grinding. The remaining budget focuses on base maintenance repairs such as a digout and replacing the pavement and pavement recycling. Caltrans does not have an asset management program for pavement. However, the Pavement Program is in the process of procuring a state-of-the-art Pavement Management System (PaveM). The data needed to implement the PaveM are already being

TABLE D1
RESPONSES TO SURVEY QUESTIONS 1 AND 2

		1. PB?		2. MGMT USE							
STATE HIGHWAY AGENCY	RESPONSE RECEIVED?	USE A PERFORMANCE BASED APPROACH ? 1 = Y	1=NO	TRACK DATA ONLY	STRATEGIC PERFORMANCE MEASURES	JUST BEGUN MQA EFFORT	M&O PERFORMANCE MEASURES USED	M&O LOS = PRELIMINARY	M&O LOS = MATURE	MQA NOT WELL DESCRIBED IN STATEMENTS	OPTIONAL COMMENT
AL	1	1				1					
AK	1	1		1							
AZ	1	1					1				
AR	1		1								
CA	1	1						1			1
CO	1	1					---*		1		
CT	1		1								
DE	1		1								
DC	1	1		1							
FL	1	1							1		
GA											
HI											
ID	1	1			1						
IL											
IN	1	1						1			
IA	1	1						1			1
KS	1	1		1							
KY	1		1								
LA	1	1						1			
ME											
MD	1	1		1							
MA											
MI	1		1								
MN	1	1					1				1
MS	1	1						1			
MO	1	1					1				
MT	1	1			1						
NE	1		1								
NV	1	1				1					
NH	1		1								
NJ											
NM	1		1								
NY	1	1			1						
NC	1	1							1		
ND											
OH	1	1							1		
OK											
OR											
PA											
RI	1	1				1					
SC	1	1					1				
SD	1		1								
TN	1	1		1							
TX	1	1					1				1
UT	1	1							1		
VT	1	1							1		
VA	1	1					1				
WA	1	1							1		
WV	1		1								
WI	1	1							1		
WY	1	1						1			
TOTAL	41	31	10	5	3	3	6	6	8	0	4

*"Performance measures" was changed to "M&O LOS—Mature" based on state DOT literature.

TABLE D2
RESPONSES TO SURVEY QUESTIONS 3 AND 4

	3 AND 4. ASSETS AND ACTIVITIES																					3 AND 4. DELIVERY					
STATE HIGHWAY AGENCY	ROAD SURFACE	BRIDGES	OTHER STRUCTURES	DRAINAGE	ROADSIDE AND MEDIAN VEGETATION	SLOPES	PAVEMENT MARKINGS	TRAFFIC SIGNALS	ROADWAY LIGHTING	SIGNS	GUARDRAIL	ITS DEVICES	CLEANING, BROOMING, DEBRIS REMOVAL	LITTER PICKUP	INCIDENT-EMERGENCY RESPONSE	REST AREAS	WINTER MAINTENANCE	MEDIAN BARRIERS	ROAD-EDGE AND RAMP DELINEATORS	OTHER	NO RESPONSE	DELIVERED BY STATE DOT=VAR LABOR	DEL BY OTHER GOVT LVLS=ST DOT RESP	DEL BY OTHER GOVT LEVELS=THEIR RESP	OTHER	OPTIONAL COMMENT	NO RESPONSE
AL																											
AK	1	1		1	1	1	1	1		1	1						1					1					
AZ	1			1	1		1			1	1		1	1	1	1						1					
AR																											
CA	1	1		1	1	1	1	1		1	1	1	1	1		1	1	1	1	1		1					
CO	1	1	1	1	1	1	1	1		1	1		1	1		1	1	1	1			1				1	
CT																											
DE																											
DC																					1						1
FL	1	1		1	1	1	1		1	1	1		1	1	1	1			1			1					
GA																											
HI																											
ID	1	1					1	1	1	1	1	1			1	1	1					1					
IL																											
IN	1			1			1			1	1							1				1					
IA	1	1		1	1	1	1			1	1		1	1		1	1	1	1			1				1	
KS	1	1	1	1	1	1	1			1	1		1	1					1			1					
KY																											
LA																					1						1
ME																											
MD	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0		1		1	0		
MA																											
MI																											
MN	1	1		1			1			1							1			1		1					
MS	1	1		1	1		1			1	1											1					
MO	1	1		1	1		1	1		1					1	1	1					1					
MT	1	1			1		1	1	1							1	1					1					
NE																											
NV																											
NH																											
NJ																											
NM																											
NY	1	1	1	1	1	1	1	1		1	1		1	1		1	1					1	1				
NC	1	1		1	1		1	1		1	1				1	1	1					1					
ND																											
OH	1	1		1	1		1		1	1	1		1	1				1	1			1					
OK																											
OR																											
PA																											
RI																											
SC	1			1	1	1	1			1	1		1	1								1					
SD																											
TN	1			1	1	1	1			1	1		1	1			1	1	1	1		1	1				
TX	1			1	1		1	1		1	1		1	1		1		1	1	1		1			1		
UT	1			1	1	1	1			1	1		1	1			1	1	1			1					
VT	1	1		1			1				1		1	1			1					1					
VA	1	1		1	1		1	1	1	1	1	1			1	1			1			1					
WA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1					
WV																											
WI	1	1		1	1		1			1	1			1			1	1	1	1			1			1	
WY	1	1	1	1	1	1	1	1		1	1		1	1		1		1	1	1		1					
TOTAL	26	20	6	24	22	13	26	13	7	24	23	5	16	17	8	15	16	12	14	6	2	25	3	1	1	3	2

