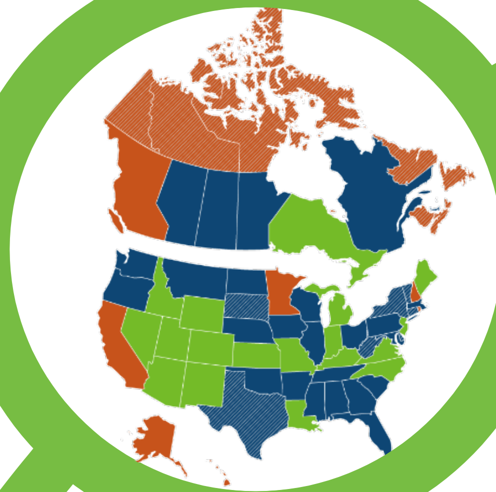
IMPLEMENTATION OF AASHTO PAVEMENT ME DESIGN



A Synthesis of Highway Agency Practice

Prepared for:
TPF-5(305) Regional and National Implementation and Coordination of ME Design Technical Advisory Committee

Prepared by:
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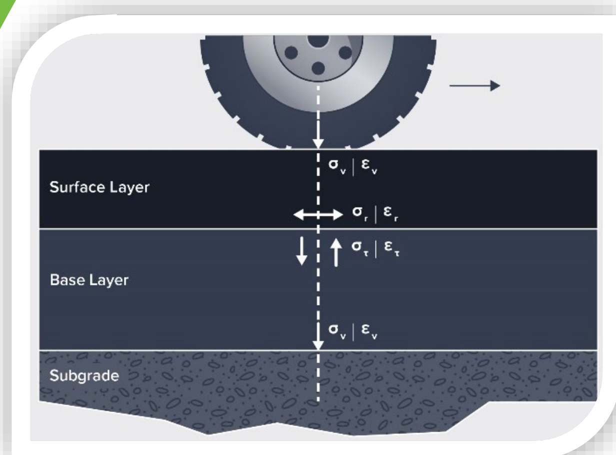

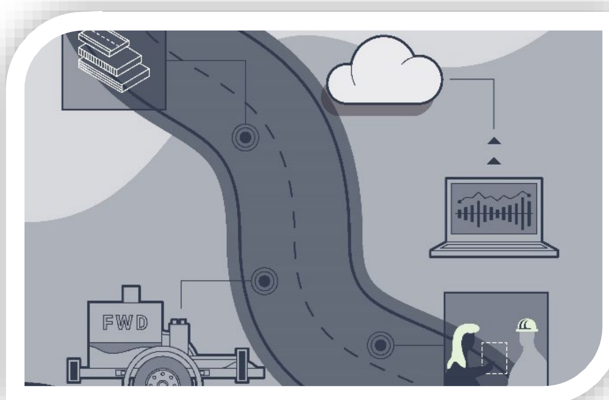

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CREDITS

Cover images: map made for project; cross section (FHWA 2023); illustration (FHWA 2022).

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EXECUTIVE SUMMARY

In 2008, the American Association of State Highway and Transportation Officials (AASHTO) published an interim edition of the *Mechanistic-Empirical Pavement Design Guide (MEPDG): A Manual of Practice (MOP)* (AASHTO 2008). This groundbreaking document presented the first mechanistic-empirical (ME) pavement design procedure based on nationally calibrated pavement performance prediction models. Second and third editions of the MOP, containing updated information, additional guidance, and improved nationally calibrated models, were published in 2015 and 2020, respectively (AASHTO 2015; AASHTO 2020a). A supplement to the third edition was issued in 2021 (AASHTO 2021). An accompanying software program, AASHTOWare Pavement ME Design (PMED), was developed and released in 2011. Multiple updates have been made to the software since its initial release with the latest web-based version (v3.0) made available in July 2022. Together, the MEPDG procedure and the AASHTOWare PMED software (herein, collectively referred to as AASHTO Pavement ME) provide an improved process for conducting pavement analyses and for developing designs based on ME principles.

