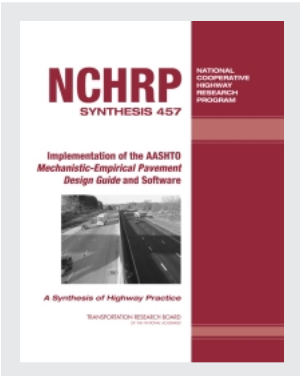

Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide and Software

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 457

Implementation of the AASHTO *Mechanistic-Empirical Pavement Design Guide* and Software

A Synthesis of Highway Practice

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in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

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

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

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The project that is the subject of this report was a part of the National Cooperative Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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FOREWORD

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

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

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

PREFACE

By Jo Allen Gause
Senior Program Officer
Transportation Research Board

In 2008, AASHTO published the *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice* (*MEPDG*) and released the first version of the accompanying software program, AASHTOWare Pavement ME Design™ (formerly DARWin-ME) in 2011. The *MEPDG* and accompanying software are based on mechanistic-empirical (ME) principles and are a significant departure from the previous empirically based AASHTO pavement design procedures. This synthesis documents the experience of transportation agencies in the implementation of the *MEPDG* and the software.

Information used in this study was gathered through a literature review and a survey of state departments of transportation and Canadian provincial transportation agencies. Follow-up interviews with selected agencies provided additional information.

Linda M. Pierce, Applied Pavement Technology, Inc., Santa Fe, New Mexico, and Ginger McGovern, Consultant, Oklahoma City, Oklahoma, 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 with the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

IMPLEMENTATION OF THE AASHTO *MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE* AND SOFTWARE

SUMMARY

In 2008, AASHTO published the *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice* (*MEPDG*) and released the first version of the accompanying software program AASHTOWare Pavement ME Design™ (formerly DARWin-ME) in 2011. The *MEPDG* and accompanying software are based on mechanistic-empirical (ME) principles and, as such, are a significant departure from the previous empirically based AASHTO pavement design procedures.

Moving from previous empirically based to ME-based design procedures provides a number of advantages, including the evaluation of a broader range of vehicle loadings, material properties, and climatic effects; improved characterization of the existing pavement layers; and improved reliability of pavement performance predictions. However, implementation of the *MEPDG* may require a significant increase in the required time to conduct a pavement design, in the needed data (e.g., traffic, materials, and calibration and verification to local conditions), and in the knowledge and experience of the personnel conducting the pavement design or analysis.

The objective of this synthesis is to document the strategies and lessons learned from highway agencies in the implementation of the *MEPDG* (and accompanying AASHTOWare Pavement ME Design™ software), as well as the reasons why some agencies have not or may not proceed with implementation. This synthesis is intended to aid in the facilitation and enhancement of the *MEPDG* and AASHTOWare Pavement ME Design™ implementation process through the demonstration of procedures and practices of highway agencies that have successfully implemented this pavement design procedure.

This synthesis is based on the results of a literature review of agency *MEPDG* implementation efforts, a survey of highway transportation agencies (U.S. state highway agencies, Puerto Rico, and the District of Columbia, and Canadian provincial and territorial governments), and follow-up questions with agencies that have implemented the *MEPDG*. In total, 57 agencies [48 U.S. (92%) and nine Canadian (69%) highway transportation agencies] provided responses to the agency survey.

For this synthesis, implementation is defined as the *MEPDG* and AASHTOWare Pavement ME Design™ being used to design or evaluate pavement structures, either for a limited number of pavement sections (e.g., interstate only), for a specific pavement type (e.g., asphalt or concrete), or for a specific pavement treatment (i.e., new, reconstructed, and rehabilitated), or for all pavement designs on the state highway network.

Of the 57 agencies that responded to the survey, three indicated that they have fully implemented the *MEPDG*, forty-six are in the process of implementing, and eight indicated that they have no plans at this time for implementing the *MEPDG*. The majority of the agencies indicated that the *MEPDG* will be used for the design and analysis of new or reconstructed asphalt pavements and jointed plain concrete pavements (JPCP). Most agencies reported that the *MEPDG* will be used for the design and analysis of asphalt overlays of existing asphalt pavements, existing concrete pavements, and fractured concrete pavements. For concrete overlays, most agencies indicated that the *MEPDG* will be used for the design and analysis

of unbonded JPCP overlays of existing JPCP, JPCP overlays of existing asphalt pavements, and bonded concrete overlays of existing JPCP.

In relation to *MEPDG* input values, agencies responded that, for the most part, the *MEPDG* default or agency-determined regional values are being used to characterize traffic and materials inputs (excluding truck volume and vehicle class distribution, which is predominately based on site-specific input values). In addition, 12 agencies indicated that the applicable *MEPDG* performance prediction models have been calibrated to local conditions.

A number of implementation aids were common among the agencies that have or will implement the *MEPDG* within the next 3 years (2013–2015). For example, 27 of the 32 responding agencies indicated having a *MEPDG* champion and 18 of 32 agencies indicated having an established *MEPDG* oversight committee.

When asked about activities that would aid the implementation effort, the majority of agencies indicated the need for assistance in the local calibration of the *MEPDG* performance prediction models and training in the use of the AASHTOWare Pavement ME Design™ software. Additional suggestions included developing a dedicated *MEPDG* website for sharing technical information, training in the interpretation of *MEPDG* results, training in methods for obtaining inputs, training in ME principles, and training in how to modify pavement sections to meet design criteria.

The results of the literature review indicated that a number of common elements were included in agency implementation plans, including identification of the pavement types to include in the implementation process, determining the data need requirements, defining materials and traffic input libraries, establishing threshold limits and reliability levels for each pavement performance prediction model, verifying the predicted pavement performance, updating agency documents to include analyzing pavement structures with the *MEPDG*, and providing training to agency staff on ME principles, *MEPDG*, and AASHTOWare Pavement ME Design™.

Three agency case examples were developed covering the implementation efforts of the departments of transportation of Indiana, Missouri, and Oregon. As part of the agency survey, these three agencies reported that the *MEPDG* had been implemented in their respective states. The agency case examples were developed using information provided by each agency in the agency survey, supplemented with follow-up questions and a review of agency-provided documents.

CHAPTER ONE

INTRODUCTION

BACKGROUND

In 2008, AASHTO published the *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice* (*MEPDG*) and in 2011 released the first version of the accompanying software, AASHTOWare Pavement ME Design™ (formerly MEPDG v1.100). The *MEPDG* and AASHTOWare Pavement ME Design™ software are based on mechanistic-empirical (ME) principles and, as such, are a significant departure from the previous empirically based AASHTO pavement design procedures. Moving from previous empirically based to ME-based design procedures provides a number of advantages, including the evaluation of a broader range of vehicle loadings, material properties, and climatic effects; improved characterization of the existing pavement layers; and improved reliability of pavement performance predictions. However, implementation of the *MEPDG* may require an increase in the amount of time required to develop the design and evaluate the results, an increase in the needed data (e.g., traffic, materials, and calibration and verification to local conditions), and personnel knowledge and experience in ME pavement design procedures. In addition, implementation of the *MEPDG* may require assistance from agency groups or divisions in the areas of materials, geotechnical, pavement design, pavement management, traffic, and construction.

Highway agencies have taken different approaches in the adoption and implementation of the *MEPDG*, which is not surprising given the complexity of the *MEPDG*, as well as the unique knowledge, experience, requirements, resources, and policies of each agency. Given the current maturity of the *MEPDG* and the continuing implementation efforts being made by many highway agencies, it is of interest to document what highway agencies are doing in terms of implementation, what strategies or approaches have worked well, and why some agencies have elected not to adopt the *MEPDG* at this time.

STUDY OBJECTIVE

The objective of this synthesis is to document the strategies and lessons learned from highway agencies in the implementation of the *MEPDG*, as well as the reasons why some agencies have not or may not proceed with implementation.

METHODOLOGY

This synthesis report was prepared using information from a literature review, a survey of highway agencies, three agency case examples, and follow-up questions on highway agency implementation of the *MEPDG*.

A literature search was conducted to review relevant documents, research findings, and agency practices related to the implementation of the *MEPDG*. The literature search was conducted by accessing the Transportation Research Information Service (TRIS) database, the TRB Research in Progress (RIP) database, and relevant AASHTO, NCHRP, and FHWA documents. The literature review provided an extensive list of research documents associated with the *MEPDG* performance prediction models, material and traffic characterization, and climate impacts. In contrast, comparatively few documents are available that summarize the *MEPDG* implementation practices of highway agencies.

An agency questionnaire (Appendix A) was developed that focused on the practices, policies, and procedures that have been successfully used by highway agencies for implementing the *MEPDG*. In addition, the questionnaire requested information related to:

- Reasons an agency has postponed or has yet to implement the *MEPDG*;
- Organizational structure and the steps that were required to work within this structure for successful implementation;
- Identification of implementation reports and on-going or proposed studies;
- Lessons learned that can be used to help other agencies in the implementation process; and
- Development of training programs and implementation guides.

Questionnaires were distributed (January 2013) to the pavement design engineers of the U.S. state highway agencies, Puerto Rico, District of Columbia, and Canadian provinces and territories. Fifty-seven [48 U.S. (92%) and nine Canadian (69%)] highway transportation agencies provided responses to the agency survey.

Responses to the questionnaire have been summarized (Appendix B) and used during the development of this synthesis report.

REPORT STRUCTURE

This synthesis report includes six chapters. This current chapter provides the background, objectives, and approaches used in the development of the synthesis. Chapter two presents a brief overview of the *MEPDG* and the accompanying AASHTOWare Pavement ME Design™ software; chapter three summarizes the findings of the agency survey; chapter four provides a list of common elements of agency implementation plans; chapter five summarizes three agency case examples on the implementation of the *MEPDG*; and chapter six presents report conclusions.

CHAPTER TWO

MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE AND AASHTOWare PAVEMENT ME DESIGN™ SOFTWARE OVERVIEW

INTRODUCTION

This chapter briefly describes the *MEPDG* (AASHTO 2008), the AASHTO *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide* (*MEPDG Local Calibration Guide*) (AASHTO 2010), and the AASHTO-Ware Pavement ME Design™ software, with the intent to summarize the key points, rather than duplicate the information provided in existing AASHTO documentation.

MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE, A MANUAL OF PRACTICE

Mechanistic-based pavement design procedures incorporate factors that directly relate to pavement performance, such as traffic loadings, climatic effects, material properties, and existing soil conditions. Since the late 1950s, pavement design has evolved from empirical-based methods, such as that developed at AASHO Road Test (HRB 1961), to ME-based procedures, as contained within the *MEPDG*.

As described in the summary of survey results, the majority of U.S. highway and Canadian provincial and territorial transportation agencies (39) utilize the AASHTO *Guide for the Design of Pavement Structures* (AASHTO 1993). Although the AASHTO 1993 *Guide* has served the pavement design community reasonably well, there are a number of limitations with this *Guide's* design procedure (e.g., limited material types, truck configurations that are no longer used, one climate zone) that can be overcome using an ME-based design procedure.

Having recognized the need for a nationally developed and calibrated ME pavement design procedure, the AASHTO Joint Technical Committee on Pavements proposed a research effort to develop such a design procedure that would be based on current state-of-the-practice pavement design methods (AASHTO 2008). This proposal lead to the initiation of NCHRP Project 1-37, Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures, and subsequently, NCHRP Project 1-37A, Guide for the Design of New and Rehabilitated Pavement Structures, and NCHRP Project 1-40, Facilitating the Implementation of the Guide for the Design of New and Rehabilitated Pavement Structures. The products of these projects included an ME pavement design guide, rudimentary software, and a performance prediction model calibration guide.

The *MEPDG* can be used to analyze a broad range of pavement design types, materials, traffic loadings, and climate regions. A summary of *MEPDG* features includes:

- **Traffic.** Truck traffic is characterized according to the distribution of axle loads for a specific axle type (i.e., axle-load spectra), hourly and monthly distribution factors, and distribution of truck classifications (i.e., the number of truck applications by FHWA vehicle class). Truck traffic classification groups have been developed to provide default values for normalized axle-load spectra and truck volume distribution by functional classification. The *MEPDG* also provides the ability to analyze special axle configurations.
- **Materials.** Materials property characterization includes asphalt, concrete, cementitious and unbound granular materials, and subgrade soils. Laboratory and field testing are in accordance with AASHTO and ASTM test protocols and standards. The key layer property for all pavement layers is modulus (dynamic modulus for asphalt layers, elastic modulus for all concrete and chemically stabilized layers, and resilient modulus for unbound layers and subgrade soils).
- **Climate.** Consideration of climate effects on material properties using the Integrated Climatic Model. This is used to model the effects of temperature, moisture, wind speed, cloud cover, and relative humidity in each pavement layer. These effects, for example, include aging in asphalt layers, curling and warping in concrete pavements, and moisture susceptibility of unbound materials and subgrade soils.
- **Performance prediction.** The *MEPDG* includes transfer functions and regression equations to predict pavement distress and smoothness, characterized by the International Roughness Index (IRI).

Another integral aspect of the *MEPDG* is the incorporation of input hierarchical levels. Although the analysis method is independent of the input level (i.e., regardless of the input level, the same analysis is conducted), the idea of including a hierarchical level for inputs is based on the concept that not all agencies will have detailed input data or that every pavement needs to be designed with a high level of input accuracy. For example, an agency would not necessarily use the same level of inputs for pavements on farm-to-market roads as they would for an urban interstate.

The inputs levels included in the *MEPDG* are as follows (AASHTO 2008):

Level 1. Inputs are based on measured parameters (e.g., laboratory testing of materials, deflection testing) and site-specific traffic information. This level represents the greatest input parameter knowledge, but requires the highest investment of time, resources, and cost to obtain.
Level 2. Inputs are calculated from other site-specific data or parameters using correlation or regression equations. This level may also represent measured regional (non-site-specific) values.
Level 3. Inputs are based on expert opinion, and global or regional averages.

The *MEPDG* recommends that the pavement designer use as high a level of input as available. Selecting the same hierarchical level for all inputs, however, is not required (AASHTO 2008). Each agency is expected to determine the input level related to roadway importance, and data collection effort costs and time.

The *MEPDG* (AASHTO 2008) provides recommended input levels for site conditions and factors (Chapter 9), rehabilitation design (Chapter 10), and material properties (Chapter 11).

National calibration of the pavement prediction models used in the *MEPDG* are based on the data included as part of the Long-Term Pavement Performance (LTPP) research program, and recent research studies from the Minnesota pavement test track (MnROAD) and the FHWA accelerated loading facility. Table 1 provides a list of pavement types that are included in the *MEPDG*.

At this time, a number of pavement, treatment, and material types had not been incorporated in the *MEPDG* (AASHTO 2008) or the performance prediction models had not been nationally calibrated for use in the *MEPDG* and AASHTOWare Pavement ME Design™ software (AASHTO 2008). For example, these include:

- Performance prediction models for asphalt-treated permeable base under asphalt pavements have not been nationally calibrated.
- Semi-rigid pavements cannot currently be modeled using the *MEPDG* and AASHTOWare Pavement ME Design™ software.
- Pavement preservation treatments (e.g., seal coats, microsurfacing, thin asphalt overlays, hot in-place recycling, cold in-place recycling), except for mill and asphalt overlay, are not accounted for in the *MEPDG* and AASHTOWare Pavement ME Design™ software. However, pavement preservation and maintenance may be accounted for indirectly during the local calibration process (AASHTO 2010).
- Jointed reinforced concrete pavements cannot be modeled using the *MEPDG* and AASHTOWare Pavement ME Design™ software.

Performance prediction models included in the *MEPDG* are provided in Table 2.

Since the release of the NCHRP 1-37A final report in 2004, a number of additional study efforts have been completed or are currently on-going to improve the *MEPDG* performance model prediction. These include:

- Reflective cracking model—*NCHRP Report 669*: *Models for Predicting Reflection Cracking of Hot-Mix Asphalt Overlays* (Lytton et al. 2010).
- Rutting models—*NCHRP Report 719*: *Calibration of Rutting Models for Structural and Mix Design* (Von Quintus et al. 2012).

TABLE 1
PAVEMENT TYPES INCLUDED IN THE *MEPDG*

Asphalt Pavements	Concrete Pavements
• Conventional—2 to 6 in. asphalt layer over unbound aggregate and soil-aggregate layers. • Deep strength—thick asphalt layer(s) over an aggregate layer. • Full-depth—asphalt layer(s) over stabilized layer or embankment and foundation soil. • Semi-rigid—asphalt layer(s) over cementitious stabilized materials. • Cold in-place recycle (CIR)—designed as a new flexible pavement. • Hot in-place recycle (HIR)—designed as mill and fill with asphalt overlay. • Asphalt overlays (>2 in.)—over existing asphalt and intact concrete pavements, with or without pre-overlay repairs, and milling.	• JPCP—with or without dowel bars, over unbound aggregate, and/or stabilized layers. • CRCP—over unbound aggregate, and/or stabilized layers. • JPCP overlays (>6 in.)—over existing concrete, composite, or asphalt pavements (minimum thickness of 6 in. and 10 ft or greater joint spacing). • CRCP overlays (>7 in.)—over existing concrete, composite, or asphalt pavements (minimum thickness of 7 in.). • JPCP restoration—diamond grinding, and a variety of pavement restoration treatments.

Source: AASHTO (2008).
JPCP = jointed plain concrete pavements; CRCP = continuously reinforced concrete pavements.

TABLE 2
PERFORMANCE PREDICTION MODELS INCLUDED IN THE MEPDG

Asphalt Pavements	Concrete Pavements
• Rut depth—total, asphalt, unbound aggregate layers, and subgrade (inches). • Transverse (thermal) cracking (non-load-related) (feet/mile). • Alligator (bottom-up fatigue) cracking (percent lane area). • Longitudinal cracking (top-down) (feet/mile). • Reflective cracking of asphalt overlays over asphalt, semi-rigid, composite, and concrete pavements (percent lane area). • IRI—predicted based on other distresses (inches/mile).	• Transverse cracking (JPCP) (percent slabs). • Mean joint faulting (JPCP) (inches). • Punchouts (CRCP) (number per mile). • IRI—predicted based on other distresses (JPCP and CRCP) (inches/mile).

Source: AASHTO (2008).

JPCP = jointed plain concrete pavements; CRCP = continuously reinforced concrete pavements.

- Longitudinal cracking model—NCHRP Project 1-52, *A Mechanistic-Empirical Model for Top-Down Cracking of Asphalt Pavement Layers* [http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3152].

The general approach for conducting a pavement design and analysis is structured according to three major stages, each containing multiple steps; each stage of the *MEPDG* design process is summarized as follows (AASHTO 2008):

- Stage 1—Determine materials, traffic, climate, and existing pavement evaluation (for overlay designs) input values for the trial design.
- Stage 2—Select threshold limits and reliability levels for each performance indicator to be evaluated for the trial design. Conduct the analysis on the trial design. If the predicted performance does not meet the criteria at the specified reliability level, the trial design is modified (e.g., thickness, material properties) and re-run until the performance indicator criteria is met (see *MEPDG*, Tables 14-3 through 14-5).
- Stage 3—Evaluate pavement design alternatives. This analysis is conducted outside the *MEPDG* and may include an engineering analysis and life-cycle cost analysis of viable alternatives.

GUIDE FOR THE LOCAL CALIBRATION OF THE MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE

The performance prediction models contained within the *MEPDG* have been nationally calibrated using the in-service pavement material properties, pavement structure, climate and truck loading conditions, and performance data obtained from the LTPP program. The *MEPDG* performance prediction models may or may not account for site-specific conditions (e.g., unique traffic loadings, soil conditions, material properties). According to the *MEPDG Local Calibration Guide*, it is highly recommended that each agency conduct an analysis of the *MEPDG* results to determine if the nationally calibrated performance models accurately predict field performance (AASHTO 2010). If not, the performance prediction models used in the *MEPDG* may require calibration to local conditions. Because of the limited availability of site-specific measured properties (Level 1), the *MEPDG* performance prediction models are primarily based on Level 2 and Level 3 inputs (AASHTO 2010).

To aid in local calibration efforts, AASHTO has published the *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide* (AASHTO 2010). The *Calibration Guide* provides the following procedures for calibrating the *MEPDG* to local conditions:

Step 1. Select hierarchical input level. Selection of the hierarchical input level is a policy-based decision that can be influenced by the agency's field and laboratory testing capabilities, material and construction specifications, and traffic collection procedures and equipment. An agency may choose different hierarchical input levels depending on data availability.

Step 2. Develop experimental plan and sampling template. Selection of pavement segments (and replicates, if possible) that represent the agencies standard specifications, construction and design practices, and materials. Selected pavement segments could represent a variety of design types (i.e., new, reconstructed, rehabilitated), pavement types, traffic levels (or facility), and climate. LTPP or other research test sections may also be included in the experimental plan.

Step 3. Estimate sample size. Ensure that the proper number of pavement segments is included in the calibration effort so that the results are statistically meaningful. The recommended minimum number of pavement segments includes:

- Rut depth and faulting: 20 pavement segments.
- Alligator and longitudinal cracking: 30 pavement segments.
- Transverse slab cracking: 30 pavement segments.

- Transverse cracking: 26 pavement segments.
- Reflection cracking: 26 pavement segments.

Step 4. Select roadway segments. Selection of applicable roadway segments, replicate segments, LTPP sites, and research segments to fill the experimental plan developed in Task 2. It is recommended that selected pavement segments have at least three condition observations over an 8- to 10-year period.

Step 5. Evaluate project and distress data. Verify that the required input data (e.g., material properties, construction history, traffic, measured condition) are available for each selected pavement segment (refer to *MEPDG* for a detailed list of input requirements). If discrepancies exist between an agency and the LTPP *Distress Identification Manual* (Miller and Bellinger 2003) data definitions and/or measurement protocols, the agency data may require conversion to meet the *MEPDG* format. Check pavement segments to ensure they encompass an ample condition range. The *MEPDG* recommends that the average maximum condition level exceed 50% of the design criteria. For example, if an agency's rut depth threshold is 0.50 in., the average maximum rut depth of the pavement segments would be at least 0.25 in.

Step 6. Conduct field testing and forensic investigation. This step includes conducting field sampling and testing of pavement segments to obtain missing data, if necessary.

Step 7. Assess local bias. Plot and compare the measured field performance to the *MEPDG* predicted performance (at 50% reliability) for each pavement segment. Evaluate each performance prediction model in relation to:

- Prediction capability—linear regression of the measured and predicted condition values, compute the *R*-square value. Generally, *R*-square values above 0.65 are considered to have good prediction capabilities.
- Estimate the accuracy—calculate the means of the standard error of the estimate (S_e) and compare with the *MEPDG* performance prediction models (Table 3).
- Determine the bias for each performance prediction model (i.e., hypothesis testing). If the null hypothesis is rejected, the performance prediction model should be recalibrated. If the null hypothesis is accepted (i.e., no bias), compare the S_e of the local data with the globally calibrated data (see Step 9).

Step 8. Eliminate local bias. If the null hypothesis is rejected in Step 7, significant bias exists. Determine the cause of the bias, remove the bias, if possible, and rerun the analysis using the adjusted calibration coefficients. Features to consider in removing bias include traffic conditions, climate, and material characteristics.

Step 9. Assess standard error of the estimate. In this step, the S_e for the locally calibrated models is compared with the S_e of the *MEPDG* performance prediction models and checked for reasonableness. Reasonable S_e values are provided in Table 4.

Potential courses of action include:

- For errors that are not statistically significantly different, use the locally calibrated performance prediction model coefficients (go to Step 11).
- For errors that are statistically significantly different and the S_e of the locally calibrated performance prediction model is less than the *MEPDG* performance prediction model, use the locally calibrated performance prediction model coefficients (go to Step 11).
- For errors that are statistically significantly different and the S_e of the locally calibrated performance prediction model is greater than the *MEPDG* performance prediction model, the locally calibrated performance prediction model should be recalibrated to lower the standard error. Alternatively, the locally calibrated performance prediction model could be accepted knowing it has a higher standard error than the *MEPDG* performance prediction model.

Step 10. Reduce standard error of the estimate. If the standard error cannot be reduced, proceed to Step 11.

TABLE 3
SUMMARY OF MODEL STATISTICS

Pavement Type	Performance Prediction Model	Model Statistics		
		R-Square	S_e	Number of data points, *N*
New Asphalt	Alligator cracking	0.275	5.01	405
	Transverse cracking	1[1]: 0.344 2: 0.218 3: 0.057	N/A	N/A
	Rut depth	0.58	0.107	334
	IRI	0.56	18.9	1,926
New JPCP	Transverse cracking	0.85	4.52	1,505
	Joint faulting	0.58	0.033	1,239
	IRI	0.60	17.1	163

Source: Titus-Glover and Mallela (2009).
[1]Level of input used in calibration.
JPCP = jointed plain concrete pavements; IRI = international roughness index; N/A = not available.

TABLE 4
STANDARD ERROR OF THE ESTIMATE VALUES

Pavement Type	Performance Prediction Model	S_e
Asphalt-surfaced	Alligator cracking (percent lane area)	7
	Longitudinal cracking (feet/mile)	600
	Transverse cracking (feet/mile)	250
	Reflection cracking (feet/mile)	600
	Rut depth (inches)	0.10
Concrete-surfaced	Transverse cracking—JPCP (percent slabs)	7
	Joint faulting—JPCP (inches)	0.05
	Punchouts—CRCP (number per mile)	4

Source: AASHTO (2009).
JPCP = jointed plain concrete pavements; CRCP = continuously reinforced concrete pavements.

If the standard error can be reduced, determine if the standard error of each cell of the experimental matrix is dependent on other factors and adjust the local calibration coefficients to reduce the standard error (Table 5).

Step 11. Interpretation of the results. Compare the predicted distress (and IRI) with measured distress to verify that acceptable results are being obtained.