TABLE D3
RESPONSES TO SURVEY QUESTIONS 5, 6, AND 7

	5. PMs AND LOS					6. GOALS AND TARGETS										7. MQA-SUPPORTED TASKS										
STATE HIGHWAY AGENCY	UNIFORM VALUES STATEWIDE	REGIONAL VARIATIONS IN VALUES	OTHER	OPTIONAL COMMENT	NO RESPONSE	SET GOALS OR TARGETS? 1=Y	1=NO	AS FCN OF PROJECTED M&O BUDGET	AS LEGISLATIVELY MANDATED COMMITMENT	COMMITMENT TO ST ACCOUNTABILITY PGM	AGENCY ESTABLISHED GOAL OR OBJECTIVE	INTERNAL ANALYSIS = REALISTIC TARGET	OTHER		NO RESPONSE	TRACKING COND & PERF	NEEDS-BASED ESTIMATES	M&O PRIORITIZATION	BUDGET DEVEL & JUSTIFICATION	RESOURCE ALLOCATION	LOS - COST RELATIONSHIPS	REAUTHORIZATION LEGISLATION	INNOVATIVE COMMUNICATIONS	OTHER	OPTIONAL COMMENT	NO RESPONSE
AL																										
AK																										
AZ	1					1						1					1	1	1	1						
AR																										
CA	1	1	1			1		1			1	1	1			1	1	1	1	1	1					
CO	1					1		1					1			1			1	1						
CT																										
DE																										
DC																										
FL	1					1			1							1	1	1								
GA																										
HI																										
ID																										
IL																										
IN	1						1									1										
IA	1					1				1			1			1		1	1							
KS																										
KY																										
LA					1										1				1							
ME																										
MD																										
MA																										
MI																										
MN	1					1					1		1			1	1	1	1		1		1		1	
MS	1					1		1				1				1	1	1	1	1	1	1	1			
MO	1			1		1					1					1		1	1	1						
MT																										
NE																										
NV																										
NH																										
NJ																										
NM																										
NY																										
NC	1					1					1					1	1				1					
ND																										
OH	1						1									1	1	1	1	1						
OK																										
OR																										
PA																										
RI																										
SC	1					1		1								1	1	1	1							
SD																										
TN	0		0			0					0					0										
TX	1			1		1						1	1			1		1						1		
UT	1	1				1		1								1	1	1	1	1	1					
VT	1					1					1					1	1	1	1	1						
VA	1	1				1		1			1	1				1	1		1	1	1					
WA	1					1		1	1	1						1	1	1	1	1	1					
WV																										
WI	1	1		1		1		1			1	1	1			1	1	1	1	1						
WY	1			1		1		1								1		1			1			1		
TOTAL	19	4	1	4	1	17	2	9	2	2	7	6	6	0	1	18	13	15	15	11	8	1	2	2	1	0