In 2012, the National Cooperative Highway Research Program (NCHRP) commissioned Synthesis Study 20-05/Topic 44-06 to document the experience of highway agencies in the implementation of the 2008 MEPDG and AASHTOWare PMED. That NCHRP study compiled information on agency implementation efforts and reported the findings in the 2014 NCHRP Synthesis 457, *Implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide and Software* (Pierce and McGovern 2014). In addition to revealing the progress made by U.S. and Canadian agencies—3 agencies fully implemented, 46 in the process of implementation, and 8 with no plans to implement—the synthesis presented strategies and lessons learned by many of the agencies.

Several years have passed since the publishing of NCHRP Synthesis 457, and most highway agencies have continued their efforts to adopt AASHTO Pavement ME. Informal tracking of implementation progress through the annual Pavement ME User Group meetings initiated in 2016 indicated that the number of fully implemented agencies increased to around 16 in 2019. However, a reduction in this number was observed between 2020 and 2022, suggesting a stagnation or regression in the progress of implementation by agencies.

The objectives of this synthesis are to document the latest progress made by highway agencies in implementing AASHTO Pavement ME and to highlight the implementation experiences (e.g., challenges, successful strategies, lessons learned) of selected agencies. This information will benefit agencies interested in adopting or enhancing the use of the MEPDG procedure and PMED tool in the future.

The information contained in this synthesis was obtained using three sources. First, a comprehensive literature review was conducted focusing on implementation activities undertaken since 2014. Second, an AASHTO web-based survey was distributed to pavement engineers in each of the 50 U.S. State departments of transportation (DOTs), as well as selected Canadian provincial ministries of transportation (MOTs), asking for information on their efforts to implement AASHTO Pavement ME. Thirty-two State DOTs and five provincial MOTs responded to the survey. Finally, representatives from three of the responding State DOTs—the Colorado DOT, the Florida DOT, and the Kentucky Transportation Cabinet—were interviewed to obtain additional information about their implementation efforts. These interviews, along with similar dialogs with eight other DOTs in 2022, provided the basis for case studies that highlight the challenges that agencies faced and the strategies they used to overcome the challenges.

Based on the information collected under this study, some key suggestions for facilitating the adoption of AASHTO Pavement ME within a highway agency and ensuring its successful long-term use are:

- Obtain and sustain upper management support and adequate funding.
- Designate and sustain a long-term champion, along with steering and technical support committees to assist the champion.
- Ensure adequate staffing and resources are available for making the transition to AASHTO Pavement ME and for using in on a production basis.
- Involve and solicit the inputs of various internal and external stakeholders, such as agency materials, construction, and pavement management staff and representatives from pavement industry, consultants, academia, and other highway agencies.
- Provide continual support and training for both internal and external design staff, covering all technical aspects, including the AASHTOWare PMED software and the local calibration procedures and tool (CAT).
- Use a staged approach to implementation that focuses on simpler and more readily attainable designs first, followed by more complex designs requiring longer durations to complete.
- Focus calibration efforts on only those pavement performance parameters that typically come into play in design (i.e., minimize efforts in developing calibration coefficients that have little to no effect on performance).
- Consider the development and use of a State-specific Pavement ME-based design catalog, suitable for common sets of conditions defined by geography, terrain, soils, traffic, district practices, and other factors.
- Expand and update source data used to characterize materials and traffic and to calibrate/validate the AASHTOWare PMED models.

CHAPTER 1. INTRODUCTION

Background

Thomas Telford and John Loudon McAdam are commonly credited with the design and construction of the first modern roads considering items such as the traffic loading and stone thickness in the 19^{th} century (Longfellow 2023). In the 1890s, the Goods Road Movement, primarily made up of bicycling enthusiasts, demanded paved road improvements, and the release of the Ford Model T in 1908 added more widespread pressure for paved roads.