AASHTOWare PAVEMENT ME DESIGN™

The ability to conduct the analysis described in the *MEPDG* without the aid of a computer program would be extremely time-consuming, if even possible. As previously noted, one of the products of the NCHRP 1-37A project was accompanying rudimentary software. There were a number of issues that

TABLE 5
FACTORS FOR ELIMINATING BIAS AND REDUCING THE STANDARD ERROR

Pavement Type	Distress	Eliminate Bias	Reduce Standard Error
Asphalt	Total rut depth	$k_{r1} = -3.35412$ $\beta_{r1} = 1$ $\beta_{s1} = 1$	$k_{r2} = 1.5606$ $k_{r3} = 0.4791$ $\beta_{r2} = 1$ $\beta_{r3} = 1$
	Alligator cracking	$k_{f1} = 0.007566$ $C_2 = 1$	$k_{f2} = 3.9492$ $k_{f3} = 1.281$ $C_1 = 1$
	Longitudinal cracking	$k_{f1} = 0.007566$ $C_2 = 3.5$	$k_{f2} = 3.9492$ $k_{f3} = 1.281$ $C_1 = 7$
	Transverse cracking	$\beta_{t3} = 1$ $k_{t3} = 1.5$	$\beta_{t3} = 1$ $k_{t3} = 1.5$
	IRI	$C_4 = 0.015$ (new) $C_4 = 0.00825$ (overlay)	$C_1 = 40$ (new) $C_1 = 40.8$ (overlay) $C_2 = 0.4$ (new) $C_2 = 0.575$ (overlay) $C_3 = 0.008$ (new) $C_3 = 0.0014$ (overlay)
Semi-Rigid Pavements		$\beta_{c1} = 1$ $C_2 = 1$	$C_1 = 1$ $C_2 = 1$ $C_4 = 1{,}000$
JPCP	Faulting	$C_1 = 1.0184$	$C_1 = 1.0184$
	Transverse cracking	$C_1 = 2$ $C_4 = 1$	$C_2 = 1.22$ $C_5 = -1.98$
	IRI—JPCP	$J_4 = 25.24$	$J_1 = 0.8203$
CRCP	Punchouts	$C_3 = 216.842$	$C_4 = 33.1579$ $C_5 = -0.58947$
	Punchouts fatigue	$C_1 = 2$	$C_2 = 1.22$
	Punchouts crack width	$C_6 = 1$	$C_6 = 1$
	IRI—CRCP	—	$C_1 = 3.15$ $C_2 = 28.35$

Adapted from AASHTO (2010).
JPCP = jointed plain concrete pavements; CRCP = continuously reinforced concrete pavements.

required modification before making the software package commercially available. In 2011, AASHTOWare released the first version of DARWin-ME, which was rebranded to AASHTOWare Pavement ME Design™ in 2013. A number of enhancements have been included in the AASHTOWare Pavement ME Design™ software making it a dynamic and effective tool for conducting pavement design evaluations. Enhancements over the rudimentary software include, for example, reduced runtime, an improved graphical user interface, and the ability to store input values into a database.

The AASHTOWare Pavement ME Design™ software was developed in accordance with the procedures and practices defined in the *MEPDG*. In that regard, the AASHTOWare Pavement ME Design™ software is comprised of a series of modules that lead the designer through the analysis procedure. Because the *MEPDG* and accompanying software require the designer to consider different levels of various aspects of the pavement layers (e.g., binder type, aggregate structure), the AASHTOWare Pavement ME Design™ software is technically an analysis tool (i.e., the designer must specify the pavement structural section to be analyzed). The various modules of the AASHTOWare Pavement ME Design™ software include (AASHTO 2011):

- **General design inputs**, which include information related to the pavement design type (new pavement, overlay, or restoration), pavement type [e.g., asphalt, jointed plain concrete pavements (JPCP), continuously reinforced concrete pavements (CRCP), asphalt overlay, concrete overlay], design life, and month/year of construction and opening to traffic.
- **Performance criteria** are used in the analysis to determine whether or not the specified pavement section is to be accepted or rejected. The performance criteria are agency-specific (although default values are provided) and therefore should be based on tolerable or acceptable levels of distress and roughness. In this module, the designer specifies both the limiting value for each performance prediction model and the level of reliability.
- **Traffic**—traffic data are required to determine the impact of vehicle loadings onto the pavement structure. Required traffic data may be based on weigh-in-motion sites, automatic vehicle classification sites, statewide averages, and/or national averages. Needed traffic items include base year truck volume and speed, axle configuration, lateral wander, truck wheelbase, vehicle class distribution, growth rate, hourly and monthly truck adjustment factors, axles per truck, and axle-load distribution factors. In addition, the designer can input a traffic capacity value to cap the traffic volume over the design period. National default values are available for the majority of inputs.
- **Climate**—climate data are used in the analysis process to determine the environmental effects on material responses (e.g., impact of temperature on the stiffness of asphalt layers, moisture impacts to unbound materials) and pavement performance (e.g., asphalt rutting, asphalt thermal cracking, concrete curling). At the time of this report, the current software version (v1.3) included climate data for 1,083 U.S. and Canadian weather stations. In addition, virtual weather stations can be generated from existing weather stations and new weather stations can be added.
- **Asphalt layer design properties** include surface shortwave absorptivity, fatigue endurance limit (if used), and the interface friction. The fatigue cracking endurance limit has not yet been calibrated (AASHTO 2008).
- **Concrete layer design properties**—for JPCP, this information includes, for example, joint spacing and sealant type, dowel diameter and spacing, use of a widened lane and/or tied shoulders, and information related to the erodibility of the underlying layer. For CRCP, design properties include, for example, percent steel, bar diameter, and bar placement depth.
- **Pavement structure**—the pavement structure module allows the designer to insert the material types, asphalt mix volumetrics, concrete mix information, mechanical properties, strength properties, thermal properties, and thickness for each layer of the pavement section to be analyzed.
- **Calibration factors**—within the software there are two opportunities to specify the performance prediction model calibration coefficients: (1) program-level and (2) project-specific (AASHTO 2013). The program-level calibration coefficients are the nationally calibrated factors. Unless otherwise noted, the software will utilize the program-level calibration coefficients in the analysis. The project-specific calibration coefficients do not change the program-level coefficients and are only used on designer-specified projects. Both the program-level and the project-specific calibration coefficients can be modified by the designer.
- **Sensitivity**—allows the designer to define minimum and maximum values for selected parameters (e.g., air voids, percent binder, layer modulus) to determine the impact on the predicted condition.
- **Optimization**—this feature is used to determine the minimum layer thickness of a single layer that satisfies the performance criteria. In this mode, the designer inputs the minimum and maximum layer thickness for the layer in question; the software iterates the layer thickness within the specified range while all other inputs remain constant; and the software determines the minimum layer thickness required to meet all performance criteria.
- **Reports**—the input summary, climate summary, design checks, materials properties summary, condition prediction summary, and charts can be provided as a PDF file (v9 or above) and Microsoft Excel format (2003 or newer).

TRAINING AND WORKSHOPS

The following is a list of currently available training courses and workshops on ME Design, *MEPDG*, and AASHTOWare Pavement ME Design™ software.

- FHWA Design Guide Implementation Team (http://www.fhwa.dot.gov/pavement/dgit/dgitcast.cfm).
  - Introductory Design Guide (2004)—webcast includes discussion of asphalt and concrete concepts and implementation activities.
  - Obtaining Materials Inputs for ME Design (2005)—webcast covers the required material inputs required to a design.
  - Executive Summary for Mechanistic-Empirical Design (2005)—webcast discusses the benefits and needs for adoption of ME pavement design.
  - Use of Pavement Management System Data to Calibrate ME Pavement Design (2006)—webcast covers the various ways that pavement management system data can be used as input to and for calibration of the *MEPDG*.
  - Traffic Inputs for ME Pavement Design (2006)—webcast covers traffic inputs required in the *MEPDG* and how to extract the data using the NCHRP 1-39 TrafLoad software.
  - Climatic Considerations for Mechanistic-Empirical Pavement Design (2006)—webcast includes description of modeling climatic effects on pavement performance, reducing climatic effects through materials selection and design, and analyzing current state design methods for climatic effects.
  - AASHTOWare Pavement ME Design™ webinar series (2013)—a total of ten webinars on software use related to climatic inputs, traffic inputs, material and design inputs, and demonstration of new and rehabilitated pavement designs.
- FHWA and AASHTOWare Pavement ME Design™ Webinars (http://www.aashtoware.org/Pavement/Pages/Training.aspx). Each of the following webinars has been pre-recorded and is directed toward the user of the software. Each webinar is two hours long.
  - Getting Started with ME-Design
  - Climate Inputs
  - Traffic Inputs
  - Material and Design Inputs for New Pavement Design
  - Material and Design Inputs for Pavement Rehabilitation with Asphalt Overlays
  - Material and Design Inputs for Pavement Rehabilitation with Concrete Overlays
- National Highway Institute (NHI: http://www.nhi.fhwa.dot.gov/default.aspx).
  - NHI 131060 Concrete Pavement Design Details and Construction Practices—instructor-led course that provides participants with current guidelines on design and construction details for concrete pavements. Topics include important concrete pavement design details, including subgrade preparation, base selection, drainage design, thickness design, joint design, and shoulder characterization. The course explains how to select the proper details to enhance structural performance. Emphasis is given to JPCP, although the course includes instruction on jointed reinforced concrete pavements (JRCP) and CRCP.
  - NHI 132040 Geotechnical Aspects of Pavements—instructor-led training that includes discussions on geotechnical exploration and characterization of in-place and constructed subgrades; design and construction of subgrades and unbound layers for paved and unpaved roadways, with emphasis on the AASHTO 1993 *Guide* and the *MEPDG*. Drainage of bases, subbases, and subgrades and its impact on providing safe, cost-effective, and durable pavements; problematic soils, soil improvement, stabilization, and other detailed geotechnical issues in pavement design and construction; and construction methods, specifications, and quality control and assurance inspection for pavement projects.
  - NHI 151044 Traffic Monitoring and Pavement Design Programs—web-based training (free) that promotes the interaction and collaboration between traffic monitoring program staff and pavement program staff. The presentation supports implementation of the *MEPDG*. FHWA's Office of Highway Policy Information, in collaboration with the Design Guide Implementation Team, created this presentation to help ensure that pavement data needs are met with the existing traffic monitoring program or adjustments to the program.
  - NHI 151050 Traffic Monitoring Programs: Guidance and Procedures—instructor-led course that provides guidance on how to manage a successful traffic monitoring program. The training begins with an overview of federal traffic monitoring regulations and a presentation of the host state's traffic monitoring program. Subsequent lessons introduce federal guidance, effective practices, and recommended procedures for developing a data collection framework for traffic volume, speed, classification, weight, and nonmotorized programs. The course also incorporates related traffic monitoring elements of transportation management and operations, traffic data needs and uses, traffic data submittal requirements, and relevant traffic monitoring research. The critical importance of quality data collection is emphasized to support project planning, programming, design, and maintenance decisions.

CHAPTER THREE

SURVEY OF AGENCY PAVEMENT DESIGN PRACTICES

INTRODUCTION

A survey was developed to determine the implementation efforts of U.S., Puerto Rico, and Canadian state highway and provincial transportation agencies in relation to the *MEPDG* and accompanying AASHTOWare Pavement ME Design™ software. The questionnaire focused on the practices, policies, and procedures that have been successfully used by highway agencies for implementing the *MEPDG* and AASHTOWare Pavement ME Design™. In addition, the survey requested information related to:

- Agency decision-making authority for pavement design.
- Organizational structure and steps required to work within this structure for successful implementation.
- Use of consultants and in-house personnel for pavement design.
- Level of staff expertise in ME pavement design principles.
- Availability and quality of required data inputs.
- Current status of implementation.
- Reasons an agency has postponed or has yet to implement the *MEPDG* and AASHTOWare Pavement ME Design™ software.
- Agency implementation challenges or impediments.
- Approaches and parties involved in the evaluation and adoption of the *MEPDG*.
- Agency lessons learned that can be used to help other agencies in the implementation process.
- Benefits accrued to the agency from implementation (tangible and intangible).
- Development of training programs and implementation guides.

The intended recipients of the survey questionnaire were the pavement design engineers of the state highway agencies, Puerto Rico, and the District of Columbia, and Canadian provincial and territorial governments. The detailed survey questionnaire is provided in Appendix A, and the agency responses are provided in Appendix B.

As of March 2013, 57 agencies (90%) responded to the survey, including 47 U.S. highway agencies, Puerto Rico, and nine Canadian provincial and territorial governments.

AGENCY PAVEMENT TYPES

The following provides definitions used in the survey and in this synthesis for new construction pavement types, all of which are based on the pavement type definitions included in the *MEPDG* (AASHTO 2008). (Note: not all of the following pavement types have nationally calibrated pavement performance prediction models.)

- Composite—new thin or thick asphalt surface layer over a new concrete layer. Base layers may consist of unbound aggregate and/or stabilized layers.
- CRCP—concrete pavement with longitudinal reinforcement to hold shrinkage cracks tightly closed. Base layers may consist of unbound aggregate and/or stabilized layers.
- Full-depth asphalt—relatively thick asphalt surface layer placed over stabilized subgrade or placed directly on subgrade.
- JPCP—concrete pavement with short joint spacing, and with or without dowel bars (10 to 20 ft). Base layers may consist of unbound aggregate and/or stabilized layers.
- Semi-rigid—thin or thick asphalt surface layer placed over a cementitious stabilized material. Base layers may consist of unbound aggregate and/or stabilized layers.
- Thick asphalt—asphalt surface layer greater than 6 in. thick over unbound aggregate base layers.
- Thin asphalt—hot or warm mix asphalt (that will be designated as asphalt in this synthesis, but is intended to imply either layer type) surface layer less than 6 in. thick placed over unbound aggregate base layers.

In addition, the pavement type definitions for preservation and rehabilitation treatments used in the survey and in this synthesis include (not all of the following treatment types are included in or have nationally calibrated performance prediction models) (AASHTO 2008):

- Bonded CRCP overlay—placing a CRCP overlay directly over (i.e., no interlayer) an existing concrete pavement that is in good structural condition.
- Bonded JPCP overlay—placing a JPCP overlay directly over (i.e., no interlayer) an existing concrete pavement that is in good structural condition.
- Cold in-place recycle (CIR) with asphalt overlay—milling (typically 3 to 4 in.) and mixing the existing asphalt surface with recycling agent, additives, and virgin aggregate, relaying, and compacting in-place followed by an asphalt overlay.
- CIR without asphalt overlay—milling (typically 3 to 4 in.) and mixing the existing asphalt surface with recycling agent, additives, and virgin aggregate, relaying, and compacting in-place followed by either a thin

asphalt overlay and/or a chip seal(s) or other surface treatment(s).

- Crack or break and seat with an unbonded overlay—crack or break and seat of an existing concrete pavement and overlay with an unbonded CRCP or JPCP overlay.
- Crack or break and seat with asphalt overlay—crack or break and seat of an existing concrete pavement and overlay with an asphalt layer.
- Dowel bar retrofit—placing dowel bars at the transverse joints and cracks of an existing JPCP concrete pavement to restore load transfer.
- Diamond grinding—removing a thin layer (0.12 to 0.25 in.) of the existing concrete surface using equipment fitted with closely spaced diamond saw blades.
- Full-depth reclamation (FDR) with asphalt overlay—removal of the full depth of the existing asphalt layer and predetermined portion of the underlying base by pulverizing, blending, and re-compacting followed by an asphalt overlay.
- FDR without structural overlay—removal of the full-depth of the existing asphalt layer and predetermined portion of the underlying base by pulverizing, blending, and re-compacting followed by a thin asphalt overlay, chip seal(s), or other surface treatment(s).
- Hot in-place recycle (HIR) with asphalt overlay—correction of distress within the upper 2 in. of an existing asphalt pavement by softening the asphalt surface layer with heat, mechanically loosening it, and mixing it with a recycling agent, unbound aggregates, rejuvenators, and/or virgin asphalt followed by an asphalt overlay.
- HIR without asphalt overlay—correction of distress within the upper 2 in. of an existing asphalt pavement by softening the asphalt surface layer with heat, mechanically loosening it, and mixing it with a recycling agent, unbound aggregates, rejuvenators, and/or virgin asphalt followed by a surface treatment, thin asphalt overlay, or no treatment application.
- Mill and asphalt overlay of existing composite—milling the surface of an existing composite pavement and overlaying with an asphalt overlay.
- Mill and asphalt overlay of existing asphalt—milling the surface of an existing asphalt pavement and overlaying with an asphalt overlay
- Rubblization with an unbonded overlay—fracturing an existing concrete pavement and overlaying with an unbonded concrete overlay.
- Rubblization with asphalt overlay—fracturing an existing concrete pavement and overlaying with an asphalt overlay.
- Asphalt overlay of existing concrete—placing an asphalt overlay on an existing concrete pavement.
- Asphalt overlay of existing asphalt—placing an asphalt overlay on an existing asphalt pavement.
- Unbonded CRCP overlay—placing an interlayer (typically asphalt) over an existing concrete pavement followed by placement of a CRCP overlay.
- Unbonded JPCP overlay—placing an interlayer (typically asphalt) over an existing concrete pavement followed by placement of a JPCP overlay.

Figure 1 provides a summary of responses on new construction pavement types used by the responding agencies, including thick asphalt pavement (46 agencies), JPCP (44 agencies), thin asphalt pavement (41 agencies), and semi-rigid pavement (29 agencies). Agencies also indicated designing full-depth asphalt pavements (21 agencies) and composite pavements (18 agencies), and nine agencies reported designing CRCP. In addition, 12 agencies reported using other pavement types,

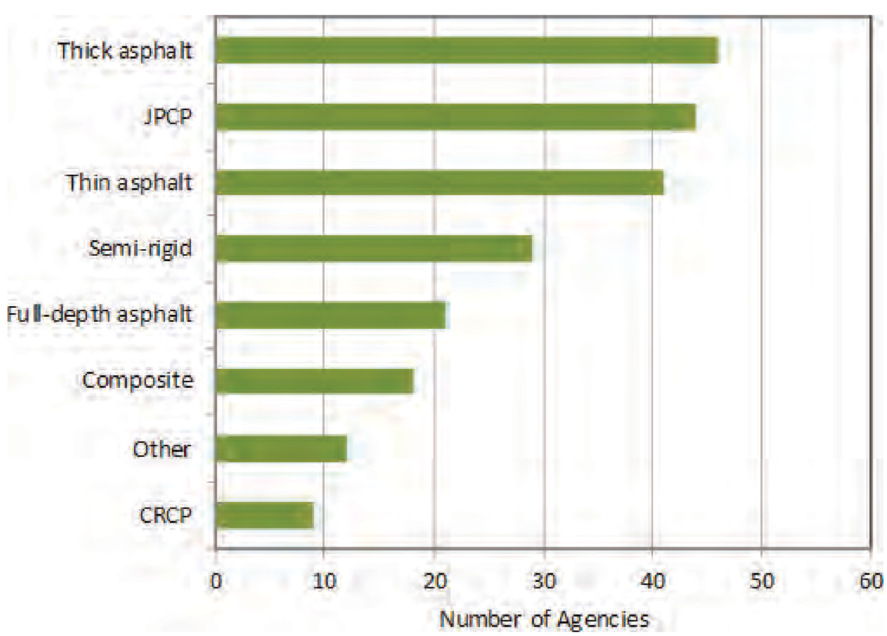

FIGURE 1 Use of new construction pavement types.

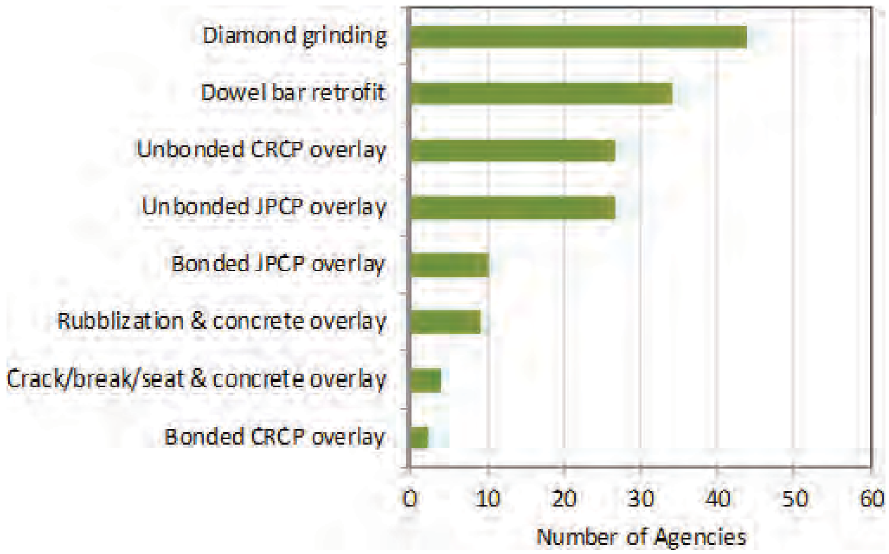

FIGURE 2 Use of concrete-surfaced preservation and rehabilitation pavement types.

with a chip seal(s) over unbound or bound aggregate layers as the predominant other pavement type (four agencies).

Figures 2 and 3 summarize responses to the types of preservation and rehabilitation treatments used by the responding agencies for concrete- and asphalt-surfaced pavements, respectively. For asphalt-surfaced pavement preservation and rehabilitation treatments, 54 agencies use asphalt overlays of existing asphalt, 51 use mill and asphalt overlay of existing asphalt, and 42 use asphalt overlay of existing concrete pavements. Meanwhile, 34 agencies indicated that they use FDR with an asphalt overlay, and 35 use mill and asphalt overlay of an existing composite pavement and rubblization with an asphalt overlay.

For concrete-surfaced pavement preservation and rehabilitation, the predominant treatment types included diamond grinding (44 agencies), dowel bar retrofit (34 agencies), and unbonded JPCP and CRCP overlays (27 agencies each).

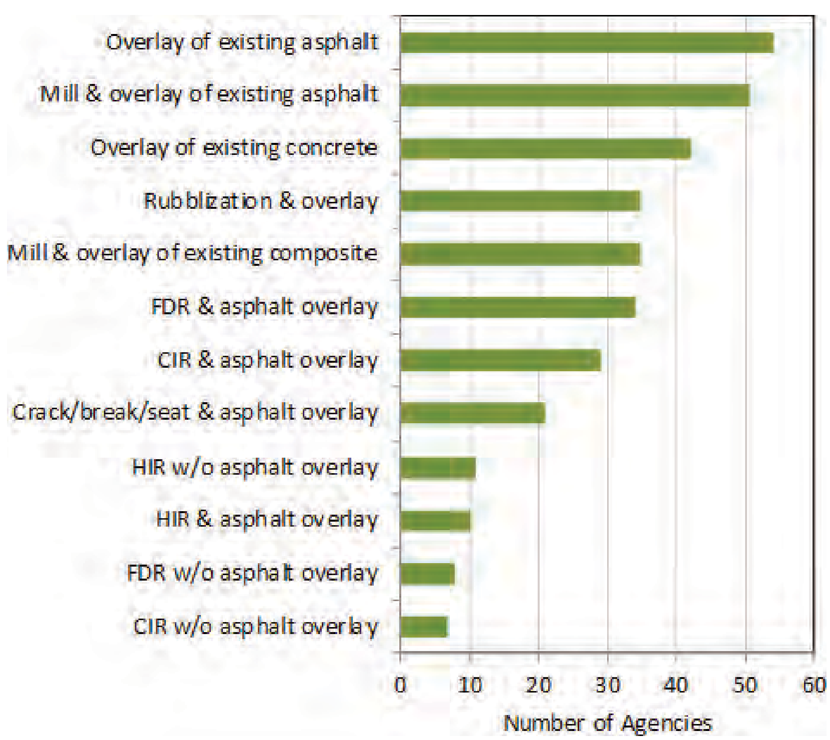

FIGURE 3 Use of asphalt-surfaced preservation and rehabilitation pavement types.

AGENCY PAVEMENT DESIGN METHODS

The transportation agencies surveyed currently use a variety of methods for pavement design, and most agencies (40) use more than one pavement design method for a given pavement type. AASHTO empirical methods are by far the most utilized, with 48 of the responding agencies using the AASHTO *Interim Guide for Design of Pavement Structures* (AASHTO 1972) through the AASHTO *Guide for Design of Pavement Structures*, with 1998 Supplement (AASHTO 1998). Based on the results of the agency survey, the AASHTO 1993 *Guide for the Design of Pavement Structures* (AASHTO 1993) is the most commonly used design method, with 39 responding agencies reporting its use for at least one type of pavement design. Table 6 summarizes the agency pavement design methods.

Twenty-four of the responding agencies mentioned the use of some type of ME design method. These methods include the *MEPDG* (used or being evaluated by 13 agencies) and other ME design methods developed by the agency or others (11 agencies). Three agencies have developed design catalogs based on ME design procedures. The following agencies reported the use of these other ME design methods:

- Alaska Department of Transportation and Public Facilitates (ADOT&PF)—ME design procedure for asphalt pavements (ADOT&PF 2004).
- California Department of Transportation (Caltrans)—CalME for flexible pavements (Ullidtz et al. 2010).
- Colorado DOT—ME design procedure for bonded concrete overlays of asphalt pavements (Tarr et al. 1998).
- Idaho Transportation Department—Winflex program (Bayomy 2006) or the Everpave program (Mahoney et al. 1989) for asphalt overlay design.
- Illinois DOT—ME design procedure for flexible pavements, rigid pavements, and asphalt overlay of rubblized pavements (IDOT 2013).
- Kentucky Transportation Cabinet—ME design process (Havens et al. 1981).
- Minnesota DOT—MnPAVE for new flexible and asphalt overlay design.
- Mississippi DOT—Dynatest ELMOD program (http://www.dynatest.com/software/elmod) for asphalt overlay design of flexible and semi-rigid pavements.
- Saskatchewan Highways and Infrastructure—Shell ME pavement design modified for Saskatchewan.
- Texas DOT—Texas DOT CRCP–ME design method for concrete pavements (Ha et al. 2012) and the FPS21 for flexible pavement design (Liu and Scullion 2011).
- Washington State DOT—Washington State DOT Everpave program (Mahoney et al. 1989) for asphalt overlay design.

This information is further summarized in Figure 4 according to those agencies that use only empirical-based design procedures, empirical-based and *MEPDG*, *MEPDG* only, empirical-based and other ME design procedure, and only other ME design procedures.

MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE IMPLEMENTATION STATUS

Three agencies reported that they have implemented the *MEPDG*, eight expressed no plans to implement the *MEPDG* at this time, 43 indicated that they plan to implement the *MEPDG* within five years, and three did not provide information on the timing of their implementation plans. Figure 5 provides a summary of the implementation status of the surveyed agencies.

In a follow-up survey of responding agencies (conducted July 2013), many agencies indicated an on-going *MEPDG* implementation effort. For example, the following is a list of agency implementation activities:

- Alabama—Currently concluding traffic study and have future plans for development of a materials library, followed by local calibration.
- Arizona—Full implementation on major roadways is expected in early 2014.
- Georgia—Currently conducting local calibration.

TABLE 6
AGENCY USE OF PAVEMENT DESIGN METHODS

Method	New Construction		Rehabilitation		Number of Agencies
	Asphalt	Concrete	Asphalt	Concrete	
AASHTO 1972	7	2	5	1	7
AASHTO 1986	1	0	2	0	2
AASHTO 1993	35	23	31	19	39
AASHTO 1998 Supplement	4	11	4	8	13
AASHTO *MEPDG*[1]	12	10	10	7	13
Agency Empirical Procedure	7	1	9	3	13
WINPAS (ACPA 2012)	0	5	0	4	7
MS-1 (AI 1999)	1	0	3	0	3
ME-based Design Table or Catalog	1	3	0	2	3
Other ME Procedure	8	3	6	2	11
Other	5	7	7	8	14

[1]A number of agencies indicated that the *MEPDG* is currently being used or under evaluation; however, only three agencies indicated that the *MEPDG* has been implemented.