TABLE D4
RESPONSES TO SURVEY QUESTIONS 8 AND 9

	8. CUSTOMER INPUT												9. INDUSTRY INPUT											
STATE HIGHWAY AGENCY	CUSTOMER INPUT? 1=Y	1=NO	TELEPHONE & MAILED SURVEYS	SURVEY CARDS	TROUBLE CALLS, COMPLAINTS	WRITTEN COMPLAINTS	FOCUS GROUPS, DISCUSSION GROUPS	CITIZENS' PANELS	WEBSITE, SOCIAL MEDIA	OTHER	OPTIONAL COMMENTS	NO RESPONSE	INDUSTRY INPUT? 1=Y	1=NO	SURVEYS OF FIRMS	GENERAL MEETINGS, PRESENTATIONS	BY-INVITATION MEETINGS	INDUSTRY ASSOC REVIEW AND COMMENT	NEWSLETTER DISTRIBUTION	WEBSITE, SOCIAL MEDIA	FOCUS GROUPS, DISCUSSION GROUPS	FORMALLY ORGANIZED INDUSTRY PANELS	OTHER	OPTIONAL COMMENT	NO RESPONSE
AL																								
AK																								
AZ		1												1										
AR																								
CA	1									1			1			1	1	1	1	1	1	1		
CO		1												1										
CT																								
DE																								
DC																								
FL	1		1	1									1			1		1				1		
GA																								
HI																								
ID																								
IL																								
IN		1												1										
IA	1		1								1			1										
KS																								
KY																								
LA												1												1
ME																								
MD																								
MA																								
MI																								
MN	1		1				1	1	1		1			1									1	
MS	1		1				1							1										
MO	1		1	1	1		1		1	1			1			1	1	1		1				
MT																								
NE																								
NV																								
NH																								
NJ																								
NM																								
NY																								
NC		1												1										
ND																								
OH		1									1			1										
OK																								
OR																								
PA																								
RI																								
SC	1		1											1										
SD																								
TN	0		0	0	0	0								0				1						
TX	1				1	1					1		1											
UT	1		1											1										
VT		1												1										
VA	1		1	1	1	1								1										
WA	1			1					1					1										
WV																								
WI		1									1			1										
WY	1		1								1			1										
TOTAL	12	7	9	4	3	2	3	1	3	2	6	1	4	15	0	3	2	4	1	2	1	2	0	1	1

TABLE D5
RESPONSES TO SURVEY QUESTIONS 10 AND 11

	10. MQA APPLIED TO CONTRACTS?								11. INNOVATIVE OPS? ==> RESEARCH NEED							
STATE HIGHWAY AGENCY	APPLIED TO CONTRACTS? 1-Y	1=NO	SAME AS FOR EMPLOYEES	DEFINED SPEC FOR CONTRACTS	COMBINES FORCE ACCT AND CONTRACT	OTHER	OPTIONAL COMMENT	NO RESPONSE	WINTER OPERATIONS	TRAFFIC SIGNALS	ITS DEVICES	ELECTRONIC / ENVIRON SYSTEMS	INCIDENT & EMERGENCY RESPONSE	OTHER	OPTIONAL COMMENT	NO RESPONSE
AL																
AK																
AZ		1														1
AR																
CA	1		1													1
CO	1		1	1												1
CT																
DE																
DC																
FL	1		1													1
GA																
HI																
ID																
IL																
IN		1														1
IA	1		1		1		1		1						1	
KS																
KY																
LA								1								1
ME																
MD																
MA																
MI																
MN		0					1		1							
MS	1					1										1
MO	1				1					1			1			
MT																
NE																
NV																
NH																
NJ																
NM																
NY																
NC	1				1					1						
ND																
OH	1		1											1		
OK																
OR																
PA																
RI																
SC		1														1
SD																
TN		0														0
TX		1					1							1	1	
UT	1		1						1							
VT	1		1													1
VA	1				1											1
WA							1			1	1	1	1	1		
WV																
WI		1					1									1
WY		1					1		1							
TOTAL	11	6	7	1	4	1	6	1	4	3	1	1	2	3	2	11