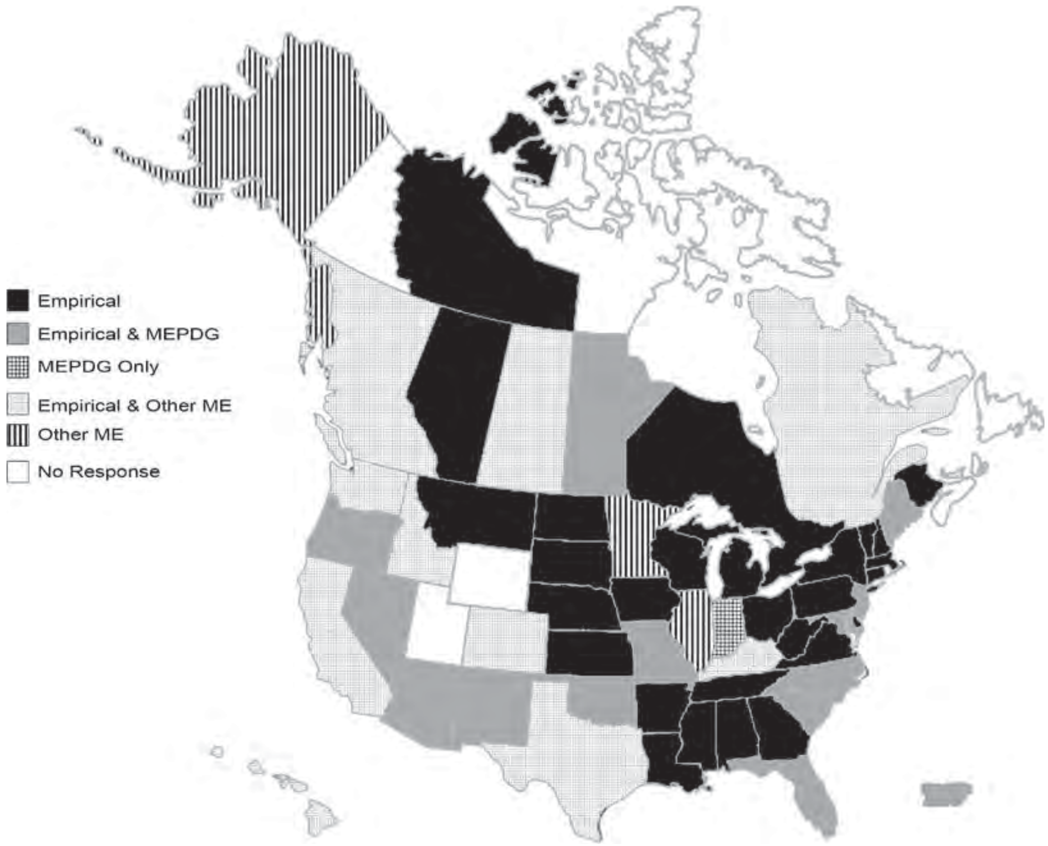

FIGURE 4 Agency pavement design methods.

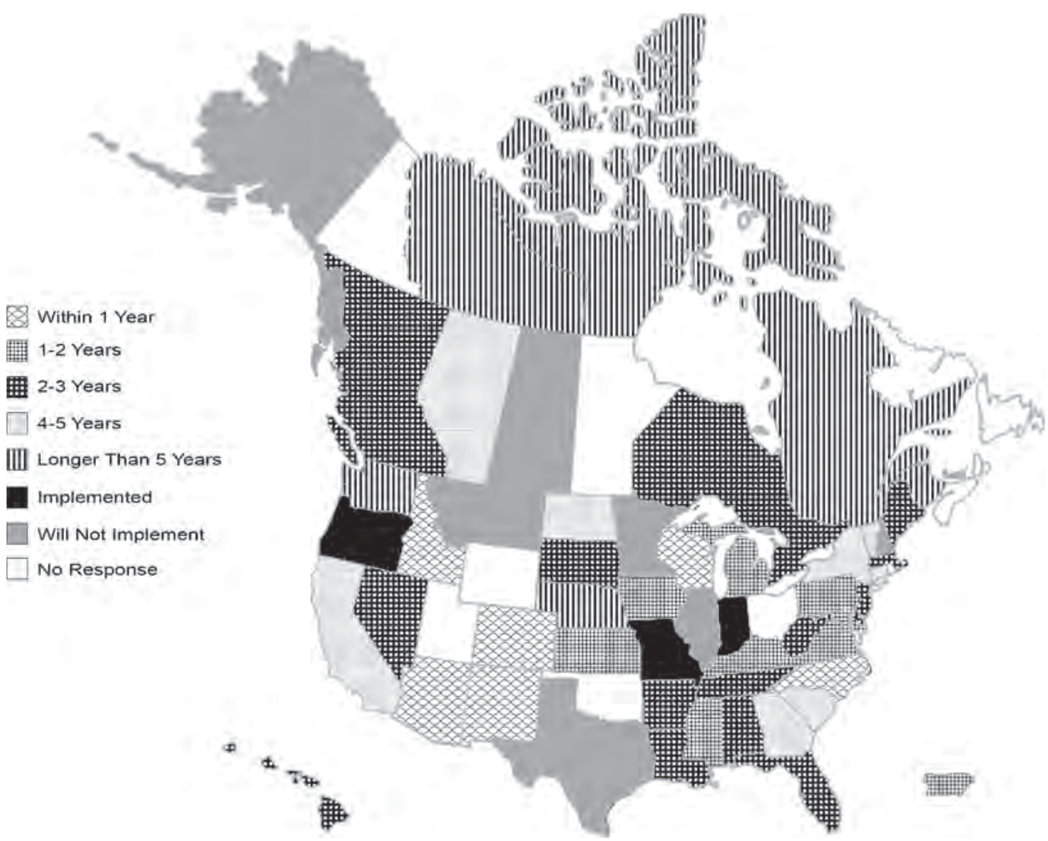

FIGURE 5 Summary of agency *MEPDG* implementation status.

- Idaho—Consultant-conducted training on software operation, and development of an ME user guide and implementation roadmap. Internal staff is currently comparing design results between the current procedure and the *MEPDG*. Idaho Transportation Department is planning on using the current pavement design procedure as a starting point in the *MEPDG* once the performance prediction models have been locally calibrated; pavement designs will be required to meet the performance prediction criteria determined using the *MEPDG*.
- Iowa—Locally calibrated the performance prediction models, but are currently re-evaluating the concrete performance prediction models.
- Louisiana—Plans to begin the local calibration process, and has conducted comparisons between current procedure and the *MEPDG* on several interstate projects.
- Michigan—Plans on transitioning to the *MEPDG* in 2014.
- Mississippi—Performance prediction models are currently being locally calibrated. Once the local calibration has been completed, Mississippi DOT will conduct 2-year side-by-side comparison of results using the current procedure and the *MEPDG*. At this time, plan on implementing the *MEPDG* for the design of new or reconstructed pavements.
- Oklahoma—*MEPDG* is being used for the design of new or reconstructed concrete pavements and concrete overlays on interstate and other high-traffic routes. Oklahoma DOT is in the process of locally calibrating the asphalt pavement performance prediction models.
- Ontario—Conducting local calibration with plans for implementation in 2014.
- South Carolina—Conducting side-by-side comparisons and materials characterization. Future plans for local calibration.
- Wisconsin—Completed studies related to asphalt mixtures, concrete properties, and resilient modulus determination of subgrade soils (http://wisdotresearch.wi.gov/whrp). Wisconsin DOT is in the process of developing a user manual and conducting local calibration. Implementation is anticipated to occur in 2014.

Of the eight agencies that expressed no plans to implement the *MEPDG*, five are currently using agency-developed (or developed by others) ME and empirical design procedures. Five of the eight agencies reported that they consider their current design practices to be acceptable. Additional reasons cited by the eight agencies for not adopting the *MEPDG* at this time include software cost (four agencies), waiting for more agencies to implement the *MEPDG* (three agencies), and disagreement with the *MEPDG* modeling approach (two agencies).

CURRENT AND EXPECTED USE OF THE *MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE*

Of the three agencies that noted having completed implementation of the *MEPDG*, only one (Indiana DOT) reported that it uses the *MEPDG* exclusively for the evaluation of all pavement designs. The other two agencies, Missouri DOT and Oregon DOT, reported that they use empirical design methods in addition to the *MEPDG*.

TABLE 7
SUMMARY OF *MEPDG* USE OR PLANNED USE BY PAVEMENT TYPE

Pavement Type	Number of Responses
New asphalt pavement	45
New JPCP	39
Asphalt overlay of existing asphalt pavement	38
Asphalt overlay of existing JPCP	34
Asphalt overlay of existing fractured JPCP	27
Unbonded JPCP overlay of existing JPCP	22
JPCP overlay of existing asphalt pavement	21
Asphalt overlay of existing CRCP	15
Bonded overlay of existing JPCP	13
New CRCP	12
Asphalt overlay of existing fractured CRCP	11
Unbonded JPCP overlay of existing CRCP	11
CRCP overlay of existing flexible pavement	7
Unbonded CRCP overlay of existing JPCP	7
Bonded concrete overlay of existing CRCP	6
Unbonded CRCP overlay of existing CRCP	6

Of the 46 agencies that reported they are using or evaluating the *MEPDG*, 45 indicated that it was being used or will be used to design new asphalt pavements, 39 that it was being used or will be used to design new JPCPs, and 12 that it was being used or will be used to design new CRCP. For overlay thickness design, 38 agencies indicated that the *MEPDG* is being used or will be used to design asphalt overlays of existing asphalt pavements and 34 agencies are using or will use the *MEPDG* to design asphalt overlays of existing JPCP. Agencies also indicated that the *MEPDG* was being used or will be used to design asphalt overlays of fractured JPCP (27 agencies), unbonded JPCP overlays of existing JPCP (22 agencies), and JPCP overlays of existing asphalt pavements (21 agencies). A summary of agency *MEPDG* use by pavement type is shown in Table 7.

Agencies that have not yet completed implementation stated that they needed to determine the benefits of using the *MEPDG* over their existing design method(s), develop an implementation and training plan, and evaluate the applicability of the *MEPDG* to their current conditions. Less frequently cited was the need to obtain approval or buy-in from others in the agency or to evaluate the economic impacts of using the *MEPDG* method.

MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE CHAMPIONS

Thirty-two of the responding agencies indicated that they have an *MEPDG* champion and 23 of the responding agencies indicated that the *MEPDG* champion is the state pavement engineer or pavement design engineer (or similar title or position). For 29 agencies, the *MEPDG* was or will be evaluated before implementation by the pavement design engineer, materials engineer, and pavement management, research, and design offices. The chief engineer (25 agencies) and pavement engineer (or similar title or position) (38 agencies) were listed as the most likely to ultimately decide whether or not the *MEPDG* should be implemented.

AGENCY STRUCTURE

As part of the agency survey, agencies were asked a number of organization-related questions. These included organizational structure (centralized or decentralized), how effective communication was across agency functions (e.g., construction, design, maintenance), which agencies had a *MEPDG* champion, and which agencies established a *MEPDG* oversight committee. Table 8 provides a summary of the agency responses to these organizational questions. Although it is difficult to generate a direct relationship between an agency's organizational structure and the *MEPDG* implementation status, doing so results in several interesting findings. For example, the agency structure does not appear to have an impact on the implementation status, but does indicate that most agencies (31 of the 44) responding to this survey question function under a centralized organizational structure (i.e., pavement designs are conducted, reviewed, and approved by the central or headquarters office). The communication level (consistent communication versus limited communication across agency functions) also does not appear to have much impact; there is a relatively even split across all implementation status, excluding the three agencies that have implemented the *MEPDG*. However, all agencies that indicated that the *MEPDG* is or will be implemented within 2 years have an *MEPDG* champion (18 agencies). For agencies that indicated implementation will be more than 2 years, 14 indicated an *MEPDG* champion, whereas 12 agencies noted that they did not. In addition, the majority of agencies (five of six) that indicated that the *MEPDG* is or will be implemented within 1 year have an *MEPDG* oversight committee. For those agencies that indicated implementation will be greater than one year, 13 reported that they did have an *MEPDG* oversight committee, and 22 that they did not.

IMPLEMENTATION CHALLENGES

Agencies indicated that there were several challenges to implementing the *MEPDG*, including software complexity, availability of needed data, defining input levels, and the need for local calibration.

Software

Agencies reported that AASHTOWare Pavement ME Design™ software is more complex than previous versions of AASHTO pavement design procedures. Agencies also indicated that training in ME fundamentals, *MEPDG* methods, and operation and functionality of the AASHTOWare Pavement ME Design™ software may be required.

Data Availability

As described previously, the *MEPDG* and AASHTOWare Pavement ME Design™ software requires significantly more data inputs than previous empirical and other developed ME pavement design software. Of the four types of data needed, agencies noted that pavement condition data (32 agencies) is the most readily available, followed by existing pavement structure data (31 agencies), and traffic data (28 agencies). Only 17 agencies indicated that materials data were readily available. In addition, agencies noted that obtaining materials characterization data required a significant level of effort to collect and additional equipment and field testing, as well as the additional time needed to conduct and evaluate the results and establish a materials library. Agencies also noted the challenge in obtaining traffic and materials data owing to agency divisional boundaries, and the unfamiliarity of other agency offices with the *MEPDG* data requirements and pavement design practices in general.

INPUT LEVELS

One of the features of the AASHTOWare Pavement ME Design™ software is its ability to use default, regional, or site-specific values for traffic and materials data inputs. Agencies reported that regional and site-specific data are needed for

TABLE 8
SUMMARY OF AGENCY ORGANIZATION (NUMBER OF AGENCIES)

Implementation Status	Agency Structure (centralized/ decentralized)	Communication Level[1] (consistent/ limited)	*MEPDG* Champion (yes/no)	*MEPDG* Oversight Committee (yes/no)
Implemented	2/1	3/0	3/0	2/1
Within 1 year	3/3	4/2	6/0	5/1
1 to 2 years	7/2	5/4	9/0	5/4
2 to 3 years	10/3	5/8	9/4	6/7
4 to 5 years	6/2	5/3	3/5	2/6
More than 5 years	3/2	3/2	2/3	0/5

[1]Consistent communication across agency functions; limited communication across agency functions.

the *MEPDG*, but that it is expensive and time-consuming to collect. Vehicle classification and average annual daily truck traffic are the only site-specific traffic inputs that agencies are likely to have available for use. Many agencies do have regional inputs for hourly and monthly traffic adjustment factors and use default values for axles per truck, axle configuration, wheelbase, and wander. Agencies stated that it requires additional time to compile all of the traffic data needed for regional and/or site-specific inputs.

Table 9 provides a summary of responses related to the use of default, regional, and site-specific values for each of the traffic and material inputs. Of those agencies that responded to this survey question, the majority indicated the use of either the *MEPDG* default values or regional values. Relatively few agencies indicated the use of site-specific values.

LOCAL CALIBRATION

One of the steps in the local calibration process includes the evaluation and determination of how well the *MEPDG* predicted pavement performance (i.e., distress and IRI) corresponds to observed field performance (AASHTO 2010).

TABLE 9
SUMMARY OF AGENCY INPUT VALUE USE

Traffic and Material Characteristic	Number of Agencies			
	MEPDG	Regional	Site-specific	No response
All Traffic	16	4	10	5
Vehicle class distribution	3	5	13	14
Hourly adjustment factors	12	12	9	2
Monthly adjustment factors	8	12	12	3
Axles per truck	8	14	9	4
Axle configuration	14	17	3	1
Lateral wander	15	16	4	0
Wheelbase	15	18	2	0
All Materials	24	1	7	3
All Asphalt Layers	22	2	8	3
Mixture volumetrics	10	3	16	6
Mechanical properties	11	7	12	5
Thermal properties	17	14	4	0
Asphalt Surface Layers Only	28	1	4	2
Mixture volumetrics	12	3	14	6
Mechanical properties	13	7	10	5
Thermal properties	20	12	3	0
Asphalt Base Layers Only	28	0	4	3
Mixture volumetrics	10	4	15	6
Mechanical properties	11	9	10	5
Thermal properties	21	11	3	0
All Concrete Layers	21	5	8	1
Poisson's ratio	14	15	4	2
Unit weight	9	9	12	5
Thermal	16	13	3	3
Mix	11	4	12	8
Strength	11	4	13	7
All Chemically Stabilized Layers	25	4	6	0
Poisson's ratio	21	9	2	3
Unit weight	21	5	6	3
Strength	19	4	8	4
Thermal	23	11	0	1
All Sandwiched Granular Layers	24	3	7	1
Poisson's ratio	20	10	2	3
Unit weight	18	6	7	4
Strength	16	6	8	5
Thermal properties	22	10	1	2
All Non-stabilized Base Layers	23	3	6	3
Poisson's ratio	13	17	3	2
Modulus	8	5	15	7
Sieve analysis	9	5	16	5
All Subgrade Layers	23	2	5	5
Poisson's ratio	14	18	3	0
Modulus	5	5	16	9
Sieve analysis	6	7	14	8
All Bedrock Layers	20	6	3	6
Poisson's ratio	20	12	1	2
Unit weight	21	2	10	2
Strength	20	10	2	3

TABLE 10
AGENCY DISTRESS DEFINITIONS (NUMBER OF AGENCIES)

Pavement Type	Condition Indicator	Did Not Respond	Distress Not Used	Agency Distress Definition Similar to LTPP	Agency Distress Definition Not Similar to LTPP
All	IRI	12	2	40	3
Asphalt	Longitudinal cracking	15	7	32	3
	Alligator cracking	15	0	36	6
	Thermal cracking	17	4	28	8
	Reflective cracking	15	6	30	6
	Rut depth	14	0	38	5
JPCP	Transverse cracking	17	2	35	3
	Joint faulting	17	4	33	4
CRCP	Punchouts	38	6	11	2

By making these comparisons, the agency is able to determine if local calibration of the performance prediction models is necessary or if the *MEPDG* performance prediction models are adequate.

Because the *MEPDG* performance prediction models are based on data contained within the LTPP database, agency pavement condition measurements need to be consistent with the *Distress Identification Manual* (AASHTO 2010). At the time the *Distress Identification Manual* (Miller and Bellinger 2003) was being developed (circa 1987), transportation agencies were encouraged to adopt the standard distress definitions and to modify the procedures to fit their specific data collection needs for pavement management and design. If the agency distress definitions are different than those used in the *MEPDG* (AASHTO 2008), the impact of the distress definition differences needs to be evaluated (AASHTO 2010). Table 10 provides a summary of agency survey responses in how well their distress definitions match those of the *Distress Identification Manual.*

Most responding agencies indicated that IRI (40 agencies), rut depth (38 agencies), and alligator cracking (36 agencies) data were consistent with the *Distress Identification Manual*. For JPCP, the responding agencies reported that transverse cracking (35 agencies) and faulting (33 agencies) were consistent with the LTPP method, as was punchout measurement for agencies that constructed CRCP. The most often reported distresses that were not consistent with LTPP data collection procedures include longitudinal cracking, thermal cracking, and reflective cracking for asphalt pavements.

A number of agencies indicated that they have conducted local calibration of the asphalt and/or concrete performance prediction models contained within the *MEPDG*. Five agencies indicated local calibration of the asphalt models (Table 11) and seven indicated calibration of the concrete models (Table 12). In addition, the Hawaii and New Jersey DOTs reported that the asphalt IRI performance prediction model has been calibrated to local conditions; however, the remainder of the asphalt pavement performance models will be conducted at a future date.

During the local calibration process an agency defines the threshold limits and reliability limits for each of the performance prediction models. Those agencies that indicated local calibration of the performance prediction models had been conducted were asked to provide the threshold limits, reliability levels, and model coefficients for each locally calibrated performance prediction model. Tables 13 and 14 list the *MEPDG* default performance criteria and reliability levels for asphalt and concrete pavement, respectively. Tables 15–21 provide the performance criteria and reliability levels for the Colorado, Florida, and Arizona DOTs. Information on perfor-

TABLE 11
AGENCY LOCAL CALIBRATION—ASPHALT MODELS

Agency	IRI	Longitudinal Cracking	Alligator Cracking	Thermal Cracking	Rut Depth: Asphalt layer	Rut Depth: Total	Reflective Cracking
Arizona	✓	Do not use	✓	*MEPDG*	✓	✓	✓
Colorado	✓	✓	✓	✓	✓	✓	✓
Hawaii	✓	[1]	[1]	[1]	[1]	[1]	[1]
Indiana	✓	Do not use	✓	*MEPDG*	*MEPDG*	Do not use	Do not use
Missouri	✓	*MEPDG*	*MEPDG*	✓	✓	✓	*MEPDG*
New Jersey	✓	[1]	[1]	[1]	[1]	[1]	[1]
Oregon	✓	✓	✓	✓	✓	✓	*MEPDG*

[1]Future plans.
✓Indicates performance prediction models have been locally calibrated.

TABLE 12
AGENCY LOCAL CALIBRATION—CONCRETE MODELS

Agency	JPCP			CRCP	
	IRI	Transverse cracking	Faulting	IRI	Punchouts
Arizona	✓	✓	✓	✓	✓
Colorado	✓	✓	✓	Do not use	Do not use
Florida	✓	✓	✓	Do not use	Do not use
Indiana	✓	*MEPDG*	*MEPDG*	Do not use	Do not use
Missouri	✓	*MEPDG*	*MEPDG*	Do not use	Do not use
North Dakota	✓	*MEPDG*	*MEPDG*	Do not use	Do not use
Oregon	✓	*MEPDG*	*MEPDG*	✓	✓

✓Indicates performance prediction models have been locally calibrated.

TABLE 13
MEPDG DEFAULT CRITERIA AND RELIABILITY VALUES—ASPHALT

Performance Criteria	Limit	Reliability
Initial IRI (inches/mile)	63	N/A[1]
Terminal IRI (inches/mile)	172	90
Longitudinal cracking (feet/mile)	2,000	90
Alligator cracking (percent area)	25	90
Transverse cracking (feet/mile)	250	90
Chemically stabilized layer—fatigue fracture (percent)	25	90
Permanent deformation—total pavement (inches)	0.75	90
Permanent deformation—asphalt only (inches)	0.25	90
Reflective cracking (percent)	100	50[1]
Asphalt overlay—JPCP transverse cracking (percent slabs)	15	90
Asphalt overlay—CRCP punchouts (number per mile)	10	90

N/A = not available.
[1]Cannot be changed by the user.

mance threshold limits and reliability levels was also obtained for the Indiana, Missouri, and Oregon DOTs. The performance threshold limits and reliability levels for these three agencies are included as part of the agency case examples described in chapter five.

Tables 15 and 16 provide the Colorado DOT's performance threshold limits and reliability levels for asphalt and concrete pavements, respectively. The Colorado DOT distress threshold limits were determined from pavement management data, whereas the reliability levels were based on input from pavement managers and pavement design staff.

Florida DOT has locally calibrated the JPCP performance prediction models. Threshold limits and reliability levels used by Florida DOT are provided in Table 17. The performance threshold limits and reliability levels are based on existing practice and experience, ranges provided in the *MEPDG* (AASHTO 2008), and engineering judgment.

TABLE 14
MEPDG DEFAULT CRITERIA AND RELIABILITY VALUES—CONCRETE

Performance Criteria	Limit	Reliability
Initial IRI (in./mi)	63	N/A[1]
Terminal IRI (in./mi)	172	90
JPCP transverse cracking (percent slabs)	15	90
JPCP mean joint faulting (in.)	0.12	90
CRCP punchouts (number per mile)	10	90

N/A = not available.
[1]Cannot be changed by the user.

Arizona DOT has locally calibrated both asphalt and JPCP performance prediction models. Threshold limits for asphalt and concrete pavements are provided in Tables 18 and 19, respectively. Table 20 provides the reliability levels, by functional class, used by Arizona DOT. Performance thresholds and reliability levels are based on engineering judgment, pavement management criteria, sensitivity analysis, functional class (i.e., a higher reliability to minimize the consequence of early failure on more heavily trafficked routes), and previous Arizona DOT reliability levels. The threshold limit for IRI is based on the Arizona DOT standard specifications and values achieved regularly during construction (see Table 21).

Tables 22 and 23 provide a summary of the agency calibration coefficients for concrete and asphalt pavements, respectively. Note shaded cells indicate that the agency uses a different calibration coefficient value than the *MEPDG* default value. It can also be noted that there is significant variation between the agency reported and *MEPDG* default calibration coefficients, in some instances the difference is an order of magnitude.

TABLE 15
PERFORMANCE CRITERIA AND RELIABILITY (ASPHALT)—COLORADO DOT

Functional Class	IRI[1, 2] (in./mi)	Longitudinal Cracking[1, 2] (ft/mi)	Alligator Cracking[2, 3] (percent area)	Transverse Cracking[2, 3] (ft/mi)	Asphalt Rut Depth[1, 2] (in.)	Total Rut Depth[1, 2] (in.)	Total Cracking[3, 4] (percent area)	Reliability (percent)
Interstate	160	2,000	10	1,500	0.25	0.40	55	80–95
Principal Arterial	200	2,500	25	1,500	0.35	0.50	105	75–95
Minor Arterial	200	3,000	35	1,500	0.50	0.65	155	70–95
Major Collector	200	3,000	35	1,500	0.50	0.65	155	70–90
Minor Collector	[5]	[5]	[5]	[5]	[5]	[5]	[5]	50–90
Local	[5]	[5]	[5]	[5]	[5]	[5]	[5]	50–80

[1]New construction, determines the year to first rehabilitation (minimum age of 12 years).
[2]Rehabilitation, maximum value at end of design life.
[3]Maximum value at end of design life.
[4]Alligator + reflective.
[5]To be determined.

TABLE 16
PERFORMANCE CRITERIA AND RELIABILITY (CONCRETE)—
COLORADO DOT

Functional Class	IRI[1, 2] (in./mi)	Transverse Cracking[1] (percent slabs)	Mean Joint Faulting[3] (in.)	Reliability (percent)
Interstate	160	7.0	0.12	80–95
Principal Arterial	200	7.0[4]	0.14	75–95
Minor Arterial	200	7.0[4]	0.20	70–95
Major Collector	200	7.0[4]	0.20	70–90
Minor Collector	[5]	[5]	[5]	50–90
Local	[5]	[5]	[5]	50–80

[1]New construction, determines the year to first rehabilitation (minimum age of 27 years).
[2]Rehabilitation, maximum value at end of design life.
[3]Maximum value at end of design life.
[4]Under evaluation.
[5]To be determined.

TABLE 17
PERFORMANCE CRITERIA AND RELIABILITY (CONCRETE)—FLORIDA DOT

Functional Class	IRI (in./mi)	Transverse Cracking (percent slabs)	Mean Joint Faulting (in.)	Reliability (percent)
All	180	10	0.12	75–95

TABLE 18
PERFORMANCE CRITERIA (ASPHALT)—ARIZONA DOT

Functional Class	IRI (in./mi)	Alligator Cracking (percent area)	Transverse Cracking (ft/mi)	Total Rut Depth[1] (in.)	Total Cracking[2,] (percent area)
Interstate	150	10	1,000	0.50	10
Primary	150	15	1,500	0.50	15
Secondary	150	25	1,500	—	25

[1]At the end of a 15-year performance period.
[2]Alligator + reflective.

TABLE 19
PERFORMANCE CRITERIA (CONCRETE)—ARIZONA DOT

Functional Class	IRI (in./mi)	Mean Joint Faulting (in.)	Transverse Cracking (percent slabs)
Interstate	150	0.12	10
Primary	150	0.12	15
Secondary	150	0.12	25

TABLE 20
RELIABILITY LEVELS—ARIZONA DOT

Functional Class	Reliability (percent)
Interstate and Freeway	97
Non-interstate Highways (>10,000 ADT)	95
Non-interstate Highways (2,001 to 10,000 ADT)	90
Non-interstate Highways (501 to 2,000 ADT)	80
Non-interstate Highways (<500 ADT)	75

ADT = average daily traffic.

TABLE 21
INITIAL IRI VALUES—ARIZONA DOT

Pavement Type	Initial IRI (in./mi)
New and Reconstructed Asphalt	45
Asphalt Overlay of Existing Asphalt Pavement	52
New JPCP	63
Asphalt Rubber Friction Course over JPCP or CRCP	50

ACTIVITIES TO AID IMPLEMENTATION

Agencies were asked about specific activities that might help them in implementing the *MEPDG*. The following is a summary of the responses:

- Training in AASHTOWare Pavement ME Design™ (35 agencies).
- Assistance with calibrating models to local conditions (35 agencies).
- Dedicated AASHTO MEPDG/ME Design website for sharing technical information (34 agencies).
- Training in interpretation of AASHTO Pavement ME Design software results (32 agencies).
- Training in methodology for obtaining AASHTO MEPDG/ME Design inputs (31 agencies).
- Training in ME design principles (28 agencies).
- Training in how to modify pavement sections to meet design criteria (25 agencies).
- Establishment of an expert task or user group (24 agencies).
- Ability to share ME Design databases with other agencies (17 agencies).

CHALLENGES AND LESSONS LEARNED

Survey respondents provided a number of challenges and lessons learned during the implementation process. One of the more common responses was the lack of readily available

TABLE 22
AGENCY LOCAL CALIBRATION COEFFICIENTS—CONCRETE

Feature	*MEPDG*	Arizona	Colorado	Florida	Missouri
Cracking					
C1	2.0	2.0	2.0	2.8389	2.0
C2	1.22	1.22	1.22	0.9647	1.22
C4	1.0	0.19	0.6	0.5640	1.0
C5	–1.98	–2.067	–2.05	–0.5946	–1.98
Std. Dev.	[1]	[4]	[7]	[1]	[1]
Faulting					
C1	1.0184	0.0355	0.5104	4.0472	1.0184
C2	0.91656	0.1147	0.00838	0.91656	0.91656
C3	0.002848	0.00436	0.00147	0.002848	0.002848
C4	0.000883739	1.1E-07	0.008345	0.000883739	0.000883739
C5	250	20000	5999	250	250
C6	0.4	2.309	0.8404	0.0790	0.4
C7	1.8331	0.189	5.9293	1.8331	1.8331
C8	400	400	[8]	400	400
Std. Dev.	[2]	[5]		[2]	[2]
Punchout					
C1	2.0	2.0	Not applicable	Not applicable	2.0
C2	1.22	1.22			1.22
C3	216.8421	85			216.8421
C4	33.15789	1.4149			33.15789
C5	–0.58947	–0.8061			–0.58947
Crack	[1]	[1]			[1]
Std. Dev.	[3]	[6]			[3]
IRI (CRCP)					
C1	3.15	3.15	Not applicable	Not applicable	3.15
C2	28.35	28.35			28.35
Std. Dev.	5.4	5.4			5.4
IRI (JPCP)					
J1	0.8203	0.6	0.8203	0.8203	0.82
J2	0.4417	3.48	0.4417	0.4417	1.17
J3	1.4929	1.22	1.4929	2.2555	1.43
J4	25.24	45.2	25.24	25.24	66.8
Std. Dev.	5.4	5.4	5.4	5.4	5.4

[1]Pow(5.3116 x CRACK,0.3903) + 2.99
[2]Pow(0.0097 x FAULT,0.05178) + 0.014
[3]2 + 2.2593 x Pow(0.4882 x PO)
[4]Pow(9.87x CRACK,0.4012) + 0.5
[5]Pow(0.037 x FAULT,0.6532) + 0.001
[6]1.5 + 2.9622 x Pow(PO,0.4356)
[7]Pow(57.08 x CRACK, 0.33) + 1.5
[8]0.0831 x Pow(FAULT,0.3426) + 0.00521
[9]0.1 for A-7-6 soils
[10]0.001 for A-7-6 soils
[11]3 for A-7-6 soils

TABLE 23
AGENCY LOCAL CALIBRATION COEFFICIENTS—ASPHALT

Feature	*MEPDG*	Arizona	Colorado	Missouri	Oregon
Cracking					
C1 Bottom	1.0	1.0	0.07	1.0	0.56
C1 Top	7.0	7.0	7.0	7.0	1.453
C2 Bottom	1.0	4.5	2.35	1.0	0.225
C2 Top	3.5	3.5	3.5	3.5	0.097
C3 Bottom	6000	6000	6000	6000	6000
C3 Top	0	0	0	0	0
C4 Top	1000	1000	1000	1000	1000
Std. Dev. Top	[1]	[1]	[1]	[1]	[1]
Std. Dev. Bottom	[2]	[2]	[12]	[2]	[2]
Fatigue					
BF1	1	249.00872	130.3674	1	1
BF2	1	1	1	1	1
BF3	1	1.23341	1.2178	1	1
Thermal Fracture					
Level 1	1.5	1.5	7.5	0.625	1.5
Level 2	0.5	0.5	0.5	0.5	0.5
Level 3	1.5	1.5	1.5	1.5	1.5
Std. Dev. (Level 1)	[3]	[3]	[3]	[3]	[3]
Std. Dev. (Level 2)	[4]	[4]	[4]	[4]	[4]
Std. Dev. (Level 3)	[5]	[5]	[5]	[5]	[5]
Rutting (asphalt)					
BR1	1.0	0.69	1.34[13]		1.48
BR2	1.0	1.0	1.0		1.0
BR3	1.0	1.0	1.0		0.9
Std. Dev.	[6]	[9]	[14]	[6]	[6]
Rutting (subgrade)					
BS1 (fine)	1.0	0.37	0.84	0.4375	1.0
Std. Dev. (fine)	[7]	[10]	[15]	[7]	[7]
BS1 (granular)	1.0	0.14	0.4	0.01	1.0
Std. Dev. (granular)	[8]	[11]	[16]	[8]	[8]
IRI					
C1 (asphalt)	40	1.2281	35	17.7	40
C2 (asphalt)	0.4	0.1175	0.3	0.975	0.4
C3 (asphalt)	0.008	0.008	0.02	0.008	0.008
C4 (asphalt)	0.015	0.028	0.019	0.01	0.015
C1 (over concrete)	40.8	40.8	40.8	40.8	40.8
C2 (over concrete)	0.575	0.575	0.575	0.575	0.575
C3 (over concrete)	0.0014	0.0014	0.0014	0.0014	0.0014
C4 (over concrete)	0.00825	0.00825	0.00825	0.00825	0.00825

[1]200 + 2300/(1 + exp(1.072 – 2.1654 x LOG_{10} (TOP + 0.0001)))
[2]1.13 + 13/(1 = exp(7.57 – 15.5 x LOG_{10}(BOTTOM + 0.0001)))
[3]0.1468 x THERMAL + 65.027
[4]0.2841 x THERMAL + 55.462
[5]0.3972 x THERMAL + 20.422
[6]0.24 x Pow(RUT, 0.8026) + 0.001
[7]0.1235 x Pow(SUBRUT, 0.5012) + 0.001
[8]0.1447 x Pow(BASERUT, 0.6711) + 0.001
[9]0.0999 x Pow(RUT, 0.174)+0.001
[10]0.05 x Pow(SUBRUT, 0.085) + 0.001
[11]0.05 x Pow(BASERUT, 0.115) + 0.00110
[12]1 + 15(1 + exp(-1.6673 – 2.4656*LOG10(BOTTOM+0.0001)))
[13]Under review
[14]0.2052 x Pow(RUT,0.4) + 0.001
[15]0.1822 x Pow(SUBRUT, 0.5) +0.001
[16]0.2472 x Pow(BASERUT, 0.67) + 0.001
[17]0.01 for A-7-6 soil

traffic and materials data, and the large effort required to obtain the needed data. Agencies also indicated that contracting the applicable office (e.g., materials, traffic) early on in the implementation process to make sure that everyone understands what data are needed and why, and being prepared to conduct field sampling and testing if the needed data are not available. The following summarizes the responses:

- Challenges (one agency response for each statement)
  - District offices are resistant to change from empirical-based designs to ME-based designs. There is a higher comfort level with the inputs and resulting outputs (i.e., layer thickness) with the AASHTO 1993 *Guide.* Making the shift to using design inputs and predicting distresses in the *MEPDG*, rather than obtaining layer thickness as the final result, has been difficult.
  - Changes to the pavement condition data collection procedures that have resulted in inconsistency with data measurement and the ability to obtain reliable pavement condition data for use in the calibration process.
  - Lack of resources to conduct local calibration and training of staff.
  - The *MEPDG* is too complex for most practicing engineers; however, this may be improved through training to increase the engineer's confidence in the design procedure.
  - Rework required as a result of newer versions of software that yield different results than previous versions (e.g., moving from NCHRP 1-37A to *MEPDG* v1.1) and the difference required recalibration of performance prediction models to local conditions.
- Lessons learned (one agency response for each statement)
  - Establish realistic timelines for the calibration and validation process.
  - Allow sufficient time for obtaining materials and traffic data.
  - Ensure the data related to the existing pavement layer, materials properties, and traffic is readily available.
  - If necessary, develop a plan for collecting the needed data; this can require an expensive field sampling and testing effort.
  - Develop agency-based design inputs to avoid varying inputs and outputs to minimize design variability.
  - Provide training to agency staff in ME design fundamentals, MEPDG procedures, and the AASHTOWare Pavement ME DesignTM software.

CHAPTER FOUR

COMMON ELEMENTS OF AGENCY IMPLEMENTATION PLANS

INTRODUCTION

As noted in chapter three, the majority of highway agencies currently design their highway pavements in accordance with the AASHTO 1993 *Guide*, which is primarily based on empirical relationships derived from the AASHO Road Test. As such, the performance prediction relationships are representative of the design present at the Road Test. However, since that time (1958 to 1960), significant changes have occurred in pavement cross sections, advances in material characterization, changes in vehicle truck type, and increased volume and weight distribution of traffic making the empirical-based design process limiting. At the same time, highway agencies are familiar with the AASHTO 1993 *Guide* and, for the most part, it has served the pavement design community well.

The development of the *MEPDG* raises issues and challenges related to implementation. These include, but are not limited to, material and traffic characterization, incorporation of climatic effects, verification of predicted performance, evaluation and acceptance of a new method, justification of benefits over the current process, staffing requirements, budget needs, and training.

COMMON ELEMENTS

Based on the survey of agencies, approximately 43 agencies indicated that they are in the process of evaluating the *MEPDG*. However, 15 agencies have progressed further into the implementation process, such that implementation is anticipated to occur within the next 2 years. Additional review of the agency implementation practices may provide valuable insight into the features (or elements) of the *MEPDG* implementation process. The literature review indicated that a number of agencies have developed implementation plans, materials and traffic libraries, agency-specific user input guides, and training programs. Determining which elements to include in the implementation plan is based on the approach that best meets the individual agency needs. The following summarizes the literature review of common elements of agency implementation plans.

Pavement Types

This implementation element identifies the pavement types that will be analyzed or designed using the *MEPDG* (Coree et al. 2005). Pavement types may include new, reconstructed, and rehabilitated asphalt and concrete pavements. In addition, agencies may also define pavement types according to functional classes (e.g., interstate pavements only). An agency's decision may be based on agency policy, practice, or criticality of the roadway (e.g., interstate versus farm-to-market). Initially, applying the implementation effort for new construction is an approach used by several agencies (Mallela et al. 2009; Timm et al. 2010). Then, as familiarity, knowledge, and data become available, extending implementation to other pavement types is commonly conducted.

Data Needs and Required Information

There are a large number of inputs needed to conduct an *MEPDG* analysis. Evaluation of input needs not only outlines and identifies the various sources of available data, but also is used to identify where additional testing may be required to obtain missing data. The following provides a summary of needed data and related information.

- Hierarchical level—Data availability, practices and procedures, time required to collect needed data, budget constraints, required resources, and agency policy (Coree et al. 2005; Hoerner et al. 2007).
- Climate data—Stations with preferably 20 years of continuous data; consider identifying a generic station for use in the calibration process and add additional sites as needed (Coree et al. 2005).
- Material and traffic input values—Typical values based on *MEPDG* default values, existing conditions, laboratory and field testing, construction specifications, and testing equipment needs (Coree et al. 2005; Hoerner et al. 2007; Schwartz 2007).
- To ease the implementation effort, the development of an input library (database) that can be accessed within the AASHTOWare Pavement ME Design™ software will not only reduce the amount of required data entry but will also reduce the potential of data error and/or utilization of incorrect parameters (Coree et al. 2005; Schwartz 2007; Mallela et al. 2009; Timm et al. 2010). The agency-specific materials and traffic input libraries allow for collecting, organizing, and arranging data utilized in the AASHTOWare Pavement ME Design™ software (AASHTO 2013).
- Testing program—Type of tests and the number of test samples needed to obtain missing or needed data (Hoerner et al. 2007; Schwartz 2007).

- Pavement performance—Adequacy of pavement management system data and other data (e.g., LTPP) to support local calibration (Schwartz 2007).
- Calibration test sites—Number of pavement segments by pavement type, functional class, distress type, traffic volumes, and climatic regions (Coree et al. 2005; Hoerner et al. 2007; Schwartz 2007; Mallela et al. 2009; Bayomy et al. 2010; Bayomy et al. 2012).

Performance Prediction Models, Threshold Limits, and Reliability

Determine performance criteria and reliability level for each distress indicator and IRI. It is up to the agency to determine what constitutes an acceptable design based on the level of accepted distress (Coree et al. 2005; Hoerner et al. 2007; Schwartz 2007).

MEPDG Verification

An *MEPDG* analysis is conducted to verify that the design results meet agency expectations (AASHTO 2010). Verification is conducted using agency-identified performance criteria and reliability levels, material inputs, and traffic inputs for a standard agency pavement design(s) (AASHTO 2010). One or more climate regions and truck traffic volume levels are typically analyzed as part of this effort (AASHTO 2010). The *MEPDG* predicted conditions are compared with the agency-measured distress. If the predicted condition reasonably (agency determined) matches the measured distress, then the *MEPDG* default calibration coefficients can be adopted; if not, local calibration is highly recommended (Coree et al. 2005; Hoerner et al. 2007; AASHTO 2010).

Local Calibration

Local calibration of the performance prediction models was summarized in chapter two of this synthesis and the reader is referred to the *Local Calibration Guide* (AASHTO 2010) for specific details. Selection of a statistically significant number of highway sections for each distress type, and use of LTPP sites is encouraged (Coree et al. 2005; Schwartz 2007; Mallela et al. 2009; Timm et al. 2010).

Calibration Database

As new materials, new design features, modifications to construction specifications, and additional performance data become available the development of a calibration database may be warranted (Hoerner et al. 2007). The calibration database can be updated as necessary and utilized in the future calibration efforts. Not only will this provide consistency from one calibration effort to the next, it will also make the calibration process less burdensome (Hoerner et al. 2007). The calibration database contains pertinent information related to the calibration process, such as project information (design properties, location) traffic data, climate station information (station location or list of stations used to create a virtual weather station), material properties, falling weight deflectometer (FWD) data (if applicable), pavement design, and pavement performance data (Hoerner et al. 2007; Pierce et al. 2011).

Local Calibration Validation

Once the local calibration coefficients have been determined, validation of the resulting models using different locations and design features is recommended (AASHTO 2010).

Concurrent Designs

The ability to compare the results of previous design procedures with the *MEPDG* may facilitate the implementation process. Concurrent designs can help to familiarize and improve the staff confidence in the *MEPDG* design results (Timm et al. 2010).

Documentation

Documentation may include an agency-specific pavement design manual and users guide that includes (Coree et al. 2005; Hoerner et al. 2007; Schwartz 2007):

- Descriptions of the analysis and input value details,
- Identification of the process for accessing material and traffic libraries,
- Details on how to modify a pavement structure to meet performance criteria,
- Calibration and validation procedures,
- A definition of how to incorporate future enhancements, and
- A catalog design for use by local agencies.

Training

A training program may be developed in-house or through universities, consultants, and national programs (e.g., National Highway Institute) in relation to ME procedures, *MEPDG*-specific analysis, AASHTOWare Pavement ME Design™ functionality and operation, and analysis of results (Coree et al. 2005; Hoerner et al. 2007; Schwartz 2007; and Timm et al. 2010).

In addition, agencies have found it beneficial to have an *MEPDG* champion and an *MEPDG* oversight committee (Coree et al. 2005; Hoerner et al. 2007; MIDOT 2012). The *MEPDG* oversight committee can assist with decision making, more efficiently utilize existing personnel and resources, and expand the coordination and data acquisition process across agency divisions and offices. The *MEPDG* committee may include representatives from roadway design, construction, planning (traffic), materials (asphalt, concrete, aggregates, and soils), roadway maintenance, pavement testing and evaluation, pavement design, pavement management, research, and industry. Example tasks of the *MEPDG* oversight committee may include (MIDOT 2012):

- Facilitating change from current pavement design procedure to the *MEPDG*.
- Making decisions on equipment and personnel (e.g., purchasing equipment and hiring agency personnel versus contracting with universities and consultants).
- Facilitating testing needs.
- Establishing acceptable performance criteria and reliability levels.
- Finalizing the level of input and input values.
- Reviewing design results to learn the impacts of different inputs.
- Developing and facilitating training, including manuals and documents.
- Exploring research needs and developing research ideas and proposals.
- Facilitating industry participation and addressing their requests and concerns.

CHAPTER FIVE

CASE EXAMPLES OF AGENCY IMPLEMENTATION

INTRODUCTION

During the development of the design procedure and with the release of the *MEPDG* and accompanying software, transportation agencies have been confronted with determining and defining data needs; determining applicability and use of the design procedure for the highway network; evaluating the sensitivity of the performance prediction based on material, traffic, and climatic inputs; and calibrating of the performance prediction models to local conditions. Much of this effort has been documented through various agency and national research studies. The level of activity is demonstrated by more than 600 documents directly associated with the *MEPDG*, and there are hundreds more dealing with materials properties, performance prediction, and traffic analysis.

One challenge that agencies face is assimilating the information obtained from the various research studies, reports, and articles, and applying those results within their own agency. However, one benefit of a nationally developed pavement design approach is the ability for agencies to share information related to evaluation, implementation, and calibration. In this manner, agencies that have implemented the *MEPDG* can share lessons learned with agencies that are in the process of, are just beginning, or have yet to begin the evaluation and implementation process.

Based on the survey responses, three agencies indicated that the *MEPDG* has been implemented: Indiana, Missouri, and Oregon. Table 24 provides an overview of the organizational information related to these agencies. Missouri and Oregon DOTs indicated that the pavement designs are conducted, reviewed, and approved by a central or headquarters office (centralized), whereas Indiana DOT is decentralized and pavement designs are conducted by district personnel. All agencies indicated that there was an *MEPDG* champion leading the implementation effort, and Indiana and Oregon both have an implementation oversight or review committee. In addition, all agencies indicated there was consistent coordination (e.g., open discussion and access to data and information) across the entire agency.

The three DOTs have implemented a number of the pavement types and rehabilitation treatments included in the *MEPDG*. Table 25 lists the predominant pavement types and preservation and rehabilitation treatments implemented by each of the three agencies.

In an effort to provide information that may be useful for other agencies in the implementation of the *MEPDG*, this chapter describes the implementation processes used by these three agencies. The majority of each agency case example is based on the results of the survey conducted for this synthesis, and supplemented with follow-up questions and agency-provided documents and research reports (when applicable).

INDIANA DEPARTMENT OF TRANSPORTATION

Indiana DOT manages and maintains a highway network of 27,879 lane-miles that includes 5,146 lane-miles of interstate routes, 5,529 lane-miles of non-interstate National Highway System (NHS) routes, and 17,204 lane-miles of non-NHS routes (BTS 2011). Table 26 lists new construction, preservation, and rehabilitation pavement types used on the state highway system.

Indiana DOT operates under a decentralized organizational structure—pavement designs are conducted, reviewed, and approved at the district level. Major projects, such as warranty, alternative bid, and design-build, are designed and finalized by the Central Office. Indiana DOT also indicated that there is open discussion and access to data and information across all offices within the agency.

Pavement Design Process

As noted previously, pavement designs are conducted, reviewed, and approved by the Design Office within each of the six Indiana DOT districts. Pavement designs for new and overlaid JPCP and asphalt pavements are based on the *MEPDG* and are either conducted by a consultant or by an agency engineer. If conducted by a consultant, all required data inputs and calibration coefficients are provided in the final submittal documents. Most pavement designs are finalized by the Indiana DOT Engineering Office.

MEPDG Implementation Process

Based on the recommendations of the Indiana DOT Pavement Steering Committee, with full commitment from the executive staff, Indiana DOT began evaluation of the *MEPDG* in 2002 and fully implemented the design procedure in 2009.

TABLE 24
SUMMARY OF AGENCY ORGANIZATION

Agency	Organizational Structure	*MEPDG* Champion	Oversight Committee	Interagency Communication[1]
Indiana DOT	Decentralized	State pavement design engineer and research manager	Yes	Consistent coordination
Missouri DOT	Centralized	Chief engineer	No	Consistent coordination
Oregon DOT	Centralized	State pavement design engineer	Yes	Consistent coordination

[1]Consistent coordination—open discussion and access to data and information across all divisions.

TABLE 25
SUMMARY OF *MEPDG* IMPLEMENTED PAVEMENT TYPES

Agency	New Construction	Rehabilitation
Indiana DOT	Asphalt and JPCP	Asphalt and JPCP overlays
Missouri DOT	Asphalt and JPCP	Asphalt and JPCP overlays
Oregon DOT	Asphalt (high-volume roadways only), JPCP, and CRCP	CRCP overlays

TABLE 26
PAVEMENT TYPES—INDIANA DOT

New Construction	Preservation and Rehabilitation
• Thin (<6 in.) asphalt over unbound aggregate • Thick (>6 in.) asphalt over unbound aggregate • Asphalt over subgrade/stabilized subgrade • Asphalt over cementitious stabilized layers (e.g., lime, lime-fly ash, cement) • Composite (new asphalt over new concrete) • JPCP	• Asphalt overlays of existing asphalt, concrete, and fractured concrete pavements • Concrete overlay of existing asphalt • Bonded and unbonded JPCP concrete overlays • HIR without an asphalt overlay • Full-depth reclamation with an asphalt overlay • Crack or break and seat with an asphalt overlay • Rubblization with an asphalt overlay • Dowel bar retrofit

In general, the implementation plan included the following (Nantung et al. 2005):

- Review current state of knowledge in pavement engineering and management.
- Review and document hierarchical design input parameters for each level of design accuracy (document sensitivity of design inputs to distress and smoothness prediction).
- Review and document relevant data contained in the Indiana DOT and LTPP databases.
- Review the readiness of laboratory and field equipment needed for quantifying higher-level *MEPDG* inputs. Acquire needed equipment and develop a testing program.
- Develop and execute a plan to establish:
  – Local calibration and validation of distress prediction models,
  – Regions and segments for traffic input module, and
  – Software populated with additional climatic data.
- Establish a “mini LTPP” program to more accurately calibrate the *MEPDG* performance prediction models.
- Develop correlations and equations for soil resilient modulus, load spectra regions and segments based on existing WIM (weigh-in-motion) and AVC (automated vehicle classification) data, and a process to aid designers in easily migrating traffic data into the software.
- Provide technology, knowledge transfer, and *MEPDG* training to other divisions, districts, local agencies, contractors, and consultants.
- Revise *Indiana DOT Design Manual* Chapter 52, “Pavement and Underdrain Design Elements”.

In addition, a design memorandum was established indicating that the *MEPDG* should be used in the development of a pavement design recommendation. The memorandum also includes the implementation plan (INDOT 2009).

In response to the availability of data, Indiana DOT indicated that the existing pavement structure (both layer type and layer thickness), material properties, traffic data, and pavement condition data were available electronically for all state highways. Therefore, Indiana DOT focused much of its evaluation effort on material characterization, traffic, performance prediction, and in-house training of pavement design personnel.

TABLE 27
MEPDG IMPLEMENTED PAVEMENT TYPES—INDIANA DOT

Asphalt	Concrete (JPCP)
• New construction • Overlay of existing asphalt • Overlay of existing JPCP • Overlay of existing CRCP • Overlay of fractured JPCP	• New construction • Overlay of existing asphalt • Unbonded overlay

During 2009, Indiana DOT conducted an *MEPDG* analysis of more than 100 pavement sections, which included all new pavement designs and all existing pavement designs that had yet to be awarded for structural adequacy before construction (Nantung 2010). The pavement design types included in the Indiana DOT *MEPDG* implementation are shown in Table 27.

The majority of the focus by Indiana DOT is in the implementation of the *MEPDG* (Nantung et al. (2005). One unique characteristic of the Indiana DOTs implementation effort is that it was conducted using Indiana DOT staff.

Materials Characterization

A sensitivity analysis of material inputs was conducted on an atypical Indiana DOT pavement structure using input values similar to those used in the previous Indiana DOT design procedures (AASHTO *1993 Guide*). The input values (using Level 3 inputs) for the pavement design were varied (one parameter at a time) and the predicted performance compared with those of the base design. For concrete pavements, Indiana DOT concluded that additional laboratory testing would be necessary to quantify concrete strength parameters, as well as other mix parameters (e.g., coefficient of thermal expansion) not currently available. To achieve this, Indiana DOT worked with five local contractors who conducted concrete strength testing to evaluate the construction specification requirements. For asphalt pavements, Indiana DOT developed a database for dynamic modulus, creep compliance, and indirect tensile strength of asphalt mixtures commonly specified by Indiana DOT. The layer thicknesses for the Indiana DOT LTPP asphalt pavement sites were also re-evaluated using the *MEPDG*. The calibration coefficients for the asphalt performance prediction models were then adjusted so that the predicted performance more closely reflected the actual measured performance. Finally, asphalt models were further calibrated using data from the Indiana DOT accelerated pavement testing facility and "mini LTPP" sites.