TABLE D6
RESPONSES TO SURVEY QUESTIONS 12 AND 13

	12. TO WHOM COMMUNICATE?													13. METHODS OF COMMUNICATION									
STATE HIGHWAY AGENCY	INTERNALLY WITHIN DOT	TRANSPORTATION COMMISSION	LEGISLATURE	GOVERNOR, EXEC STAFF	OTHER STATE AGENCIES	STATE TASK FORCES OR GROUPS	OTHER STATE DOTS, FHWA	PROFESSIONAL, INDUSTRY GROUPS	NON-GOVT ADVOCACY GROUPS	GENERAL PUBLIC	OTHER	OPTIONAL COMMENT	NO RESPONSE	PERF ACCOMPLISHMENT REPORTS	NEWSLETTERS	AGENCY WEBSITE ARTICLES	DASHBOARDS	SOCIAL MEDIA	EMAILS, LISTSERVE	POSTAL MAILINGS	OTHER	OPTIONAL COMMENT	NO RESPONSE
AL																							
AK																							
AZ	1																				1		
AR																							
CA	1	1	1	1	1	1	1	1	1	1	1			1	1		1		1	1			
CO	1	1	1	1										1							1		
CT																							
DE																							
DC																							
FL	1	1												1			1		1				
GA																							
HI																							
ID																							
IL																							
IN	1													1			1						
IA	1				1						1	1		1	1		1					1	
KS																							
KY																							
LA													1										1
ME																							
MD																							
MA																							
MI																							
MN	1		1	1						1		1		1	1	1	1	1					
MS	1	1									1			1		1							
MO	1	1	1	1			1	1		1				1	1	1	1						
MT																							
NE																							
NV																							
NH																							
NJ																							
NM																							
NY																							
NC	1	1	1	1						1				1		1	1						
ND																							
OH	1																1						
OK																							
OR																							
PA																							
RI																							
SC	1	1												1									
SD																							
TN	0		0						0			0		0			0						
TX	1	1	1				1							1									
UT	1		1	1													1						
VT	1	1	1												1	1		1					
VA	1	1	1	1		1	1	1		1				1		1	1				1		
WA	1		1	1						1				1			1						
WV																							
WI	1		1				1	1		1	1			1					1		1		
WY	1	1	1	1						1		1		1	1	1						1	
TOTAL	19	11	12	9	2	2	5	4	1	8	4	3	1	15	6	7	11	2	3	1	4	2	1

TABLE D7
RESPONSES TO SURVEY QUESTIONS 14 AND 15

	14 DATA COLLECTION TEAMS													15. DOCS				DOCS RECEIVED
STATE HIGHWAY AGENCY	HQ-BASED TEAMS GATHER INFO STATEWIDE	DISTRICT TEAMS=OTHER DISTRICTS	DISTRICT TEAMS=OWN DISTRICTS	INDEP THIRD PARTIES	COMBINATION OF ABOVE	DATA COLL FOR GEN'L USE, NOT ONLY M&O	OTHER	QC ON DATA COLL? 1=Y (CONT NEXT COL'S)	1=NO	1=INDETERMINATE: INSP BY OTHERS	IF YES, DESCRIPTION	OPTIONAL COMMENT	NO RESPONSE	IN MRUTC DOC LIBRARY	DOCS PROVIDED (LINK, UPLOAD, EMAIL, ETC)	NO DOCS TO BE PROVIDED	OK TO SEND TO MRUTC? 1=Y, 0=N	
AL																		
AK					1			1				0			1		1	FIELD DATA COLL MANUAL
AZ			1					1			1						1	
AR																		
CA					1		0	1			1			1	1		---	LINK TO LEGISLATIVE REPORTS
CO					1				1						1		1	RECEIVED LOS MANUAL
CT																		
DE																		
DC													1					
FL					1			1			0				1		1	LINK TO MRP SITE
GA																		
HI																		
ID					1				1							1	0	
IL																		
IN	1							1			1					1		
IA			1					1			1			1	1		1	PERF MEAS SURVEYOR MANUAL
KS					1		1	1			1			1			1	
KY																		
LA													1					
ME																		
MD	0				1	1				1		1			0		1	
MA																		
MI																		
MN					1				1					1	0		1	
MS					1	1		1			1				1		0	AMMO MANUAL NOT FOR POSTING
MO					1	1								1	1		1	MODOT WEBSITE - ORG RESULTS
MT			1					1			1				0		1	
NE																		
NV																		
NH																		
NJ																		
NM																		
NY					1			1			1				---		0	
NC					1			1			1			1				
ND																		
OH	1							1			0				1		1	LINK TO RECORDABLE COND SHEET
OK																		
OR																		
PA																		
RI																		
SC	1							1			1			1			1	
SD																		
TN			1					1			1			1			1	
TX	1						1	1			1				1		1	PVMT CONDITION (PMIS) MANUAL
UT			1					1			1				1		1	MMQA+ MANUAL
VT					1													
VA				1				1			1			1	1		1	RCA 2 DATA COLL MANUAL
WA		1						1			1			1				DOCS RECD FOR CASE EXAMPLE
WV																		
WI							1	1			1			1	1		1	DOCS RECD FOR CASE EXAMPLE
WY					1			1			1			1			0	
TOTAL	4	1	5	1	14	3	3	20	3	1	17	1	2	12	12	2	17	