For unbound layers and subgrade soils, strengths are determined according to resilient modulus (AASHTO T307, Determining the Resilient Modulus of Soils and Aggregate Materials) obtained from triaxial testing. The agency has also generated a subgrade resilient modulus database, and developed a simplified approach for resilient modulus testing and a predictive equation for estimating material coefficients k_1, k_2, and k_3 using soil property tests (Kim and Siddiki 2006).

Traffic

To improve the ability of pavement designers to obtain traffic-specific data, Indiana DOT developed a software tool that provides visualization of WIM and AVC site locations and easy access for obtaining the required *MEPDG* input data. The software tool also allows the user to select relevant traffic data and directly export it to the *MEPDG* software. Indiana DOT also conducted a sensitivity study to determine the influence of traffic inputs on the predicted performance, generated WIM and AVC geographic information system maps, and analyzed WIM and AVC data to generate axle-load spectra data. Indiana DOT also provides the truck weight road group (TWRG) database for Level 2 inputs. The TWRG is divided into four groups based on the average annual daily truck traffic (AADTT).

Identifying Existing Conditions

Indiana DOT annually collects automated pavement condition and IRI data collection and video logging on the entire highway network. The data contained within the pavement management system also provides sufficient project-level information that was available for use during the calibration process. In addition to pavement distress and IRI data, the pavement management system also includes as-designed layer type and thickness, and the progression of pavement distress and IRI over time. Indiana DOT indicated that the distress definitions used by the agency match those in the *Distress Identification Manual* for smoothness and all asphalt and concrete distress types predicted in the *MEPDG*.

Input Level

The level of input selected for each of the *MEPDG* input values for Indiana DOT is shown in Table 28.

Local Calibration

Indiana DOT has conducted a local calibration of the *MEPDG* performance prediction models for IRI and asphalt alligator cracking (Table 29). The DOT also determined that the *MEPDG* performance prediction models for asphalt thermal cracking, asphalt rutting, concrete transverse cracking, and concrete faulting models are applicable to local conditions and have therefore adopted these models without modification. Indiana DOT also indicated that the predicted distress from the asphalt longitudinal cracking, total rut depth, and asphalt thermal cracking prediction models are not used to determine the final pavement layer thicknesses.

Table 30 lists the threshold limits for asphalt (new and overlays) and concrete (new and overlays) pavements. These values differ slightly from the default values included in the *MEPDG* and are based on pavement management data,

TABLE 28
MEPDG INPUT LEVEL—INDIANA DOT

Feature	Input Level
All traffic[1]	Regional value
All asphalt layers	Regional value
All concrete layers	Regional value
All chemically stabilized layers	Regional value
All sandwiched granular layers	Regional value
All non-stabilized base layers	
Poisson's ratio	Regional value
Modulus	Regional value
Sieve analysis	Regional value
All subgrade layers	
Poisson's ratio	Regional value
Modulus	Regional value
Sieve analysis	Regional value
All bedrock layers	*MEPDG* default value

[1]AADTT is site-specific.

except for transverse cracking in asphalt pavements, which is based on department policy.

Training

Indiana DOT has developed an in-house program to train personnel in the basics of pavement engineering, pavement materials, fundamentals of ME design, application of the *MEPDG* to Indiana conditions, and software operation. Training modules include an overview of the *MEPDG* software, load spectra, material characterization (asphalt, concrete, and unbound), principles of *MEPDG* design, traffic, materials, and climate inputs, and incorporate FWD data for pavement design and rehabilitation. Training, from basic pavement knowledge to ME theory, was noted as a key to the implementation of the *MEPDG* in Indiana.

MEPDG Libraries

The AASHTOWare Pavement ME Design™ software allows access to established agency databases for materials and traffic (the climatic database is included with the software license). Indiana DOT has created *MEPDG*-based databases for climate, materials, traffic, and pavement performance data. In this regard, the pavement designer simply selects the database option at the start of the software program and then selects the needed climate, material, and traffic data for import into the analysis project. The pavement performance library, which contains agency-measured pavement performance data, was used for performance prediction verification.

Additional Efforts

In addition to personnel training and *MEPDG* libraries, the Indiana DOT has conducted additional efforts to enhance the implementation process. These include:

- Software user manual—A software user manual was developed to supplement the help manual contained within the AASHTOWare Pavement ME Design™ software and provides Indiana DOT-specific pavement types, applicable performance prediction models, and input values to guide the pavement designer.
- Concurrent designs—Concurrent designs were conducted in 2009 to compare the results of the AASHTO 1993 *Guide* with the *MEPDG*.
- Design Manual revision—Chapter 52 of the *Indiana DOT Design Manual* was revised to include reference to the use of the *MEPDG* for the design of pavement structures. This chapter also provides values for the general inputs (e.g., design life, construction months, IRI and distress performance criteria, traffic, climate), and asphalt, concrete, unbound aggregate, stabilized, and subgrade layers (INDOT 2013).
- Model verification—Indiana DOT identified 108 pavement sections that were known to be constructed without any construction-related issues (based on construction records and the knowledge of the pavement manager). These pavement sections were located on three road classes (interstate, U.S. highway, and state route) and distributed across each of the six Indiana DOT districts. All pavement sections were evaluated using the *MEPDG* based on the inputs from the construction records and theoretical asphalt mix design results. The *MEPDG* predicted performance was compared (based on a review by the agency *MEPDG* implementation committee) with the measured pavement condition for each of the 108 pavement sections.

TABLE 29
PERFORMANCE PREDICTION MODEL SELECTION—INDIANA DOT

Pavement Type	Performance Indicator	Selected Model
All	IRI	Locally calibrated model
Asphalt	Longitudinal cracking	[1]
	Alligator fatigue cracking	Locally calibrated model
	Transverse cracking	[1]
	Rut depth—asphalt layers	*MEPDG* model
	Rut depth—total	[1]
	Reflective cracking	[1]
JPCP	Transverse cracking	*MEPDG* model
	Joint faulting	*MEPDG* model

[1]Distress criteria are not used to determine the recommended pavement structure.

TABLE 30
PERFORMANCE THRESHOLD LIMITS—INDIANA DOT

Functional Class	Asphalt Pavements				Concrete Pavements		Reliability (percent)
	IRI (in./mi)	Alligator cracking (percent area)	Asphalt rutting (in.)	Transverse cracking (ft/mi)	Transverse cracking (percent slabs)	Joint faulting (in.)	
Freeway	160	10	0.40	500	10	0.15	90
Arterial, Urban	190	20	0.40	700	10	0.20	90
Arterial, Rural	200	25	0.40	600	10	0.22	85
Collector, Urban	190	30	0.40	700	10	0.25	80
Collector, Rural	200	35	0.40	600	10	0.25	75
Local	200	35	0.40	700	10	0.25	70

Modified from INDOT (2013).

Benefits

Indiana DOT estimated that the *MEPDG* implementation has resulted in cost savings of approximately $10 million per year based on a comparison of resulting pavement structures from the AASHTO 1993 *Guide* and the *MEPDG* (Nantung 2010). In addition, although more difficult to quantify, the Indiana DOT survey response also noted that the *MEPDG*-based designs have improved the reliability of the design recommendations, the characterization of local and new materials, the characterization of existing pavement layers, the characterization of traffic, the confidence in distress prediction, and the knowledge of in-house staff in pavement design and pavement performance.

Challenges

Indiana DOT indicated that one of the most challenging efforts in the implementation effort was incorporating traffic data. Although traffic data for Indiana DOT was readily available, significant data retrieval and manipulation was required prior to use in the *MEPDG*.

Indiana DOT also indicated that having buy-in from the executive staff early in the implementation process was critical to its success. In addition, it was also important to provide the executive staff with information on how the agency would benefit with the implementation of the *MEPDG*.

Lessons Learned

When asked about the lessons learned from the *MEPDG* implementation process, Indiana DOT proposed the following:

- Review data to identify potential errors.
- Setting up the traffic input data (Level 1 or Level 2) requires a significant length of time; therefore, traffic input data needs to be resolved first.
- Know the agency construction practice. Be practical in setting up the layers in the *MEPDG*. Some layers can be designed, but cannot be constructed.
- Know the details of the agency standard specifications. Indiana DOT has based most of the material inputs for Level 2 and Level 3 on the standard specification requirements for construction quality control and quality assurance.
- Some input parameters will depend on agency internal policies. For example, the initial IRI depends on the agency acceptance of pavement smoothness after construction, while the terminal IRI depends on the factor of safety for the travelling public. The threshold value for the design reliability and performance criteria in the *MEPDG* should be based on the agency policy to assume risks.
- Conduct the implementation and local calibration effort using agency personnel. The agency personnel know the policies and procedures best and therefore are more qualified to conduct the implementation and local calibration processes.
- Local calibration is a plus, but should not need a requirement for implementing the *MEPDG*. Indiana DOT used 18 LTPP test sections and agency research sections; however, this was not enough to fully calibrate the performance prediction models. However, obtaining data to meet all aspects of the calibration process may take years. Indiana DOT took the approach that it was better to conduct verification and validation of selected pavement sections with good pavement history, rather than attempt to obtain data on all agency-applicable pavement types.
- Form an oversight committee to evaluate, guide, and direct the implementation process.
- Coordinate and communicate with the materials office and the geotechnical engineering office early in the implementation process.
- Provide training in ME fundamentals, *MEPDG* procedures, and AASHTOWare Pavement ME Design™ software to agency and consulting pavement engineers.
- Work together with the pavement associations in resolving any implementation issues or concerns.
- The *MEPDG* provides an improved pavement design procedure in comparison with the AASHTO 1993 *Guide*.

TABLE 31
PAVEMENT TYPES—MISSOURI DOT

New Construction	Preservation and Rehabilitation
• Thick asphalt (>6 in.) over aggregate base • JPCP	• Asphalt overlays of existing asphalt, concrete, and composite pavement • Bonded and unbonded JPCP overlay • HIR with an asphalt overlay • CIR with an asphalt overlay • Full-depth reclamation with an asphalt overlay • Rubblization with an asphalt overlay • Dowel bar retrofit • Diamond grinding

MISSOURI DEPARTMENT OF TRANSPORTATION

Missouri DOT manages and maintains a highway network of 75,999 lane-miles, and includes 5,621 lane-miles of interstate routes, 10,607 lane-miles of non-interstate NHS routes, and 59,771 lane-miles of non-NHS routes (BTS 2011). The pavement types, new, preservation, and rehabilitation, currently constructed by Missouri DOT are listed in Table 31.

Missouri DOT operates under a centralized organizational structure—pavement designs are conducted, reviewed, and approved by the Central Office (Construction and Materials Division, Pavement Section).

MEPDG Implementation Process

In 2005, Missouri DOT determined that the benefits obtained from implementation of the *MEPDG* would outweigh the risks associated with adopting an ME-based pavement design procedure that was not yet fully evaluated, calibrated, or validated. Specifically, the reasons for moving forward with *MEPDG* implementation assumed improved reliability in prediction of pavement condition, potential cost savings, consideration of local and new materials, consideration of local traffic conditions, ability to model the effects of climate and materials aging, and improved characterization of existing pavement layer parameters. Missouri DOT became the first highway agency to initiate and implement the use of the *MEPDG* for the design of new asphalt and concrete pavements by implementing the *MEPDG* for design of thick asphalt on rubblized concrete and concrete overlays in 2008. Missouri DOT also adopted the use of input values primarily based on Level 3. As better inputs became available, those values were adopted and substituted into the *MEPDG* analysis (MODOT 2005). Table 32 lists pavement types currently evaluated using the *MEPDG*.

In 2005, Missouri DOT released the *ME Design Manual*, which provides details related to pavement design life, distress threshold values, reliability levels, and input values for traffic, pavement structure, and materials (MODOT 2005). In 2009, *ME Design Manual—Volume II* was released providing the pavement designer with input values for direct use with the AASHTOWare Pavement ME Design™ software (MODOT 2009).

In 2009, a research project, *Implementing the AASHTO Mechanistic-Empirical Pavement Design Guide in Missouri*, was completed; this provides details related to the steps and activities needed to locally calibrate the distress prediction models to Missouri conditions (Mallela et al. 2009).

Missouri DOT determined that the implementation efforts should focus on the analysis of state-collected WIM data; materials characterization of typical asphalt, concrete, aggregate base, and subgrade soils; and field testing of in situ pavements for use in distress prediction model calibration. Each of these areas is further described in the following sections.

Traffic

The traffic data evaluation was conducted by a consultant and included a comparison of the Missouri-specific traffic data with the *MEPDG* default values and the development of input values based on historical traffic data. In this study, the Missouri DOT's continuous and portable WIM sites were evaluated and the results of the traffic data analysis indicated the following (Mallela et al. 2009):

- The continuous WIM data were of sufficient quality for use in the *MEPDG*.

TABLE 32
MEPDG IMPLEMENTED PAVEMENT TYPES—MISSOURI DOT

Asphalt	Concrete (JPCP)
• New construction • Asphalt overlay of existing asphalt • Asphalt overlay of existing JPCP • Asphalt overlay of fractured JPCP	• New construction • Bonded concrete overlay of existing JPCP • JPCP overlay of existing asphalt pavement • Unbonded JPCP overlay of existing JPCP

TABLE 33
MATERIAL CHARACTERIZATION—MISSOURI DOT

Material Type	Study Results
Asphalt Mixture	Asphalt material property inputs were determined and included in the *MEPDG* materials library for typical Missouri DOT mixtures.
	The *MEPDG* dynamic modulus regression equation adequately reflects Missouri DOT mixtures.
	The *MEPDG* prediction equation has a tendency to under predict E*, especially at high frequencies
Concrete Mixture	Concrete material property inputs were determined and included in the *MEPDG* materials library for typical Missouri DOT mixtures.
	Laboratory-determined values for compressive strength, flexural strength, and elastic modulus are not statistically different from *MEPDG* Level 3 default values; therefore, use the *MEPDG* Level 3 default values.
	Until long-term data are available use the strength and modulus gain model contained in *MEPDG*.
	When Missouri DOT compressive-to-flexural strength correlation is very close to *MEPDG*, use the *MEPDG* default values.
	MEPDG underestimates compressive strength-to-elastic modulus; therefore, use the Missouri DOT-developed relationship.
Unbound Material	Unbound material property inputs were determined and included in the *MEPDG* materials library for standard (Type 5) base material and subgrade soils.

Source: Mallela et al. (2009).

- The *MEPDG* default truck traffic classification groups adequately describe the highway traffic distribution on Missouri principal arterial highways.
- The *MEPDG* defaults for vehicle class distributions, axle-load spectra, axles per truck, hourly truck usage, and default monthly adjustment factors are appropriate for routine design.

Materials Characterization

The laboratory testing for materials characterization was conducted by Missouri DOT on asphalt and concrete mixtures, dense-graded aggregate base, and subgrade materials. Table 33 provides a summary of the material testing needs and the findings of the analysis.

Test Sections

In situ pavement testing was conducted on 36 agency-specified sites and 41 LTPP sites. A list of test sites by pavement type is shown in Table 34. Each test section was 500 ft long. Pavement testing included coring to quantify asphalt layer properties (thickness, air voids, asphalt content, bulk and maximum specific gravity, and aggregate gradation), concrete properties (thickness, compressive strength, elastic modulus, and coefficient of thermal expansion), FWD testing to quantify in situ layer stiffness, manual condition surveys, and analysis of test section historical IRI data (Schroer 2012). The results of the test sections were used during the local calibration of the *MEPDG* performance prediction models.

Input Levels

Based on the local calibration effort, Missouri DOT specifies the input levels for each input feature, as shown in Table 35. For the most part, *MEPDG* default values are used, with regional values for specific inputs (e.g., vehicle class distribution, asphalt mixture volumetrics, concrete mix properties, resilient modulus, and sieve analysis for unbound layers).

TABLE 34
FIELD TESTING SITES—MISSOURI DOT

Pavement Type	Agency	LTPP	Total
New JPCP	25	7	32
New asphalt	6	14	20
Asphalt overlay of existing asphalt	0	11	11
Asphalt overlay of existing JPCP	0	5	5
Asphalt overlay of rubblized JPCP	0	4	4
Unbonded concrete overlay	5	0	5
Total	36	41	77

Source: Mallela et al. (2009).

TABLE 35
MEPDG INPUT LEVELS—MISSOURI DOT

Feature	Input Level
All traffic inputs (except as indicated below)	*MEPDG* default values
AADTT	Site-specific
Vehicle class distribution	Regional values
Axles per truck	Regional values
All asphalt layer inputs (except as indicated below)	*MEPDG* default values
Mixture volumetrics	Regional value
Mechanical properties	Regional value
All concrete layer inputs	*MEPDG* default values
Poisson's ratio	Regional value
Unit weight	Regional value
Mix properties	Regional value
Strength properties	Regional value
All chemically stabilized layer inputs	Do not use
All sandwiched granular layers	Do not use
All non-stabilized base layers (except as indicated below)	*MEPDG* default values
Modulus	Regional value
Sieve analysis	Regional value
All subgrade layers	
Modulus	Regional value
Sieve analysis	Regional value
All bedrock layers	*MEPDG* default value

Data Availability

Missouri DOT reported that the existing pavement structure (layer type and thickness), traffic, and pavement condition data are all readily available; however, material properties of the existing pavement structure are difficult to obtain. Both the traffic and pavement condition data are available agency-wide, whereas the existing pavement structure (layer type and thickness) data and material properties are only available at the district level.

Agency definitions of pavement distress are similar to those recommended in the *Distress Identification Manual.*

Local Calibration

Missouri DOT has conducted an evaluation of the *MEPDG* performance prediction models to determine applicability to Missouri conditions. A summary of the performance prediction model selection is shown in Table 36. For asphalt pavements, Missouri DOT determined that *MEPDG* performance prediction models for longitudinal cracking, alligator cracking, and reflective cracking reflect Missouri conditions; local calibration was required for transverse cracking, rut depth (asphalt and total), and IRI. For concrete pavements, the *MEPDG* performance prediction models were determined to be acceptable for transverse cracking and joint faulting, and local calibration of the IRI performance prediction model was required.

Table 37 summarizes the performance criteria used by the Missouri DOT for asphalt (new and overlays) pavements. Even though several performance prediction models have been locally calibrated, the Missouri DOT currently requires only performance criteria for alligator cracking and rut depth in the asphalt layers. The performance criterion for alligator cracking is based on the expected level of alligator cracking for a "perpetual" pavement (i.e., no deep-seated structural distress). However, the level of expected alligator cracking has not yet been verified from in-service asphalt pavements. The asphalt rutting criterion is based on the approximate depth to reduce the potential for hydroplaning.

At this time, Missouri DOT has not implemented the IRI criteria in the pavement design process because it is difficult

TABLE 36
PERFORMANCE PREDICTION MODEL SELECTION—MISSOURI DOT

Pavement Type	Performance Indicator	Selected Model
All	IRI	Locally calibrated model
Asphalt	Longitudinal cracking	*MEPDG* model
	Alligator cracking	Nationally calibrated model
	Transverse cracking	Locally calibrated model
	Rut depth—asphalt layers	Locally calibrated model
	Rut depth—total	Locally calibrated model
	Reflective cracking	*MEPDG* model
JPCP	Transverse cracking	*MEPDG* model
	Joint faulting	*MEPDG* model

TABLE 37
PERFORMANCE THRESHOLD LIMITS—MISSOURI DOT

Performance Indicator	Threshold Limit	Reliability (percent)
Alligator cracking (percent lane area)	2.00	50
Rut depth—asphalt only (in.)	0.25	50

to determine the initial as-constructed IRI. This is particularly problematic for the agency because new construction and reconstruction pavement projects are let as alternate bid contracts. Missouri DOT includes the pavement thickness requirements for both pavement types in the project proposal documents. However, because the determined layer thickness may be affected by the initial IRI value, an unfair advantage may arise because of differences in as-construction IRI compared with the initial IRI used in the design process.

The initial calibration effort for total rut depth was conducted in 2006. As pavement designs were being conducted and reviewed, Missouri DOT questioned the validity of the rut depth predictions for unbound base and subgrade layers. The more recent local calibration effort has yet to be accepted; therefore, for now, only the asphalt layer rut depth criteria has been implemented.

Training

There is currently no formal training for *MEPDG* and the AASHTOWare Pavement ME Design™ software by Missouri DOT staff; it is self-taught.

Additional Efforts

Before adopting the *MEPDG* (and AASHTOWare Pavement ME Design™ software) Missouri DOT was required to obtain buy-in from and address any concerns from the industry, as well as address any concerns or issues with the information technology department.

Benefits

As discussed previously, Missouri DOT moved forward with the *MEPDG* implementation process because of the assumed benefits that it would bring. These benefits include cost savings resulting from more economical designs, improved characterization of local materials, existing pavement layers and traffic, and improved confidence in distress prediction.

OREGON DEPARTMENT OF TRANSPORTATION

Oregon DOT manages and maintains a highway network of 18,606 lane-miles, and includes 3,126 lane-miles of interstate routes, 7,267 lane-miles of non-interstate NHS routes, and 8,213 lane-miles of non-NHS routes (BTS 2011). Table 38 lists all new construction, and preservation and rehabilitation pavement types currently constructed by Oregon DOT.

Pavement Design Process

Pavement designs for Oregon DOT are conducted by agency staff as well as private consultants. The state pavement design engineer is responsible for evaluating, conducting, reviewing, or overseeing all pavement designs for the state highway network. Currently acceptable pavement design procedures include: AASHTO 1993 *Guide*, *MEPDG*, Asphalt Institute, Portland Cement Association, Asphalt Pavement Association of Oregon (based on AASHTO 1993 *Guide*), and American Concrete Pavement Association (ODOT 2011). The standard pavement design procedure used by Oregon DOT for asphalt pavements is the AASHTO 1993 *Guide*, while the *MEPDG* analysis is conducted concurrently for comparison purposes. The *MEPDG* has been fully adopted for new concrete pavement design.

Oregon DOT operates under a centralized organizational structure—pavement designs are conducted, reviewed, and approved by the central office (Pavement Services Unit). The Pavement Services Unit reports to the state construction and materials engineer and is responsible for pavement design, pavement management, and pavement materials and construction.

MEPDG Implementation Process

Oregon DOT began evaluation of the *MEPDG* in 2006, with implementation for new construction (or reconstruction) high-volume routes in 2009. Oregon DOT has developed calibration coefficients for each of the pavement types

TABLE 38
PAVEMENT TYPES—OREGON DOT

New Construction	Preservation and Rehabilitation
• Thin (<6 in.) asphalt over unbound aggregate • Thick (>6 in.) asphalt over unbound aggregate • Asphalt over cementitious stabilized layers • Composite (new asphalt over new concrete) • JPCP • CRCP	• Asphalt overlays of existing asphalt, concrete, and composite pavements • Unbonded CRCP overlay • CIR with an asphalt overlay • Full-depth reclamation with an asphalt overlay • Rubblization with an asphalt overlay • Rubblization with a concrete overlay • Diamond grinding

TABLE 39
MEPDG IMPLEMENTED PAVEMENT TYPES—OREGON DOT

Asphalt	JPCP	CRCP
• New construction • Overlay of existing JPCP • Overlay of existing CRCP	• New construction	• New construction • Overlay of existing asphalt

shown in Table 39. Currently, Oregon DOT is re-evaluating the calibration coefficients for asphalt pavements (including overlays) and determining the implementation plan for application to asphalt and concrete overlay designs.

Oregon DOT indicated that reasons for implementing the *MEPDG* included the potential cost savings owing to more economical pavement structure recommendations, consideration of local traffic conditions, the effects of climate and materials aging on pavement performance, and consideration of the characterization of existing pavement layers. Oregon DOT also indicated that it has improved communications between the pavement design and pavement management offices.

As part of the implementation effort, Oregon DOT, through university research projects, focused on material characterization, traffic, and local calibration. Each of these efforts is summarized in the following sections.

Materials Characterization

Lundy et al. (2005) determined the dynamic modulus for Oregon DOT standard asphalt mixtures. Asphalt mixtures were varied according to air void level, binder grade, and binder content. During testing, the same aggregate source and gradation were used for all mixtures. One of the primary findings from this study was that the *MEPDG* regression equation resulted in good agreement with the laboratory results. From this analysis, the Oregon DOT adopted Level 3 inputs for asphalt material characterization.

Traffic

Oregon DOT collects WIM data on 22 sites across the state. The raw data from four of the WIM sites was used to generate “virtual” truck classifications representing three typical daily truck traffic volumes: 500 (low), 1,500 (moderate), and 5,000 (high) trucks per day. The virtual truck classifications are electronically available for import into the AASHTOWare Pavement ME Design™ software. Oregon DOT uses the following WIM data options (Elkins and Higgins 2008):

- On less critical roadways, the virtual truck classification is combined for all seasons and sites to determine average hourly volume distribution, average number of axles per truck, and average individual axle spacing. However, the axle group categories are not combined because each virtual truck classification has a distinct distribution of tandem, tridem, and quad axles.
- For more critical roadways, the virtual truck classification associated with low, moderate, or high truck volumes is used.

Input Levels

The Oregon DOT input levels for each of the *MEPDG* design inputs are listed in Table 40. For the majority of data inputs, the agency has chosen to use the *MEPDG* default values. Only a few data inputs are based on site-specific values and these include vehicle class distribution, asphalt mixture volumetrics, concrete strength properties, and modulus and sieve analysis of unbound and subgrade layers.

Identifying Existing Conditions

The existing pavement structure (layer type and thickness), associated material properties, traffic, and condition data are readily available for all state highways. Data availability and acquisition is not viewed as an insurmountable issue because the Pavement Design Unit provides a centralized connection between traffic, pavement management, materials testing, and pavement design.

Pavement condition data are collected in accordance with the *Pavement Distress Identification Manual* (Miller and Bellinger 2003). However, modifications to distress definitions and measurements have been conducted to better reflect Oregon conditions (ODOT 2011). The distress survey is conducted every other year using semi-automated pavement condition survey procedures.

Local Calibration

Oregon DOT has conducted a local calibration of the pavement performance prediction models for asphalt pavements, JPCP, and CRCP (Table 41). Local calibration was based on the evaluation of 108 pavement test sections representing typical Oregon DOT pavement designs, regional locations (coastal, valley, and eastern), and traffic levels (low, moderate, and high) (Williams and Shaidur 2013).

TABLE 40
MEPDG INPUT LEVELS—OREGON DOT

Feature	Input Level
All traffic inputs (except as indicated below)	Regional value
Vehicle class distribution	Site-specific value
AADTT	Site-specific value
Axles per truck	*MEPDG* default value
Axle configuration	*MEPDG* default value
Wheelbase	*MEPDG* default value
All asphalt layer inputs (except as indicated below)	*MEPDG* default value
Mixture volumetrics	Site-specific value
All concrete layer inputs	*MEPDG* default value
Strength properties	Site-specific value
All chemically stabilized layer inputs	Do not use
All sandwiched granular layers	Do not use
All non-stabilized base layers (except as indicated below)	*MEPDG* default value
Modulus	Site-specific value
Sieve analysis	Site-specific value
All subgrade layers	*MEPDG* default value
Modulus	Site-specific value
Sieve analysis	Site-specific value
All bedrock layers	*MEPDG* default value

Training

There is currently no formal training for *MEPDG* and the AASHTOWare Pavement ME Design™ software by Oregon DOT staff; it is self-taught.

Benefits

Oregon DOT indicated that implementation of the *MEPDG* will improve the confidence in the performance prediction models; however, benefits have yet to be quantified.

Challenges

Oregon DOT indicated that a number of issues have impeded the *MEPDG* implementation, including availability of materials characterization data, funding restrictions, limited time available, and justification of benefits for implementing more advanced procedures.

Additional Work to Justify Implementation

The Pavement Design Unit is currently evaluating the benefits of expanding the use of the *MEPDG* for the design of all new construction and rehabilitated asphalt pavements.

SUMMARY

This chapter described the successful *MEPDG* implementation efforts of three state highway transportation agencies. Implementation efforts were presented as case examples that are based on the agency survey responses and follow-up questions, and supplemented with agency documents and research reports. The case examples provided a summary of the *MEPDG* implementation processes for the Indiana, Missouri, and Oregon DOTs; specifically, information related to the agency pavement design process, *MEPDG* implementation process, local calibration efforts, staff training efforts, and development of *MEPDG* materials and traffic databases.

TABLE 41
PERFORMANCE PREDICTION MODEL SELECTION—OREGON DOT

Pavement Type	Performance Indicator	Selected Model
All	IRI	*MEPDG* model
Asphalt	Longitudinal cracking	Locally calibrated model
	Alligator cracking	Locally calibrated model
	Transverse cracking	Locally calibrated model
	Rut depth—asphalt layers	Locally calibrated model
	Rut depth—total	Locally calibrated model
	Reflective cracking	*MEPDG* model
JPCP	Transverse cracking	*MEPDG* model
	Joint faulting	*MEPDG* model
CRCP	Punchouts	*MEPDG* model

TABLE 42
SUMMARY OF *MEPDG* IMPLEMENTED PAVEMENT TYPES

Pavement Type	Indiana DOT	Missouri DOT	Oregon DOT
New construction—Asphalt	✓	✓	✓
New construction—CRCP			✓
New construction—JPCP	✓	✓	✓
Asphalt overlay of existing asphalt	✓	✓	
Asphalt overlay of existing CRCP	✓		
Asphalt overlay of existing JPCP	✓	✓	
Asphalt overlay of fractured JPCP	✓	✓	
CRCP overlay of existing asphalt			✓
JPCP bonded concrete overlay		✓	
JPCP overlay of existing asphalt	✓		
Unbonded overlay	✓	✓	

Table 42 summarizes the pavement types evaluated by these three agencies using the *MEPDG* for each agency. As noted, all agencies utilize the *MEPDG* analysis for quantifying the pavement structure for asphalt and JPCP new construction, and Oregon DOT also includes CRCP new construction. Agencies utilize the *MEPDG* for analyzing a variety of asphalt and concrete overlay options.

Table 43 lists the input levels selected by each of the three agencies. For the majority of inputs, Indiana DOT has selected regional values; Missouri DOT uses a combination of regional and *MEPDG* default values; and Oregon DOT uses predominately site-specific and *MEPDG* default values.

Table 44 lists the performance prediction models selected by each agency for asphalt and concrete pavements. All agencies evaluated the applicability of the *MEPDG* performance prediction model to local conditions. When the *MEPDG* performance prediction model did not adequately represent measured conditions, the agency recalibrated the performance prediction model. In Table 44, “National” indicates that the *MEPDG* performance prediction model was selected for use, while “Local” indicates that the performance prediction model was calibrated to local conditions.

For asphalt pavements, Indiana DOT reviews but does not consider the longitudinal cracking, total rut depth, thermal cracking, or reflective cracking criteria for determining the final pavement layer thicknesses, but has locally calibrated the alligator cracking and IRI performance prediction models, and adopted the *MEPDG* asphalt rut depth performance prediction model. For JPCP pavements, Indiana DOT has adopted the *MEPDG* performance prediction models for

TABLE 43
SUMMARY OF *MEPDG* INPUT LEVELS

Feature	Indiana DOT	Missouri DOT	Oregon DOT
All traffic inputs (except as noted)	Regional	*MEPDG*	Regional
AADTT	Site-specific	Site-specific	Site-specific
Vehicle class distribution		Regional	Site-specific
Axles per truck		Regional	*MEPDG*
Axle configuration			*MEPDG*
Wheelbase			*MEPDG*
All asphalt layer inputs (except as noted)	Regional	*MEPDG*	*MEPDG*
Mixture volumetrics		Regional	Site-specific
Mechanical properties		Regional	
All concrete layer inputs (except as noted)	Regional	*MEPDG*	*MEPDG*
Poisson’s ratio		Regional	
Unit weight		Regional	
Mix properties		Regional	
Strength properties		Regional	Site-specific
All chemically stabilized layer inputs	Regional	Do not use	Do not use
All sandwiched granular layers	Regional	Do not use	Do not use
All non-stabilized base layers (except as noted)		*MEPDG*	*MEPDG*
Poisson’s ratio	Regional		
Modulus	Regional	Regional	Site-specific
Sieve analysis	Regional	Regional	Site-specific
All subgrade layers (except as noted)			*MEPDG*
Poisson’s ratio	Regional		
Modulus	Regional	Regional	Site-specific
Sieve analysis	Regional	Regional	Site-specific
All bedrock layers	*MEPDG*	*MEPDG*	*MEPDG*

TABLE 44
SUMMARY OF AGENCY-SELECTED PERFORMANCE PREDICTION MODELS

Pavement Type	Performance Indicator	Indiana DOT	Missouri DOT	Oregon DOT
Asphalt	IRI	Local	Do not use	National
	Longitudinal cracking	Do not use	Do not use	Local
	Alligator cracking	Local	Local	Local
	Transverse cracking	Do not use	Do not use	Local
	Rut depth—asphalt layers	National	Local	Local
	Rut depth—total	Do not use	Do not use	Local
	Reflective cracking	Do not use	Do not use	National
JPCP	Transverse cracking	National	National	National
	Joint faulting	National	National	National
	IRI	Local	Local	National
CRCP	Punchouts	Not applicable	Not applicable	National
	IRI			National

Oregon DOT has adopted the *MEPDG* IRI prediction model, and has locally calibrated all other asphalt pavement performance prediction models. For concrete pavements, Oregon DOT adopted the *MEPDG* performance prediction models for both JPCP and CRCP.

both slab cracking and joint faulting, and has locally calibrated the IRI performance prediction model.

Missouri DOT has adopted the *MEPDG* performance prediction model for longitudinal cracking, thermal cracking, and reflective cracking, and for asphalt pavements has locally calibrated the IRI, alligator cracking, and asphalt and total rut depth performance prediction models. For JPCP, Missouri DOT has adopted the *MEPDG* performance prediction models for slab cracking and joint faulting, and has locally calibrated the IRI prediction models.

Oregon DOT has adopted the *MEPDG* IRI prediction model, and has locally calibrated all other asphalt pavement performance prediction models. For concrete pavements, Oregon DOT adopted the *MEPDG* performance prediction models for both JPCP and CRCP.

Implementation of the *MEPDG* (or any new process) requires more effort than just evaluating the applicability of the process to agency conditions. For example, training may be required for the ME design process, *MEPDG*, and software. In addition, it will be necessary for agencies to determine *MEPDG*-specific details, such as threshold criteria and reliability levels, input levels, materials and traffic inputs, and applicability of predicted performance to field conditions. To address these issues and concerns, agencies identified a number of aids (e.g., user guides, data libraries, and training) that can be used to assist an agency in the implementation process.

A number of these implementation aids are listed in Table 45. All agencies, to some extent, have conducted materials characterization. All agencies have also characterized traffic according to the data requirements contained within the *MEPDG*. Both Indiana and Missouri DOTs have identified calibration sections, developed materials and traffic libraries, developed implementation plans, and created an agency-specific ME user guide. Indiana DOT has also conducted concurrent designs and modified the agency design manual. Oregon DOT is in the process of developing an implementation plan for asphalt and concrete overlay design. Only Indiana DOT has developed an in-house training program for agency staff.

TABLE 45
SUMMARY OF AGENCY IMPLEMENTATION AIDS

Feature	Indiana DOT	Missouri DOT	Oregon DOT
Materials characterization			
Asphalt	✓	✓	✓
Concrete	✓	✓	
Unbound aggregate	✓	✓	
Subgrade soils	✓	✓	
Traffic characterization	✓	✓	✓
Test sections	✓	✓	
Training	✓		
Utilization of pavement management data	✓		
Material library	✓	✓	
Traffic library	✓	✓	✓
Implementation plan	✓	✓	In progress
MEPDG user guide	✓	✓	
Concurrent designs	✓		
Design manual revisions	✓		

✓ Indicates agency-developed implementation aid.

CHAPTER SIX

CONCLUSIONS

Development of the AASHTO *Mechanistic-Empirical Pavement Design Guide* (*MEPDG*) (and accompanying software) has provided the pavement design community with a pavement design and analysis process based on mechanistic-empirical (ME) procedures. ME-based pavement design procedures allow a designer to analyze and evaluate features that directly impact pavement performance, such as traffic loadings, climatic impacts, materials properties, and existing soil conditions. As with any new process, implementation of an ME-based design procedure may require additional agency efforts related to obtaining data, conducting data collection or testing to quantify materials and traffic, staff training, and comparing the results of the new procedure to the existing procedure.

The summary of agency *MEPDG* implementation efforts provided in this synthesis was obtained through a literature search, an agency web-based survey, and follow-up questions with agencies that indicated in the survey that the *MEPDG* had been implemented by their agency. The literature search was conducted on relevant documents related to agency *MEPDG* implementation efforts. Although there is extensive documentation related to *MEPDG* performance prediction modeling, materials and traffic characterization, and climate impacts, relatively few documents are readily available that summarize the agency *MEPDG* implementation efforts. The web-based survey was distributed to U.S., Puerto Rico, District of Columbia, and Canadian highway transportation agencies requesting information related to current pavement design practices, organizational structure, *MEPDG* implementation efforts, lessons learned in the implementation process, and the development of products (e.g., training programs, user guides) that could aid the implementation effort. Finally, follow-up questions were asked to further clarify the implementation efforts of the Indiana, Missouri, and Oregon departments of transportation (DOTs). The implementation efforts of these three agencies were showcased as agency implementation case examples.

OVERALL FINDINGS

Implementation of the *MEPDG* is a major change in pavement design practices for most transportation agencies. In the agency survey, 48 agencies indicated that pavements were designed using empirical-based design procedures that, for the most part, have served the pavement design community reasonably well. Although the agencies have a comfort level with their existing pavement design procedures, many are moving toward implementation of the *MEPDG*, which is demonstrated by the *MEPDG* implementation by three responding agencies, and 46 agencies that plan on implementing.

The majority of responding highway agencies have or intend to implement the *MEPDG* in the design of asphalt pavements (45 agencies), new jointed plain concrete pavements (JPCP; 39 agencies), and new continuously reinforced concrete pavements (CRCP; 12 agencies). In addition, most agencies indicated that the *MEPDG* will be used for the design of asphalt overlays of existing asphalt pavements (38 agencies), asphalt overlays of existing JPCP (34 agencies), and asphalt overlays of fractured JPCP (27 agencies). For concrete overlays, 22 agencies indicated that the *MEPDG* will be used to design unbonded JPCP overlays of existing JPCP, JPCP overlay of existing asphalt pavements (21 agencies), and bonded concrete overlays of existing JPCP (13 agencies).

The *MEPDG* requires a larger number of data inputs as compared with previous empirical-based pavement design procedures. Thirty-two agencies indicated that pavement condition data are the most readily available, followed by existing pavement structure data (31 agencies), and traffic data (28 agencies). By far the most difficult data for agencies to obtain is material characterization data, as only 17 agencies indicated that it is readily available.

In relation to the input level, the survey asked agencies to specify the level of input (i.e., *MEPDG* default, agency regional or agency site-specific value) that was used for each of 49 input categories (e.g., traffic, asphalt, concrete, unbound materials). In general, the most common response indicated that either the *MEPDG* default values and/or agency-determined regional values were used. For traffic-specific inputs, vehicle class distribution is predominantly based on site-specific values, hourly and monthly adjustment factors are evenly split between default or regional input values, and truck-specific information (e.g., axles per truck, wheelbase) are predominantly based on *MEPDG* default values. For most of the asphalt, concrete, chemically stabilized, sandwiched granular, unbound base, and subgrade soil inputs values are based on agency-determined regional values. For bedrock layers, input values are generally based on *MEPDG* default values.

As of May 2013, nine agencies indicated that some or all of the *MEPDG* performance prediction models had been calibrated to local conditions. Depending on the performance prediction model, reported calibration coefficients varied significantly.

There are several organizational commonalities among the responding agencies, including an *MEPDG* champion and establishing an *MEPDG* oversight committee. Thirty-two agencies indicated that there was an *MEPDG* champion, and for the majority of agencies (29), this person was the pavement engineer or pavement design engineer (or similar position). The *MEPDG* oversight committee has been established by 25 agencies and committee members generally included the pavement engineer, materials engineer, pavement design engineer, district or region engineer, and the research engineer or director. Although it is difficult to determine a direct correlation between implementation status and organization structure, the majority of the agencies (31) have a centralized organization structure, most have consistent communication across agency functions (25 agencies), and those agencies that had an *MEPDG* champion and/or oversight committee appeared to be further along in the implementation process (i.e., implementation was expected to occur within 2 years).

Common Elements of Agency *MEPDG* Implementation Plans

Based on the literature review of agency implementation plans, a number of common elements were identified. Determining which elements to include is based on the approach that best meets the individual agency needs. The following lists the common elements of agency *MEPDG* implementation plans:

- Pavement types included in the implementation effort.
- Data sources and necessary data collection or testing.
- Data libraries for materials and traffic inputs.
- Threshold and reliability levels for each performance prediction model.
- *MEPDG* verification—Confirmation that predicted distress meets measured distress.
- Agency documentation of *MEPDG*-specific information.
- Training of agency staff in the areas of ME principles, *MEPDG* procedures, and operation of AASHTOWare Pavement ME Design™.

Case Examples

Based on the agency survey, three agencies indicated that the *MEPDG* had been implemented: the Indiana, Missouri, and Oregon DOTs. Common organizational elements among these agencies include the open discussion and access to data and information across all agency divisions (all three agencies), the presence of an *MEPDG* champion (all three agencies), and the establishment of an oversight committee (two of the three agencies). The following summarizes the implementation efforts for each agency included in the case examples.

- **Indiana DOT.** Indiana DOT began evaluation of the *MEPDG* in 2002, with full implementation in 2009. In general, the Indiana DOT *MEPDG* implementation effort included:
  - Defining input parameters for each level of design accuracy.
  - Reviewing relevant data contained in the DOT and Long-Term Pavement Performance databases.
  - Evaluating and acquiring needed equipment and developing a testing program.
  - Conducting material and traffic characterization.
  - Locally calibrating the *MEPDG* performance prediction models.
  - Conducting concurrent designs to compare the results of the existing design procedure with the *MEPDG*.
  - Providing training in ME principles, *MEPDG* procedures, and software operation.
  - Revising the Indiana DOT *Design Manual* to incorporate the use of the *MEPDG* for the design of pavement structures.
- **Missouri DOT.** Missouri DOT initiated the *MEPDG* implementation process, with full implementation by 2009. The implementation effort for Missouri DOT included:
  - Comparing Missouri-specific traffic data with the *MEPDG* default values.
  - Conducting testing to quantify material properties (asphalt, concrete, dense-graded aggregate base, and subgrade materials).
  - Testing section evaluation (coring to quantify asphalt layer properties, concrete properties, falling weight deflectometer testing to quantify in situ layer stiffness, manual condition surveys, and analysis of historical International Roughness Index data).
  - Conducting local calibration.
- **Oregon DOT.** Oregon DOT began evaluation of the *MEPDG* in 2006, and implemented the *MEPDG* for the design of new or reconstructed pavement on high-volume routes in 2009. The Oregon DOT *MEPDG* implementation process included:
  - Characterizing properties of typical asphalt mixtures.
  - Characterizing weigh-in-motion data from 22 locations across the state.
  - Identifying existing conditions (pavement layer type and thickness, material properties, traffic, and distress condition data).
  - Conducting local calibration.

LESSONS LEARNED

The agency survey responses reported the following lessons learned during the implementation of the *MEPDG*:

- Realistic timelines for the calibration and validation process.
- Sufficient time for obtaining materials and traffic data.

- Readily available data related to the existing pavement layer, materials properties, and traffic.
- A plan for collecting needed data; this can require an expensive field sampling and testing effort.
- Agency-based design inputs to minimize design variability.
- Training of agency staff in ME design fundamentals, *MEPDG* procedures, and the AASHTOWare Pavement ME Design™ software.

ACTIVITIES TO AID IMPLEMENTATION

The amount of research that has been conducted related to the *MEPDG* is extensive. In addition, local and national research efforts related to material and traffic characterization, performance prediction, and model development will continue in the foreseeable future. Based on agency survey responses, the following provides a list of activities that would aid in the implementation effort (in rank order, highest to lowest number of responses):

- Training in AASHTOWare Pavement ME Design™ software functionality and operation (36 responses).
- Assistance with calibrating models to local conditions (36 responses).
- Dedicated website for sharing technical information (35 responses).
- Training in interpretation of results (33 responses).
- Training for obtaining inputs (32 responses).
- Training in ME design principles (29 responses).
- Training on how to modify pavement sections to meet design criteria (26 responses).
- Establishment of an expert task or user group (25 responses).
- Ability to share databases with other agencies (18 responses).

ABBREVIATIONS AND ACRONYMS

ACPA	American Concrete Pavement Association
ALF	Accelerated load facility
AVC	Automated vehicle classification
CIR	Cold in-place recycle
CRCP	Continuously reinforced concrete pavement
DOT	Department of transportation
FDR	Full-depth recycle
HIR	Hot in-place recycle
IRI	International Roughness Index
JPCP	Jointed plain concrete pavement
LTPP	Long Term Pavement Performance
ME	Mechanistic-empirical
MEPDG	AASHTO *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice*
WIM	Weigh-in-motion

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APPENDIX A
Questionnaire

Dear Survey Recipient,

The Transportation Research Board (TRB) is preparing a synthesis on Implementation of AASHTO *Mechanistic-Empirical Pavement Design Guide* (*MEPDG*) and software. This is being done for NCHRP, under the sponsorship of the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration.

The purpose of this questionnaire is to identify and summarize the implementation practices of highway agencies for the AASHTO *MEPDG* and accompanying software, AASHTOWare Pavement ME Design™ (formerly, DARWin-ME).

This survey is being sent to the pavement design engineer or the person who is leading or has led the *MEPDG*/AASHTOWare Pavement ME Design™ implementation effort for all state highway (including Puerto Rico and District of Columbia) and Canadian provincial and territorial agencies. <u>If you are not the appropriate person at your agency to complete this questionnaire, please forward it to the correct person.</u>

The results of the study will be incorporated into a synthesis of highway agency practice in the implementation of the *MEPDG* and AASHTOWare Pavement ME Design™ software. The synthesis will highlight agency practices and lessons learned, with the intent of aiding the implementation process for those agencies that have yet to or are in the process of implementing the *MEPDG*/AASHTOWare Pavement ME Design™ software.

<u>Please complete and submit this survey by February 8, 2013.</u> We estimate that it should take approximately 30 minutes to complete. If you have any questions or problems related to this questionnaire, please contact our principal investigator Dr. Linda Pierce at 505.796.6101 or lpierce@appliedpavement.com.

Questionnaire Instructions

- If you are unable to complete the questionnaire, you can return to the questionnaire at any time by reentering through the survey link as long as you access the questionnaire through the same computer. Reentering the survey will return you to the last completed question.
- If the survey requires completion by multiple people in your agency, each person should complete their portion of the survey. Once the survey is closed, the Principal Investigator will combine the surveys from each individual for a single agency response. If any discrepancies exist, the agency will be contacted for clarification.
- Survey navigation is conducted by selecting the "prev" (previous) or "next" button at the bottom of each page.

Thank you for your time and expertise in completing this important questionnaire.

Definitions

The following definitions are used in conjunction with this questionnaire:

- Agency districts/regions—this describes the different geographic areas of responsibility within a given agency.
- Agency division/section—this describes the various areas within a given agency and includes such divisions/sections as materials, construction, roadway design, planning, and maintenance.
- Catalog design—predetermined pavement thickness design table developed to simplify the pavement design process. Catalog designs generally include common traffic loading, environmental and/or subgrade conditions, and the corresponding recommended pavement layer (e.g., surfacing and base) thicknesses.
- Champion—a person responsible for and actively evaluating/implementing the AASHTO *MEPDG*/AASHTOWare Pavement ME Design™.
- Concurrent design—agency conducts the pavement design using both the agency's current pavement design procedure and the *MEPDG*/AASHTOWare Pavement ME Design™.
- CRCP—Continuously reinforced concrete pavement.
- Implementation—*MEPDG*/AASHTOWare Pavement ME Design™ (all or part) has been adopted for use in your agency.
- JPCP—Jointed plain concrete pavement.
- ME—mechanistic-empirical.
- Pavement ME Design™—accompanying AASHTOWare software for the *MEPDG*.
- PCC—portland cement concrete pavement.
- *MEPDG*—AASHTO *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice*.

General Information

1. Respondent details:
   Name: ____________________
   Title: ____________________
   Agency ____________________
   E-mail: ____________________
   Phone: ____________________

2. Which of the following new construction pavement types are used by your agency (select all that apply)?
   ☐ Thin asphalt (< 6.0 in.) over unbound aggregate
   ☐ Thick asphalt (> 6.0 in.) over unbound aggregate
   ☐ Asphalt over subgrade/stabilized subgrade
   ☐ Asphalt over cementitious stabilized layers (e.g., lime, lime-fly ash, cement)
   ☐ Composite pavements (new asphalt over new concrete)
   ☐ JPCP
   ☐ CRCP
   ☐ Others (please specify): ____________________

3. Which of the following preservation, restoration, and/or rehabilitation treatment types are used by your agency (select all that apply)?
   ☐ Asphalt overlay of an existing asphalt-surfaced pavement
   ☐ Mill and asphalt overlay of an existing asphalt-surfaced pavement
   ☐ Asphalt overlay of and existing concrete-surfaced pavement
   ☐ Mill and asphalt overlay of an existing composite (asphalt over concrete) pavement
   ☐ Bonded JPCP concrete overlay
   ☐ Unbonded JPCP concrete overlay
   ☐ Bonded CRCP overlay
   ☐ Unbonded CRCP overlay
   ☐ Hot in-place recycle without an asphalt overlay
   ☐ Hot in-place recycle with an asphalt overlay
   ☐ Cold in-place recycle without an asphalt overlay
   ☐ Cold in-place recycle with an asphalt overlay
   ☐ Full-depth reclamation without an asphalt overlay
   ☐ Full-depth reclamation with an asphalt overlay
   ☐ Crack or break and seat with an asphalt overlay
   ☐ Crack or break and seat with a concrete overlay
   ☐ Rubblization with an asphalt overlay
   ☐ Rubblization with a concrete overlay
   ☐ Dowel bar retrofit
   ☐ Diamond grinding
   ☐ Others (please specify): ____________________

4. Which pavement design method is used by your agency (select all that apply)?

	New Construction		**Rehabilitation**	
Method	**Asphalt**	**Concrete**	**Asphalt**	**Concrete**
AASHTO 1972	☐	☐	☐	☐
AASHTO 1986	☐	☐	☐	☐
AASHTO 1993	☐	☐	☐	☐
AASHTO 1998 Supplement	☐	☐	☐	☐
AASHTOWare Pavement ME Design™	☐	☐	☐	☐
Agency empirical procedure	☐	☐	☐	☐
American Concrete Pavement Association	☐	☐	☐	☐
Asphalt Institute	☐	☐	☐	☐
ME-based design table/catalog	☐	☐	☐	☐
Other ME procedure (please specify):	☐	☐	☐	☐
Other (please specify):	☐	☐	☐	☐

5. Does your agency intend on implementing the *MEPDG*/AASHTOWare Pavement ME Design™?
   ☐ No
   ☐ *MEPDG*/DARWin-ME has been implemented or is currently being evaluated (please skip to question 7)

6. You indicated your agency does not plan on implementing the *MEPDG*/AASHTOWare Pavement ME Design™, please identify why not (check all that apply)?
   - ☐ Current practice is acceptable
   - ☐ Limited availability of personnel
   - ☐ Limited knowledge/experience in mechanistic-empirical design
   - ☐ Limited support from upper management
   - ☐ Too costly
   - ☐ Too time-consuming
   - ☐ Waiting for more agencies to implement
   - ☐ Other (please specify): ______________________________

7. Has your agency or does your agency intend on implementing all or part of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?
   - ☐ New flexible pavement
   - ☐ New JPCP
   - ☐ New CRCP
   - ☐ Asphalt concrete overlay of existing flexible pavement
   - ☐ Asphalt concrete overlay of existing JPCP
   - ☐ Asphalt concrete overlay of existing CRCP
   - ☐ Asphalt concrete overlay of fractured JPCP
   - ☐ Asphalt concrete overlay of fractured CRCP
   - ☐ Bonded concrete overlay of existing JPCP
   - ☐ Bonded concrete overlay of existing CRCP
   - ☐ JPCP overlay of existing flexible pavement
   - ☐ CRCP overlay of existing flexible pavement
   - ☐ Unbonded JPCP overlay of existing JPCP
   - ☐ Unbonded JPCP overlay of existing CRCP
   - ☐ Unbonded CRCP overlay of existing JPCP
   - ☐ Unbonded CRCP overlay of existing CRCP
   - ☐ All of the above
   - ☐ If your agency has not or does not intend on implementing all pavement designs contained in the *MEPDG*/AASHTOWare Pavement ME Design™, could you please explain why?

8. If your agency has not yet implemented all or part of the *MEPDG*/AASHTOWare Pavement ME Design™, when do you intend on implementing?
   - ☐ Within 1 year
   - ☐ 1 to 2 years
   - ☐ 2 to 3 years
   - ☐ 4 to 5 years
   - ☐ Longer than 5 years
   - ☐ *MEPDG*/AASHTOWare Pavement ME Design™ has been implemented

Agency Organizational Information

9. Which of the following best describes your organizational structure related to pavement designs?
   - ☐ Centralized (pavement designs are conducted, reviewed, and approved by the central (headquarters) office).
   - ☐ Decentralized (pavement designs are conducted, reviewed, and approved at the district/region office).