TABLE D8
RESPONSES TO SURVEY QUESTIONS 16 THROUGH 18

	16. DON'T USE MQA - OTHER APPROACH?							17. REASONS DON'T USE MQA							18.	
STATE HIGHWAY AGENCY	PREV YEAR + ADJUSTMENTS	PERCENT INVENTORY	FUNDING AVAILABILITY	DEFERRED WORK, FOCUS ON CRITICAL ITEMS	OTHER PROGRAMS MEET NEEDS	OTHER	PAPER OR DESCRIPTION? 1=Y	STATE GOVT NOT YET PERF-BASED	CURRENT APPROACH OK	LOS DIFFICULT TO DEFINE	M&O MGMT EVOLVING, NO FINAL DECISIONS	INSUFFICIENT RESOURCES	CURRENT MMS DOESN'T SUPPORT MQA	OTHER	PLEASE DESCRIBE YOUR APPROACH	1=NO EXPLANATION PROVIDED
AL															1	
AK																
AZ																
AR	1		1								1	1	1			
CA																
CO																
CT	1		1	1							1	1	1			
DE	1											1				
DC																
FL																
GA																
HI																
ID																
IL																
IN																
IA																
KS																
KY		1	1					1			1					
LA																
ME																
MD																
MA																
MI			1	1				1			1		1			
MN																
MS																
MO																
MT																
NE	1								1			1	1			
NV															1	
NH		1	1	1							1	1				
NJ																
NM	1		1	1				1			1	1				
NY																
NC																
ND																
OH																
OK																
OR																
PA																
RI															1	
SC																
SD																
TN																
TX																
UT																
VT																
VA																
WA																
WV																
WI																
WY																
TOTAL	5	2	6	4	0	0	0	3	1	0	6	6	4	0	3	0

collected through the use of Ground Penetrating Radar (GPR) and Automated Pavement Condition Survey (APCS). The GPR will take an x-ray of what is under the pavement surface and create a pavement structure inventory. The APCS uses lasers to collect pavement data as the van drives along at highway speeds and takes a picture of the pavement surface to map pavement cracks. PaveM will capture inventory, use both the GPR and APCS data to predict pavement performance, and optimize and prioritize funding and workload options. This tool will lead to better decision making and pavement asset management throughout the state and will be implemented in 2013.

- Report to the Legislature: Our current report to the state legislature on California's 2011 Five Year Maintenance Plan highlighting pavement, bridge, and culverts is at http://www.dot.ca.gov/reports-legislature.htm.

6. **Do you set goals or targets for anticipated levels of future performance?—e.g., a target LOS value or a target performance level that you intend to achieve within a certain time?** Yes

If Yes, please indicate how these targets are determined: (Check all that apply.)

- As a result of internal management or engineering analysis indicating a realistic target for accomplishment
- As a function of projected M&O budget
- Solely as a commitment to meet an agency-established objective or goal
- By another method; please describe in text box below.

Other method:

- Maintenance Budget Model evaluates field maintenance assets, LOS, inventory, and average cost per inventory unit in 28 zones to determine allocations, constrained-target LOS, or unconstrained targets.
- Pavement Management System also measures the same elements of performance inventory and cost to identify project selection, priority, and type of funding, and major maintenance of the SHOPP.
- Bridge Maintenance System also does the same as the Pavement Management System.

Abbreviations used without definitions 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	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
HMCRP	Hazardous Materials Cooperative Research Program
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
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-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