10. Within your department, how effective is coordination across various agency functions (e.g., construction, design, maintenance, materials, pavement design, pavement management, planning, traffic, headquarters, and districts/regions)?
    - ☐ Consistent coordination across all agency functions (e.g., open discussion and access to data and information).
    - ☐ Limited coordination across all agency functions (e.g., we coordinate, but obtaining data and information can be challenging).
    - ☐ No coordination across all agency functions (e.g., no coordination/interaction).
    - ☐ Other (please specify): ______________________________

11. What additional work is required to justify implementing a new pavement design procedure (select all that apply)?
    - ☐ No additional work is required
    - ☐ Evaluate economic impact
    - ☐ Determine benefits over existing procedure
    - ☐ Evaluate applicability to current conditions
    - ☐ Establish an oversight committee to evaluate/approve the procedure
    - ☐ Develop an implementation plan
    - ☐ Develop a training plan
    - ☐ Obtain buy-in from other agency divisions
    - ☐ Obtain approval from upper management
    - ☐ Other (please specify): ______________________________

Data Availability for *MEPDG*/AASHTOWare Pavement ME Design™

12. Are your agency definitions for pavement distress similar to those defined in the FHWA *Distress Identification Manual for LTPP?*

Performance Indicator	Do Not Use	Yes	No
Smoothness (IRI)	☐	☐	☐
Asphalt pavements	☐	☐	☐
Longitudinal cracking	☐	☐	☐
Alligator cracking	☐	☐	☐
Thermal cracking	☐	☐	☐
Reflective cracking	☐	☐	☐
Rut depth	☐	☐	☐
JPCP	☐	☐	☐
Transverse cracking	☐	☐	☐
Joint faulting	☐	☐	☐
CRCP	☐	☐	☐
Punchouts	☐	☐	☐

13. Is the *MEPDG*/AASHTOWare Pavement ME Design™ related data readily available?

Data Availability	Not Available	Difficult to Obtain	Readily Available
Existing Pavement Structure (type and thickness)	☐	☐	☐
Material Properties	☐	☐	☐
Traffic	☐	☐	☐
Condition Data	☐	☐	☐

14. Is the *MEPDG*/AASHTOWare Pavement ME Design™ data available electronically?

Data Availability	Not Available	Difficult to Obtain	Readily Available
Existing Pavement Structure (type and thickness)	☐	☐	☐
Material Properties	☐	☐	☐
Traffic	☐	☐	☐
Condition Data	☐	☐	☐

Pavement Design Development

15. What division/section is responsible for developing pavement designs?
☐ Design Office
☐ Maintenance Office
☐ Materials Office
☐ Planning Office
☐ Research Office
☐ Other (please specify): ______________________________

16. Who in your agency conducts the pavement design (select all that apply)?
☐ Engineer
☐ Licensed Engineer
☐ Technician
☐ Consultant
☐ Other (please specify): ______________________________

17. Does your agency require the consultant to use the AASHTOWare Pavement ME Design™?
☐ Yes
☐ No specific procedure is required
☐ Required design procedure includes (please specify): ______________________________

18. Are all *MEPDG*/AASHTOWare Pavement ME Design™ data inputs made available to the consultant (e.g., traffic information, material properties, calibration coefficients)?
☐ Yes
☐ No

19. Which position approves the recommended pavement design (select all that apply)?
☐ District/Region Engineer
☐ Planning Director

☐ Research Director
☐ State Design Engineer
☐ State Maintenance Engineer
☐ State Materials Engineer
☐ State Pavement Engineer
☐ Other (please specify): ____________________

***MEPDG*/AASHTOWare Pavement ME Design™ Implementation Process**

20. For the personnel conducting the *MEPDG*/AASHTOWare Pavement ME Design™, what was their level of expertise in mechanistic-empirical practices/procedures during the evaluation/implementation process?
    ☐ No knowledge/experience
    ☐ Limited knowledge/experience (e.g., had heard of it, but was not very familiar with the details of AASHTOWare Pavement ME Design™)
    ☐ Somewhat knowledgeable/experienced (e.g., had been exposed to AASHTOWare Pavement ME Design™ procedures via webinars, papers/reports, training classes, and conferences)
    ☐ Very knowledgeable/experienced (e.g., had conducted ME designs)
    ☐ Other (please specify): ____________________

21. What were the deciding factors for implementing the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?
    ☐ Improved reliability in prediction of pavement condition
    ☐ Potential cost savings
    ☐ Evaluation of local materials
    ☐ Evaluation of new materials
    ☐ Evaluation of local traffic conditions
    ☐ Evaluation of special loading conditions (e.g., dedicated haul road, overload)
    ☐ Ability to model the effects of climate and materials aging
    ☐ Improved characterization of existing pavement layer parameters
    ☐ Improved link to pavement management
    ☐ Other (please specify): ____________________

22. What activities would aid in the *MEPDG*/AASHTOWare Pavement ME Design™ implementation effort (select all that apply)?
    ☐ Dedicated *MEPDG*/AASHTOWare Pavement ME Design™ website for sharing technical information
    ☐ Ability to share AASHTOWare Pavement ME Design™ databases with other agencies
    ☐ Training in ME design principles
    ☐ Training in methodology for obtaining *MEPDG*/AASHTOWare Pavement ME Design™ inputs
    ☐ Training in AASHTOWare Pavement ME Design™
    ☐ Training in how to modify pavement sections to meet design criteria
    ☐ Training in interpretation of AASHTOWare Pavement ME Design™ software results
    ☐ Assistance with calibrating models to local conditions
    ☐ Establishment of an expert task or user group
    ☐ Other (please specify): ____________________

23. Is there an *MEPDG*/AASHTOWare Pavement ME Design™ champion in your agency?
    ☐ No
    ☐ Yes

24. Please identify champion's position within the agency (select all that apply)
    ☐ District/Region Engineer
    ☐ Planning Director
    ☐ Research Director
    ☐ State Design Engineer
    ☐ State Maintenance Engineer
    ☐ State Materials Engineer
    ☐ State Pavement Design Engineer
    ☐ State Pavement Engineer
    ☐ Other (please specify): ____________________

25. Does your agency have an oversight/review committee that assists in the implementation process (e.g., determined what/when/how to implement)?
    ☐ No
    ☐ Yes

26. Please identify members of the oversight/review committee
    ☐ District/Region Engineer
    ☐ Planning Director

☐ Research Director
☐ State Design Engineer
☐ State Maintenance Engineer
☐ State Materials Engineer
☐ State Pavement Design Engineer
☐ State Pavement Engineer
☐ Other (please specify): ____________________

27. Prior to adoption or implementation, who was involved in the evaluation of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?
☐ Construction Office
☐ Design Office
☐ Maintenance Office
☐ Materials Office
☐ Planning Office
☐ Pavement Design Engineer
☐ Pavement Management Engineer
☐ Research Office
☐ Traffic Office
☐ Other (please specify): ____________________

28. Whose buy-in was required to implement the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?
☐ Chief Engineer
☐ District/Region Engineer
☐ Legislature
☐ Pavement Oversight Committee
☐ Pavement Design Engineer
☐ Pavement Director
☐ Planning Director
☐ Research Director
☐ Secretary of Transportation
☐ State Design Engineer
☐ State Maintenance Engineer
☐ State Materials Engineer
☐ State Pavement Engineer
☐ Transportation Commission
☐ Other (please specify): ____________________

29. Once the technical decisions were made to implement the *MEPDG*/AASHTOWare Pavement ME Design™, were there any additional decisions/efforts required prior to adoption?
☐ No
☐ Yes

30. Select additional decisions/efforts required prior to adoption (select all that apply).
☐ Acceptance/evaluation by the information technology (IT) department
☐ Address local agency concerns
☐ Address industry concerns
☐ Agency vote
☐ Other (please specify): ____________________

31. Which pavement types (by functional class) will be or have been evaluated using the *MEPDG* (select all that apply)? Note that by selecting a row containing "All" implies that the subset rows are included.

Pavement Type	Do Not Use	All Functional Classes	Local Roads	Collectors	Minor Arterials	Principal Arterials	Interstates
All new designs	☐	☐	☐	☐	☐	☐	☐
Asphalt	☐	☐	☐	☐	☐	☐	☐
JPCP	☐	☐	☐	☐	☐	☐	☐
CRCP	☐	☐	☐	☐	☐	☐	☐
Other (please specify):	☐	☐	☐	☐	☐	☐	☐
All overlay designs	☐	☐	☐	☐	☐	☐	☐
Asphalt over asphalt	☐	☐	☐	☐	☐	☐	☐
Asphalt over JPCP	☐	☐	☐	☐	☐	☐	☐
Asphalt over CRCP	☐	☐	☐	☐	☐	☐	☐

Asphalt over JPCP (fractured)	☐	☐	☐	☐	☐	☐	☐
Asphalt over CRCP (fractured)	☐	☐	☐	☐	☐	☐	☐
Bonded PCC/JPCP	☐	☐	☐	☐	☐	☐	☐
Bonded PCC/CRCP	☐	☐	☐	☐	☐	☐	☐
JPCP over JPCP (unbonded)	☐	☐	☐	☐	☐	☐	☐
JPCP over CRCP (unbonded)	☐	☐	☐	☐	☐	☐	☐
CRCP over JPCP (unbonded)	☐	☐	☐	☐	☐	☐	☐
CRCP over CRCP (unbonded)	☐	☐	☐	☐	☐	☐	☐
JPCP over asphalt	☐	☐	☐	☐	☐	☐	☐
CRCP over asphalt	☐	☐	☐	☐	☐	☐	☐
Other (please specify):	☐	☐	☐	☐	☐	☐	☐
Restoration	☐	☐	☐	☐	☐	☐	☐
JPCP restoration	☐	☐	☐	☐	☐	☐	☐
Other (please specify):	☐	☐	☐	☐	☐	☐	☐

32. What level of input has been adopted for each of the following (select all that apply)? Note that by selecting a row containing "All" implies that all subset rows are included.

Input	Do Not Use	Default Value	Regional Value	Site-Specific Value
All traffic	☐	☐	☐	☐
Vehicle class distribution	☐	☐	☐	☐
Hourly adjustment factors	☐	☐	☐	☐
Monthly adjustment factors	☐	☐	☐	☐
Axles per truck	☐	☐	☐	☐
Axle configuration	☐	☐	☐	☐
Lateral wander	☐	☐	☐	☐
Wheelbase	☐	☐	☐	☐
All materials	☐	☐	☐	☐
All asphalt layers	☐	☐	☐	☐
Mixture volumetrics	☐	☐	☐	☐
Mechanical properties	☐	☐	☐	☐
Thermal properties	☐	☐	☐	☐
Asphalt surface layers only	☐	☐	☐	☐
Mixture volumetrics	☐	☐	☐	☐
Mechanical properties	☐	☐	☐	☐
Thermal properties	☐	☐	☐	☐
Asphalt base layers only	☐	☐	☐	☐
Mixture volumetrics	☐	☐	☐	☐
Mechanical properties	☐	☐	☐	☐
Thermal properties	☐	☐	☐	☐
All concrete layers	☐	☐	☐	☐
Poisson's ratio	☐	☐	☐	☐
Unit weight	☐	☐	☐	☐
Thermal	☐	☐	☐	☐
Mix	☐	☐	☐	☐
Strength	☐	☐	☐	☐
All chemically stabilized layers	☐	☐	☐	☐
Poisson's ratio	☐	☐	☐	☐
Unit weight	☐	☐	☐	☐
Strength	☐	☐	☐	☐
Thermal	☐	☐	☐	☐
All sandwiched granular layers	☐	☐	☐	☐
Poisson's ratio	☐	☐	☐	☐
Unit weight	☐	☐	☐	☐
Strength	☐	☐	☐	☐
Thermal properties	☐	☐	☐	☐
All non-stabilized base layers	☐	☐	☐	☐
Poisson's ratio	☐	☐	☐	☐
Modulus	☐	☐	☐	☐
Sieve analysis	☐	☐	☐	☐

All subgrade layers	☐	☐	☐	☐
Poisson's ratio	☐	☐	☐	☐
Modulus	☐	☐	☐	☐
Sieve analysis	☐	☐	☐	☐
All bedrock layers	☐	☐	☐	☐
Poisson's ratio	☐	☐	☐	☐
Unit weight	☐	☐	☐	☐
Strength	☐	☐	☐	☐

33. Does your agency use nationally or locally calibrated prediction models (select all that apply)? Note that by selecting a row containing "All" implies that all subset rows are included.

Model	**Do Not Use**	**National Calibration**	**Local Calibration**	**Plans for Local Calibration/ Verification**
All asphalt models	☐	☐	☐	☐
IRI	☐	☐	☐	☐
Longitudinal cracking	☐	☐	☐	☐
Alligator cracking	☐	☐	☐	☐
Thermal cracking	☐	☐	☐	☐
Rutting (asphalt layer only)	☐	☐	☐	☐
Rutting (total)	☐	☐	☐	☐
Reflective cracking	☐	☐	☐	☐
All JPCP models	☐	☐	☐	☐
IRI	☐	☐	☐	☐
Transverse cracking	☐	☐	☐	☐
Joint faulting	☐	☐	☐	☐
All CRCP models	☐	☐	☐	☐
IRI	☐	☐	☐	☐
Punchouts	☐	☐	☐	☐

34. Where has your agency focused the implementation effort (select all that apply)?
☐ Materials characterization
☐ Traffic
☐ Climate
☐ Identification of existing pavement layers
☐ Performance prediction of existing pavement structure
☐ Local calibration
☐ Training
☐ Other (please specify): ______________________________

35. Has your agency developed/conducted any of the following (select all that apply)?

Feature	**In-house**	**Consultant**	**Academia**
Implementation plan	☐	☐	☐
Training materials	☐	☐	☐
Agency-specific user manual	☐	☐	☐
Concurrent designs	☐	☐	☐
Materials library	☐	☐	☐
Traffic library	☐	☐	☐
Pavement performance library	☐	☐	☐
Model validation	☐	☐	☐
Catalog designs	☐	☐	☐
Test sites	☐	☐	☐
Review group/committee	☐	☐	☐
Comparison of impact due to differences between agency and LTPP distress definitions	☐	☐	☐

Other (please specify): ______________________________

36. If yes, and you checked any of the boxes above and your agency is willing to share this information, please add the URL where it can be accessed, attach the document to this survey, or e-mail Dr. Pierce at lpierce@appliedpavement.com so she can make arrangements to obtain a copy.

37. What type of *MEPDG*/AASHTOWare Pavement ME Design™ training program is available for your agency's personnel (select all that apply)?
☐ None
☐ Agency-developed training program
☐ Consultant conducted training
☐ NHI training
☐ Self-taught
☐ Self-taught with champion or supervisor oversight
☐ University developed classes
☐ Other (please specify): ______________________________

38. What, if any, issues have impeded the implementation of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?
☐ No issues
☐ Availability of pavement performance data
☐ Availability of traffic data
☐ Availability of materials data/materials characterization
☐ Availability of information related to the existing pavement structure
☐ Funding restrictions
☐ Limited time available
☐ No designated champion
☐ Resistance to change from current procedures
☐ Justification of benefits for implementing more advanced procedure
☐ Additional issues (please specify below)

39. What benefits has your agency accrued due to implementation of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?
☐ Has not yet been quantified
☐ Improved reliability of design recommendations
☐ Improved characterization of local materials
☐ Improved characterization of existing pavement layers
☐ Improved characterization of traffic
☐ Improved confidence in distress prediction
☐ More economical designs

40. Indicate cost savings.
______________$/mile and/or
______________$/year

41. Please provide any challenges or lessons learned during the evaluation and implementation of the *MEPDG*/AASHTOWare Pavement ME Design™.

42. What insight have you gained that can be shared with other agencies to ease the implementation effort (e.g., calibration of a particular model was not needed, traffic characterization by functional class was appropriate)?

43. What has your agency spent on implementation?
☐ Nothing, besides the cost of the software license
☐ < $100,000
☐ $100,000 to $500,000
☐ $500,000 to $1,000,000
☐ $1,000,000 to $2,000,000
☐ > $2,000,000

44. What has your agency spent on calibration?
☐ Nothing
☐ < $100,000
☐ $100,000 to $500,000
☐ $500,000 to $1,000,000
☐ $1,000,000 to $2,000,000
☐ > $2,000,000

45. What year did the implementation process begin?

46. What year did you complete implementation?

47. Do you have any reports, memos, internal documentation, or other comments you would like to share regarding implementation of the *MEPDG*/AASHTOWare Pavement ME Design™?

APPENDIX B

Responses to Questionnaire

1. Responding agencies.

   Reponses to the questionnaire were received from forty-seven U.S. highway agencies and nine Canadian provinces (or a 90% response rate). The agencies that responded to the survey include:

- Alabama DOT
- Alaska DOT & Public Facilities
- Alberta Transportation
- Arizona DOT
- Arkansas Highway & Transportation Department
- British Columbia Ministry of Transportation and Infrastructure
- California DOT
- Colorado DOT
- Connecticut DOT
- Delaware DOT
- Florida DOT
- Georgia DOT
- Hawaii DOT
- Idaho TD
- Illinois DOT
- Indiana DOT
- Iowa DOT
- Kansas DOT
- Kentucky Transportation Cabinet
- Louisiana Department of Transportation & Development
- Maine DOT
- Manitoba Infrastructure & Transportation
- Maryland State Highway Administration
- Massachusetts DOT
- Michigan DOT
- Minnesota DOT
- Mississippi DOT
- Missouri DOT
- Montana DOT
- Nevada DOT
- New Brunswick Department of Transportation & Infrastructure
- New Hampshire DOT
- New Jersey DOT
- New Mexico DOT
- New York DOT
- North Carolina DOT
- North Dakota DOT
- North West Territories
- Ohio DOT
- Oklahoma DOT
- Ontario Ministry of Transportation
- Oregon DOT
- Pennsylvania DOT
- Prince Edward Island Transportation and Infrastructure Renewal
- Puerto Rico Highway & Transportation Authority
- Quebec Ministere des Transports
- Saskatchewan Highways & Infrastructure
- South Carolina DOT
- South Dakota DOT
- Tennessee DOT
- Texas DOT
- Vermont DOT
- Virginia DOT
- Washington State DOT
- West Virginia DOT
- Wisconsin DOT

2. Which new construction pavement types are used by your agency?

Answer Options	Response Percent	Response Count
Thick asphalt (>6.0 in.) over unbound aggregate	80.7	46
Jointed plain concrete pavement (JPCP)	77.2	44
Thin asphalt (6.0 in.) over unbound aggregate	71.9	41
Asphalt over cementitious stabilized layers	50.9	29
Asphalt over subgrade/stabilized subgrade	36.8	21
Composite pavements (new asphalt over new concrete)	31.6	18
Continuously reinforced concrete pavement (CRCP)	15.8	9
Other[1]	28.1	16

[1]Predominant response—chip seal over unbound/bound layer(s).

3. Which preservation, restoration, and/or rehabilitation treatment types are used by your agency?

Answer Options	Response Percent	Response Count
Asphalt overlay of an existing asphalt-surfaced pavement	94.7	54
Mill and asphalt overlay of an existing asphalt-surfaced pavement	89.5	51
Diamond grinding	77.2	44
Asphalt overlay of an existing concrete-surfaced pavement	73.7	42
Mill and asphalt overlay of an existing composite (asphalt over concrete) pavement	61.4	35
Rubblization with an asphalt overlay	61.4	35
Full-depth reclamation with an asphalt overlay	59.6	34

Answer Options	Response Percent	Response Count
Dowel bar retrofit	59.6	34
Cold in-place recycle with an asphalt overlay	50.9	29
Unbonded JPCP concrete overlay	47.4	27
Crack or break and seat with an asphalt overlay	36.8	21
Other[1]	24.6	14
Hot in-place recycle without an asphalt overlay	19.3	11
Bonded JPCP concrete overlay	17.5	10
Hot in-place recycle with an asphalt overlay	17.5	10
Rubblization with a concrete overlay	15.8	9
Full-depth reclamation without an asphalt overlay	14.0	8
Cold in-place recycle without an asphalt overlay	12.3	7
Unbonded CRCP overlay	10.5	6
Crack or break and seat with a concrete overlay	7.0	4
Bonded CRCP overlay	3.5	2

[1]Responses included: rubblization, microsurfacing, chip seal and gravel overlays, asphalt overlay and geogrid, ultra-thin bonded asphalt overlay, asphalt rubber open-graded friction course, full- and partial-depth concrete repair, tie bar retrofit, crack sealing, joint resealing.

4. Which pavement design methodology is used by your agency?

	New Construction		Rehabilitation	
Answer Options	Asphalt	Concrete	Asphalt	Concrete
AASHTO 1972	7	2	5	1
AASHTO 1986	1	0	2	0
AASHTO 1993	35	23	31	19
AASHTO 1998 Supplement	4	11	4	8
AASHTOWare Pavement ME Design™	12	10	10	7
ACPA	—	5	—	4
Agency empirical procedure	7	1	9	3
Asphalt Institute	1	—	3	—
ME-based design table/catalog	1	3	0	3
Other ME procedure[1]	8	3	6	2
Other[2]	5	7	7	8

[1]Texas CRCP-ME and FPS21, Idaho Winflex, WSDOT Everpave, Dynatest ELMOD, Illinois DOT ME, Kentucky ME, Colorado thin bonded overlay, Alaska flexible ME, CalME, Shell ME, MnPAVE.
[2]1981 revision of AASHTO 1972, Westergaard equation, Caltran's design methodology, PCA 1984.

5. Does your agency intend on implementing the *MEPDG*/AASHTOWare Pavement ME Design™?

Answer Options	Response Percent	Response Count
MEPDG/AASHTOWare Pavement ME Design™ has been implemented	5.3	3
MEPDG/AASHTOWare Pavement ME Design™ is being evaluation	80.7	46
No	14.0	8

6. You indicated your agency does not plan on implementing the *MEPDG*/AASHTOWare Pavement ME Design™, please identify why not?

Answer Options	Response Percent	Response Count
Current practice is acceptable	8.8	5
Other[1]	5.3	3
Too costly	5.3	3
Waiting for more agencies to implement	5.3	3

Answer Options	Response Percent	Response Count
Limited availability of personnel	1.8	1
Limited support from upper management	1.8	1
Too time consuming	1.8	1
Limited knowledge/experience in mechanistic-empirical design	0.0	0

[1]Do not agree with much of the modeling, too many bugs, too costly to implement at this time, and pavement performance not accurately predicted for asphalt pavements.

7. Has your agency or does your agency intend on implementing all or part of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?

Answer Options	Response Percent	Response Count
New flexible pavement	82.5	47
New JPCP	71.9	41
Asphalt overlay of existing asphalt pavement	70.2	40
Asphalt overlay of existing JPCP	63.2	36
Asphalt overlay of fractured JPCP	50.9	29
Unbonded JPCP overlay of existing JPCP	42.1	24
JPCP overlay of existing asphalt pavement	40.4	23
Asphalt overlay of existing CRCP	29.8	17
Bonded concrete overlay of existing JPCP	26.3	15
New CRCP	24.6	14
Asphalt overlay of fractured CRCP	22.8	13
Unbonded JPCP overlay of existing CRCP	22.8	13
CRCP overlay of existing asphalt pavement	15.8	9
Unbonded CRCP overlay of existing JPCP	15.8	9
Bonded concrete overlay of existing CRCP	14.0	8
Unbonded CRCP overlay of existing CRCP	14.0	8
If your agency has not or does not intend on implementing all pavement designs contained in the *MEPDG*/AASHTOWare Pavement ME Design™, could you please explain why?[1]	22.8	13

[1]In the process of evaluating the *MEPDG*, lack of dedicated resources, not all pavement types are used, current practice is acceptable, limited knowledge/experience in ME design, too costly, traffic volumes are not that high, problems with the asphalt rutting model and longitudinal cracking model, issues with longitudinal and alligator cracking or longitudinal cracking for JPCP, poor experience with some design types.

8. If your agency has not yet implemented all or part of the *MEPDG*/AASHTOWare Pavement ME Design™, when do you intend on implementing?

Answer Options	Response Percent	Response Count
Within 1 year	10.5	6
1 to 2 years	15.8	9
2 to 3 years	26.3	15
4 to 5 years	14.0	8
Longer than 5 years	8.8	5
MEPDG/AASHTOWare Pavement ME Design™ has been implemented	5.3	3

9. Which of the following best describes your organizational structure related to pavement designs?

Answer Options	Response Percent	Response Count
Centralized—Pavement designs are conducted, reviewed, and approved by the central/headquarters office.	57.9	33
Decentralized—Pavement designs are conducted, reviewed, and approved at the district/regional office.	22.8	13

10. Within your department, how effective is coordination across various agency functions?

Answer Options	Response Percent	Response Count
Consistent coordination across all agency functions (e.g., open discussion and access to data and information).	45.6	26
Limited coordination across all agency functions (e.g., we coordinate, but obtaining data and information can be challenging).	33.3	19
No coordination across all agency functions (e.g., no coordination/interaction).	0	0
Other[1]	3.5	2

[1]Review of major project pavement designs by committee, and consistent coordination between some agency functions.

11. What additional work is required to justify implementing a new pavement design procedure (select all that apply)?

Answer Options	Response Percent	Response Count
Determine benefits over existing procedure	49.1	28
Develop a training plan	43.9	25
Develop an implementation plan	42.1	24
Evaluate applicability to current conditions	36.8	21
Obtain approval from upper management	29.8	17
No additional work is required	19.3	11
Evaluate economic impact	17.5	10
Establish an oversight committee to evaluate/approve the procedure	14.0	8
Obtain buy-in from other agency divisions	8.8	5
Other (please specify)	14.0	8

[1]Review of major project pavement designs by committee, and consistent coordination between some agency functions.

12. Are your agency definitions for pavement distress similar to those defined in the FHWA Distress Identification Manual for LTPP?

Answer Options	Do Not Use	Yes	No	Response Count
Smoothness (IRI)	2	40	3	45
Asphalt Pavements	1	24	3	28
Longitudinal cracking	7	32	3	42
Alligator cracking	0	36	6	42
Thermal cracking	4	28	8	40
Reflective cracking	6	30	6	42
Rut depth	0	38	5	43
JPCP	2	18	3	23
Transverse cracking	2	35	3	40
Joint faulting	4	33	4	40
CRCP	6	11	2	19
Punchouts	14	15	2	31

13. Is the necessary *MEPDG*/AASHTOWare Pavement ME Design™ related data readily available?

Answer Options	Not Available	Difficult to Obtain	Readily Available	Response Count
Existing Structure (type & thickness)	3	13	31	47
Material Properties	4	25	17	46
Traffic	2	16	28	46
Condition Data	4	10	32	46

14. Is the *MEPDG*/AASHTOWare Pavement ME Design™ data available electronically?

Answer Options	No	Division/Section Only	Agency-wide	Response Count
Existing Structure (type & thickness)	15	21	10	46
Material Properties	17	27	2	46
Traffic	10	16	20	46
Condition Data	11	12	23	46

15. What division/section is responsible for developing pavement designs?

Answer Options	Response Percent	Response Count
Design Office	35.1	20
Materials Office	28.1	16
Maintenance Office	1.8	1
Planning Office	0.0	0
Research Office	0.0	0
Other[1]	17.5	10

[1]Pavement management division, district/region office, geotechnical section, materials office, and consultant.

16. Who in your agency conducts the pavement design (select all that apply)?

Answer Options	Response Percent	Response Count
Licensed Engineer	54.4	31
Engineer	50.9	29
Consultant	42.1	24
Technician	12.3	7
Other[1]	5.3	3

[1]Licensed pavement management engineer, and roadway designers.

17. Does your agency require the consultant to use the AASHTOWare Pavement ME Design™?

Answer Options	Response Percent	Response Count
Procedure other than AASHTOWare Pavement ME Design™ is required	28.1	16
AASHTOWare Pavement ME Design™ is required	3.5	2
No specific procedure is required	10.5	6

18. Are all *MEPDG*/AASHTOWare Pavement ME Design™ data inputs made available to the consultant?

Answer Options	Response Percent	Response Count
No	19.3	11
Yes	17.5	10

19. Which position approves the recommended pavement design (select all that apply)?

Answer Options	Response Percent	Response Count
State Pavement Engineer	38.6	22
District/Region Engineer	24.6	14
State Materials Engineer	14.0	8
State Design Engineer	8.8	5
Planning Director	1.8	1

Answer Options	Response Percent	Response Count
Research Director	0.0	0
State Maintenance Engineer	0.0	0
Other[1]	29.8	17

[1]Construction engineer, FHWA Division on federal projects, committee approval, Design Director, Assistant Executive Director for Infrastructure, district office, Planning/Engineering Director, Transportation Engineer Specialist, project committee, no formal approval.

20. For the personnel conducting the *MEPDG*/AASHTOWare Pavement ME Design™, what was their level of expertise in mechanistic-empirical practices/procedures during the evaluation/implementation process?

Answer Options	Response Percent	Response Count
Somewhat knowledgeable/experienced (e.g., had been exposed to ME design procedures via webinars, papers/reports, training classes, and conferences)	50.9	29
Very knowledgeable/experienced (e.g., had conducted ME designs)	7.0	4
Limited knowledge/experience (e.g., had heard of it, but was not very familiar with the details of ME design)	5.3	3
No knowledge/experience	0.0	0
Other[1]	14.0	8

[1]Still evaluating, no formal designs being conducted, between "somewhat" and "very experienced," and not currently using *MEPDG*.

21. What were the deciding factors for implementing the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?

Answer Options	Response Percent	Response Count
Improved characterization of existing pavement layer parameters	57.9	33
Potential cost savings	49.1	28
Evaluation of local materials	49.1	28
Improved reliability in prediction of pavement condition	47.4	27
Ability to model the effects of climate and materials aging	45.6	26
Evaluation of new materials	40.4	23
Evaluation of local traffic conditions	35.1	20
Evaluation of special loading conditions (e.g., dedicated haul road, overload)	31.6	18
Improved link to pavement management	24.6	14
Other[1]	24.6	14

[1]Forensic investigations, still evaluating, *MEPDG* not implemented, no support for DARWin AASHTO 93, utilizing the latest in the "State of the Practice," improved materials characterization.

22. What activities would aid in the *MEPDG*/AASHTOWare Pavement ME Design™ implementation effort (select all that apply)?

Answer Options	Response Percent	Response Count
Training in AASHTOWare Pavement ME Design™	61.4	35
Assistance with calibrating models to local conditions	61.4	35
Dedicated *MEPDG*/AASHTOWare Pavement ME Design™ website for sharing technical information	59.6	34
Training in interpretation of AASHTOWare Pavement ME Design™ results	56.1	32
Training for obtaining *MEPDG*/AASHTOWare Pavement ME Design™ inputs	54.4	31
Training in ME design principles	49.1	28
Training in how to modify pavement sections to meet design criteria	43.9	25
Establishment of an expert task or user group	42.1	24
Ability to share AASHTOWare Pavement ME Design™ databases with other agencies	29.8	17
Other[1]	15.8	9

[1]Training in how to model non-standard materials, reduced software cost, full confidence in models, a message board for getting advice, and bouncing ideas off of other designers (could be part of design website or user group mentioned above), connecting the Canadian user group with an American user group, training on how to continuously calibrate with pavement materials and pavement management data.

23. Is there an *MEPDG* champion in your agency?

Answer Options	Response Percent	Response Count
Yes	57.9	33
No	22.8	13

24. Please identify champion's position within the agency (select all that apply).

Answer Options	Response Percent	Response Count
State Pavement Engineer	19.3	11
State Pavement Design Engineer	15.8	9
State Materials Engineer	7.0	4
State Design Engineer	1.8	1
Research Director	0.0	0
District/Region Engineer	0.0	0
Planning Director	0.0	0
State Maintenance Engineer	0.0	0
Other[1]	24.6	14

[1]Pavement design committee, State/Pavement Research Engineer/Manager, Design, Materials, and/or Construction Engineer, Pavement Design Coordinator, Pavement Director, Assistant Highway Program Manager, Geotechnical Engineer, Chief Engineer, Pavement Structure Engineer.

25. Does your agency have an oversight/review committee that assists in the implementation process (e.g., determined what/when/how to implement)?

Answer Options	Response Percent	Response Count
No	26	55
Yes	21	45

26. Please identify members of the oversight/review committee.

Answer Options	Response Percent	Response Count
State Pavement Design Engineer	68.2	15
State Materials Engineer	54.5	12
State Pavement Engineer	40.9	9
District/Region Engineer	27.3	6
Research Director	22.7	5
Planning Director	4.5	1
State Design Engineer	0.0	0
State Maintenance Engineer	0.0	0
Other[1]	63.6	14

[1]Design, Materials, and/or Construction Engineer, Assistant Chief Engineer, Traffic Engineer, FHWA, Geotechnical Engineer, Concrete and Asphalt Engineers, Pavement Management Engineer, Research Engineer/Director/Manager, Field Engineer, Industry, ME Design team (Materials, Pavement, and Geotechnical Engineers), and region/district pavement designers.

27. Prior to adoption or implementation, who was involved in the evaluation of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?

Answer Options	Response Percent	Response Count
Materials Office	69.6	32
Pavement Design Engineer	63.0	29
Research Office	41.3	19
Pavement Management Engineer	37.0	17

Answer Options	Response Percent	Response Count
Design Office	26.1	12
Traffic Office	23.9	11
Planning Office	8.7	4
Construction Office	4.3	2
Maintenance Office	4.3	2
Other[1]	34.8	16

[1]Final decision not yet made, *MEPDG* not implemented yet, Chief Engineer, Rutgers University, Geotechnical Office, Pavement Design Coordinator, traffic, materials and pavements will all be involved in future implementation, and Consultant and Industry representatives.

28. Whose buy-in was required to implement the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?

Answer Options	Response Percent	Response Count
Chief Engineer	55.3	26
State Pavement Engineer	40.4	19
Pavement Design Engineer	36.2	17
State Materials Engineer	29.8	14
State Design Engineer	17.0	8
District/Region Engineer	14.9	7
Pavement Oversight Committee	14.9	7
Pavement Director	12.8	6
Research Director	8.5	4
Legislature	2.1	1
Planning Director	2.1	1
Secretary of Transportation	2.1	1
Transportation Commission	2.1	1
State Maintenance Engineer	0.0	0
Other[1]	42.6	20

[1]Director of Technical Services, Geotechnical Engineer, Pavement Management Engineer, Industry, consensus of materials office and pavement section, Deputy Secretary, not implemented or under evaluation, IT, Project Planning Director, Chief Engineer, Operations Director, Commissioner, State Construction and Materials Engineer, and local FHWA Division.

29. Once the technical decisions were made to implement the *MEPDG*/AASHTOWare Pavement ME Design™, were there any additional decisions/efforts required prior to adoption?

Answer Options	Response Percent	Response Count
No	52.5	21
Yes	47.5	19

30. Select additional decisions/efforts required prior to adoption (select all that apply)

Answer Options	Response Percent	Response Count
Acceptance/evaluation by the information technology (IT) department	50.0	12
Address industry concerns	45.8	11
Address local agency concerns	4.2	1
Agency vote	0.0	0
Other[1]	45.8	11

[1]Rigorous calibration effort, software application for rehabilitation treatments and new construction, expense of license, design inputs (e.g., traffic, materials), how our business processes need to change in order to produce a design (e.g., requesting and delivering traffic inputs and the processes of iterative design—what can be changed, when the design is complete), Treasury Board approval for spending funds, what type of output do we get, is it realistic, and will it get the buy in needed internally and externally, a traffic study, and a study to provide very limited dynamic modulus curves.

31. Which pavement types (by functional class) will be or have been evaluated using the *MEPDG* (select all that apply)? Note that by selecting a row containing "All" implies that the subset rows are included.

Answer Options	Do Not Use	All Functional Classes	Local Road	Collector	Minor Arterial	Principal Arterial	Interstate	Response Count
All new designs	3	7	2	6	5	9	8	17
Asphalt	1	20	2	7	8	16	15	33
JPCP	1	16	0	5	6	14	14	30
CRCP	13	1	0	1	1	2	2	16
All overlay designs	4	6	0	3	3	5	6	15
Asphalt over Asphalt	1	20	0	2	5	14	15	33
Asphalt over JPCP	3	14	0	2	2	11	11	27
Asphalt over CRCP	10	4	0	1	1	3	3	17
Asphalt over JPCP (fractured)	4	13	0	2	2	7	7	24
Asphalt over CRCP (fractured)	10	2	0	1	1	1	1	13
Bonded PCC/JPCP	8	5	0	0	0	3	3	16
Bonded PCC/CRCP	12	1	0	0	0	1	1	14
JPCP over JPCP (unbonded)	5	6	0	1	1	7	8	19
JPCP over CRCP (unbonded)	10	1	0	0	0	2	3	14
CRCP over JPCP (unbonded)	13	0	0	0	0	0	0	13
CRCP over CRCP (unbonded)	13	0	0	0	0	0	0	13
JPCP over Asphalt	2	7	0	1	1	8	6	17
CRCP over Asphalt	12	1	0	0	0	0	0	13
Restoration	8	1	0	1	1	1	1	10
JPCP restoration	3	9	0	3	4	5	6	17
Other[1]								13

[1]Full-depth reclamation.

32. What level of input has been adopted for each of the following (select all that apply)? Note that by selecting a row containing "All" implies that all subset rows are included.

Answer Options	Do Not Use	Default Value	Regional Value	Site-specific Value	Response Count
All traffic	4	4	10	5	18
Vehicle class distribution	0	5	13	16	23
Hourly adjustment factors	1	12	10	3	22
Monthly adjustment factors	0	12	13	4	23
Axles per truck	0	15	9	5	23
Axle configuration	0	18	3	2	23
Lateral wander	1	16	5	1	23
Wheelbase	0	19	2	1	22
All materials	5	1	7	3	12
All asphalt layers	3	2	8	4	15
Mixture volumetrics	0	3	18	6	21
Mechanical properties	0	7	14	5	21
Thermal properties	0	16	4	0	19
Asphalt surface layers only	4	1	4	3	10
Mixture volumetrics	0	3	14	7	18
Mechanical properties	0	7	11	5	18
Thermal properties	0	12	4	0	16
Asphalt base layers only	3	0	4	4	10

Answer Options	Do Not Use	Default Value	Regional Value	Site-specific Value	Response Count
Mixture volumetrics	0	4	15	7	19
Mechanical properties	0	9	11	5	19
Thermal properties	0	11	4	0	15
All concrete layers	4	5	8	1	17
Poisson's ratio	0	17	4	2	20
Unit weight	0	9	13	6	20
Thermal	0	14	4	3	19
Mix	0	4	13	9	19
Strength	0	4	14	8	19
All chemically stabilized layers	8	4	6	1	18
Poisson's ratio	1	10	2	4	16
Unit weight	1	5	7	4	16
Strength	1	4	9	5	17
Thermal	1	13	0	1	15
All sandwiched granular layers	7	3	7	2	18
Poisson's ratio	2	11	2	4	17
Unit weight	2	6	9	4	17
Strength	2	6	9	6	17
Thermal properties	2	12	1	2	14
All non-stabilized base layers	4	3	6	4	15
Poisson's ratio	0	18	3	3	23
Modulus	0	5	16	8	24
Sieve analysis	0	5	17	6	22
All subgrade layers	4	2	5	6	15
Poisson's ratio	0	19	3	1	22
Modulus	0	5	17	11	24
Sieve analysis	0	8	14	9	23
All bedrock layers	8	6	3	7	22
Poisson's ratio	2	12	1	3	17
Unit weight	2	11	2	3	17
Strength	2	10	2	4	17

33. Does your agency use nationally or locally calibrated prediction models (select all that apply)? Note that by selecting a row containing "All" implies that all subset rows are included.

Answer Options	Do Not Use	National Calibration	Local Calibration	Plans for Local Calibration	Response Count
All asphalt models	5	8	5	15	27
IRI	0	6	7	11	17
Longitudinal cracking	2	6	1	11	16
Alligator cracking	0	6	5	11	17
Thermal cracking	0	8	1	11	16
Rutting (asphalt layer only)	1	5	4	9	16
Rutting (total)	1	6	4	12	18
Reflective cracking	2	6	3	9	16
All JPCP models	6	8	4	14	26
IRI	0	4	3	7	10
Transverse cracking	0	6	0	7	10
Joint faulting	1	6	0	6	11

Answer Options	Do Not Use	National Calibration	Local Calibration	Plans for Local Calibration	Response Count
All CRCP models	17	3	2	4	23
IRI	1	1	0	1	2
Punchouts	1	1	0	1	2

34. Where has your agency focused the implementation effort (select all that apply)?

Answer Options	Response Percent	Response Count
Materials characterization	81.4	35
Traffic	65.1	28
Local calibration	65.1	28
Training	48.8	21
Performance prediction of existing pavement structure	44.2	19
Identification of existing pavement layers	41.9	18
Climate	23.3	10
Other (please specify)[1]	11.6	5

[1]Research project with university to develop implementation plan, and evaluating/have not implemented.

35. Has your agency developed/conducted any of the following (select all that apply)?

Answer Options	In-house	Consultant	Academia	Response Percent
Training materials	9	9	3	17
Traffic library	19	8	6	25
Model validation	9	8	14	25
Implementation plan	15	7	11	27
Agency-specific user manual	8	7	2	13
Materials library	17	7	18	31
Pavement performance library	17	5	3	20
Test sites	14	4	10	22
Concurrent designs	18	1	1	19
Review group/committee	19	1	3	19
Comparison of impact due to differences between agency and LTPP distress definitions	7	4	4	10
Catalog designs	8	1	1	9
Other[1]				10

[1]Still under development, differences between distress definitions and those in *MEPDG*, but impact comparison has not been conducted, and we have only worked on proper translation so that calibration can occur.

36. If yes, and you checked any of the boxes above and your agency is willing to share this information, please add the URL where it can be accessed, attach the document to this survey, or e-mail Dr. Pierce at lpierce@appliedpavement.com so she can make arrangements to obtain a copy.

- Idaho
  http://itd.idaho.gov/highways/research/archived/reports/RP193Final.pdf
- Ontario
  https://www.raqsa.mto.gov.on.ca/login/raqs.nsf/363a61d9cd2584da85256c1d0073eb7a/67c10c29044dc0a985257af400571528/$FILE/Ontario’s%20Default%20Parameters%20for%20AASHTOWare%20Pavement%20ME%20Design%20-%20Interim%20Report%20(FINAL%20NOV%202012).pdf
  Traffic information: www.icorridor.org (Login: pavement; Password: Mepdg123)
- Indiana
  http://www.in.gov/dot/div/contracts/standards/
- Quebec
  http://intranet/documentation/Publications/Banque-publications/DocumentsBPM/rtq10-01.pdf

37. What type of *MEPDG*/AASHTOWare Pavement ME Design™ training program is available for your agency's personnel (select all that apply)?

Answer Options	Response Percent	Response Count
NHI training	37.0	17
Self-taught	30.4	14
Self-taught with champion or supervisor oversight	30.4	14
Consultant conducted training	28.3	13
None	15.2	7
Agency-developed training program	13.0	6
University developed classes	6.5	3
Other[1]	26.1	12

[1]Only one pavement designer in the state, so there is not an agency-wide effort for training, FHWA, decision not yet made, AASHTO webinars, university developed overview class, purchased AASHTO service units for training, *MEPDG* manuals and AASHTOWare Pavement ME Design™ software, will be implementing further consultant conducted training, and planning on more formal training course in the future.

38. What, if any, issues have impeded the implementation of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?

Answer Options	Response Percent	Response Count
Limited time available	67.4	29
Availability of materials data/materials characterization	46.5	20
Availability of pavement performance data	39.5	17
Availability of traffic data	34.9	15
Funding restrictions	32.6	14
Availability of information related to the existing pavement structure	30.2	13
Resistance to change from current procedures	20.9	9
Justification of benefits for implementing more advanced procedure	20.9	9
No designated champion	11.6	5
No issues	7.0	3
Additional issues that have impeded implementation[1]	32.6	14

[1]Local calibration, software availability, designs are too thin to be plausible for some cases, limited confidence in distress prediction, changing versions of the software, effort required to implement (viewed as a monumental task), Industry questioning validity of local calibration results, known limitations of the software and its models that haven't been addressed/fixed to date, time for consultant to finish work, learning curve is long and steep, *MEPDG* designs require thicker asphalt than our current agency practice, however *MEPDG* designs require thinner concrete than our current agency practice, and not impeded so much as just taking a measured approach, of which time is a factor.

39. What benefits has your agency accrued due to implementation of the *MEPDG*/AASHTOWare Pavement ME Design™ (select all that apply)?

Answer Options	Response Percent	Response Count
Has not yet been quantified	71.8	28
Improved characterization of local materials	15.4	6
Improved confidence in distress prediction	15.4	6
Cost savings	12.8	5
Improved characterization of existing pavement layers	12.8	5
Improved characterization of traffic	12.8	5
More economical designs	10.3	4
Improved reliability of design recommendations	5.1	2
Additional benefits[1]	23.1	9

[1]Have not yet implemented, the research work accomplished to date on pavement performance data has allowed us to modify our existing AASHTO Design procedure and assign a structural layer coefficient of 0.54 for asphalt concrete layers, used as a tool to help validate our design tables, good information exchange with other agencies, in-house knowledge about pavements, not convinced implementation is worth the effort; however, working toward it at a slow pace to collect distress.

40. Indicate cost savings.

Answer Options	Response Count	Cost Savings
$/year	1	$10 M

41. Please provide any challenges or lessons learned during the evaluation and implementation of the *MEPDG*/AASHTOWare Pavement ME Design™.

- Calibration is very time consuming and run time of software is objectionable.
- Do not assume that all of the existing pavement layer/materials properties are readily available from as-built plans and other records to perform local calibration. An agency should confirm this before deciding to move forward with implementation. If the data are not available and the agency wants to locally calibrate, then that agency needs to plan an expensive field sampling/testing effort.
- Challenge in bringing everyone to the table. We have used research projects to do some of the work, but didn't have the software in hand when that started so some of the work was not productive.
- Obtaining reliable pavement condition data. There have been changes over time that have not been consistent. The guide is too complex for most practicing engineers. It will require significant training for our engineers to use with confidence.
- The comfort level that the designers have with the AASHTO 1993 *Guide* and shifting the way of thinking to the way the *MEPDG* evaluates the design and presents performance outputs.
- Significant amounts of work needed to be done for material characterization.
- Recommend design tables need to be developed to avoid widely varying inputs and output across all districts, and minimize design variability.
- Full implementation across all regions will be difficult due to shrinking workforce, budget cuts, and added effort to conduct training for *MEPDG*/AASHTOWare Pavement ME Design™. Agency will continue evaluating and implementing *MEPDG*/ME where practical from a headquarters level and particularly use the software as an analysis tool.
- Realistic timelines are needed for the calibration/validation process.
- Major challenge is lack of resource to do local calibration and training to regional staff.
- ME is forcing us to make pavement design a more department-wide effort. This is good from the standpoint that employees (e.g., material experts) who may not have understood how their area impacted pavement designs now see a connection between what they do and the final cross section. A general lack of specific knowledge about the models used in ME can be a hindrance. Use of existing design procedures for a long period has created a feeling of comfort that when confronted with the complexity of ME, there is resistance to change.
- Resistance to change from empirical design to AASHTOWare Pavement ME Design™ by district officers.
- Traffic is the most important thing that has to be resolved. Have a buy-in early on from the executive staff. Show the executive staff the benefits. The AASHTOWare Pavement ME Design™ is not perfect but a lot better than the AASHTO 1993 *Guide.* Have a committee to oversee the implementation but only the chair of the committee making the final decision. Be open-minded. Do not make the design to the precision of 0.1 in., be realistic. Know well about construction and its limitations. Deal with materials office and geotechnical engineering office early on.
- How can we evaluate new materials if the new materials are not locally calibrated? In-place materials rarely have the same properties as design materials. In-place material properties are an unknown. How can we differentiate between total rutting and AC rutting. Do we need to cut a trench? Our condition rating has 30 years of data, will of the department abandon these data to only collect *MEPDG* data, this is questionable. Our department's success to date regarding pavement design makes change difficult. We are not comfortable with the risk of thinner pavements.
- Seems the program is still evolving.
- Pavement management gap in terms of performance predictions, materials, and traffic. The outdated empirical methods were based on serviceability (smoothness). Those designs were never validated in terms of performance.
- "Software version changes." Working with other bureaus (specifically the bureau in which the traffic section resides) has been difficult, simply because of boundaries and unfamiliarity of one with the other, and the work that they do.
- Don't rush the process. We thought we'd be ready several years ago, then backed off. When we finally implement, to some degree anyway (within the next few months, most likely), we'll feel more assured of what we're doing.

42. What insight have you gained that can be shared with other agencies to ease the implementation effort (e.g., calibration of a particular model was not needed, traffic characterization by functional class was appropriate)?

- We are planning an extensive field sampling/testing effort to provide data for our local calibration effort. We envision using backcalculated moduli values to characterize material stiffness properties instead of laboratory derived values to populate materials libraries.
- Need a plan from the get go otherwise efforts are too ad hoc. It's a large task therefore also recommend an internal working group to tackle all issues (i.e., need reps from materials, traffic, and pavements).
- Default axle-load spectra works well for WSDOT.
- If you calibrate using local sites, only select sites where very good materials properties, traffic data, climate information, and pavement management data can be readily obtained.
- Local calibration of rutting and cracking is important.
- Use of committees with appropriate departmental experts helps to arrive at appropriate inputs. Buy-in is improved because they have had a say in the process.

- Traffic is such a key component, and has changed significantly from previous design methods, that it requires its own analysis or research project.
- This is a pavement design. Be practical. Do not chase to a precision of 0.1 in. layer thickness.
- Do it in-house. You and only you know the policies in the department. Don't outsource the efforts. Local calibration is a plus but should not be the requirement to implement the *MEPDG*. Eighteen LTPP sections or research sections will not be enough to calibrate the models. To wait to complete the matrices to do the complete local calibration will take years. It is better to do verification/validation of selected pavement sections with good pavement history. Provide training to the pavement engineers, in-house and external. Work together with the pavement associations.
- Traffic is such a key component, and has changed so significantly from previous design methods, that it requires its own analysis or research project separate from other types of work such as sensitivity analysis, and materials testing.
- Make a plan. Change it as you go. Map out the big picture. Get others involved (regions/districts, other sections, other bureaus, other divisions). Get help. Don't expect it to be a miracle program and don't try to design a Swiss watch. It's still pavement. Trust your instincts and engineering judgment. Don't expect your traffic (or any other) data to be better now than it was before.

43. What has your agency spent on implementation?

Answer Options	**Response Percent**	**Response Count**
Nothing, besides the cost of the software license	9.8	4
Less than $100,000	31.7	13
$100,000 to $500,000	29.3	12
$500,000 to $1,000,000	19.5	8
$1,000,000 to $2,000,000	4.9	2
More than $2,000,000	4.9	2

44. What has your agency spent on calibration?

Answer Options	**Response Percent**	**Response Count**
Nothing	24.4	10
Less than $100,000	29.3	12
$100,000 to $500,000	31.7	13
$500,000 to $1,000,000	9.8	4
$1,000,000 to $2,000,000	4.9	2
More than $2,000,000	0.0	0

45. What year did the implementation process begin?

See response to question 46.

46. What year did you complete or anticipate completing implementation?

Agency	**Begin Implementation**	**Complete Implementation**	**Estimated Years to Implement**
Alabama	2009	2015	6
Alberta	2008	2017	9
Arizona	2011	2013	2
British Columbia	2006	2015	9
Colorado	2006	2014	8
Connecticut	2010	2015	5
Florida	2006	2009	3
Hawaii	[1]	2016	—
Idaho	2008	2014	6
Indiana	2002	2009	7

Agency	Begin Implementation	Complete Implementation	Estimated Years to Implement
Iowa	2006	2014	8
Kansas	2012	2014	2
Kentucky	2000	2014	14
Maine	2012	2013	1
Manitoba	2007	2015	8
Maryland	2008	2014	6
Michigan	2011	2014	3
Missouri	2005	2008	3
Nevada	2007	2015	8
New Jersey	1998	2017	19
New Mexico	2008	2013	5
New York	2010	2016	6
North Carolina	2003	2013	10
Ohio	2008	[1]	—
Oklahoma	2004	2016	12
Ontario	2011	2016	5
Oregon	2006	2009	3
Quebec	2008	2020	12
South Carolina	2008	2018	10
Tennessee	2007	2016	9
Vermont	2002	2018	16
Virginia	2007	[1]	—
Wisconsin	2004	2013	9

[1]No response.

47. Do you have any reports, memos, internal documentation, or other comments you would like to share regarding implementation of the *MEPDG*/AASHTOWare Pavement ME Design™?

- Colorado:
  The bid package for consultant services is available upon request.
- Indiana
  Internal documentations available upon request.
- Michigan
  Evaluation of 1-37A Design Process for New and Rehabilitated JPCP and HMA Pavements, http://www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249-204916—,00.html.
  Characterization of Truck Traffic in Michigan for the New Mechanistic Empirical Pavement Design Guide, http://www.michigan.gov/documents/mdot/MDOT_Research_Report_RC-1537_316196_7.pdf.
  Quantifying Coefficient of Thermal Expansion Values of Typical Hydraulic Cement Concrete Paving Mixtures, http://www.michigan.gov/documents/mdot/MDOT_Research_Report_RC1503_228603_7.pdf.
  Pavement Subgrade MR Design Values for Michigan's Seasonal Changes, http://www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249-221730—,00.html.
  Backcalculation of Unbound Granular Layer Moduli, http://www.michigan.gov/documents/mdot/MDOT_Research_Report_RC-1548_363715_7.pdf.
- Oregon
  http://www.oregon.gov/ODOT/TD/TP_RES/Pages/publications.aspx.
- South Carolina
  http://www.clemson.edu/t3s/scdot/pdf/projects/final%20671.pdf.
- Wisconsin
  http://wisdotresearch.wi.gov/whrp.

Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
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
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
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