The early design of paved roads, similar to bridge design and other infrastructure features, was a trial-and-error process. Designers gained experience with various materials, layer thickness, subgrades, drainage, and climates and applied those lessons learned to the next project developing catalogs along the way. Unfortunately, whenever a new situation was encountered, the designer had to risk either a premature failure or an overdesign and a waste of resources. In 1949, the Public Road Administration (1949) noted that there was general satisfaction with this method for asphalt pavements because:

- This approach was deemed to produce “satisfactory” results for the then-prevailing traffic.
- Basic scientific knowledge was lacking.
- The general use of stage construction did not readily lend itself to the evolving scientific methods of design.

With the passage of the Federal-Aid Road Act in 1916, engineers and government agencies saw the need for a more formal methodology of pavement design. This led to a series of test roads (AASHTO 2020b), which are listed below. In the 1940s, the U.S. Army Corps of Engineers developed a method based on California Bearing Ratio (CBR) testing, and the California Division of Highways used the Hveem R-Value. These empirical methods were based on observing the relationship between a given set of inputs (traffic, climate, materials, thickness) and the pavement performance based on experimentation:

- Bates Road Test in Bates, Illinois from 1920 to 1923, which examined concrete, brick, and asphalt pavements.
- United States Bureau of Public Roads (BPR) load tests of concrete pavements at the BPR test facility in Arlington, Virginia in the 1930s.
- California Test Track near Brighton and Stockton, California, used to develop the California Method using Resistance Value (R-Value) in the 1940s.
- Road Test One-MD conducted in 1950 to 1951, studying the effect of round-the-clock truck traffic on previously constructed concrete pavements near La Plata, Maryland.
- The Western Association of State Highway Officials (WASHO) Road Test conducted in Idaho from 1953 to 1954 focused on asphalt pavements and heavy truck traffic.
- The American Association of State Highway Officials (AASHO) Road Test conducted near Ottawa, Illinois between 1958 and 1960.

When it was conducted, the AASHO Road Test was the largest road experiment for assessing pavement performance under known loads. It consisted of six two-lane pavement loops and included asphalt and concrete pavements, composed of selected base and subbase material types and thicknesses, placed on a single subgrade soil type. Performance measurements included roughness, visual distress, deflections, strains, and the Present Serviceability Index (PSI). The key product of the AASHO Road Test was an empirical pavement design procedure, which incorporated PSI and the concept of the equivalent single-axle load (ESAL) into the pavement thickness determination process.

The AASHO procedure was first published in 1961 and 1962 as the *AASHO Interim Guide for Design of Flexible Pavement Structures and Rigid Pavement Structures*, respectively. An update was published in 1972 as the *AASHTO Interim Guide for Design of Pavement Structures*. A revised version of the document, released in 1981, included a slight modification to the rigid design approach. In 1986, the *AASHTO Guide for Design of Pavement Structures* was published as the first major revision to the design procedure and in 1993 overlay design procedures were added. The final publication of this series was the *AASHTO Guide for Design of Pavement Structures*, Supplement (1998) which dealt only with improvements to concrete pavement design.

In the 1980s and 1990s, multiple improvements were made to the AASHTO empirical pavement design method, corresponding to research on ME principles:

- Mechanistic component that entails the determination of pavement responses (e.g., stresses, strains, deflections) due to loading and environmental conditions.
- Empirical component that relates the predicted mechanistic responses to the performance of the pavement structure. Predicted performance must be calibrated against actual field performance to improve reliability.

As pavement modeling and computing capacity improved, there was an increased interest in applying these technologies to pavement design. ME pavement design methods were developed by industry (e.g., Shell in 1977 [Claessen et al. 1977], Portland Cement Association [PCA] in 1984 [Packard, 1984], Asphalt Institute in 1981) and by a few State DOTs (e.g., California, Illinois, Kentucky, Minnesota, Texas, Washington). These and other pavement-related advancements prompted the AASHTO Joint Task Force on Pavements to initiate major studies on ME design beginning in the late 1980s. Under National Cooperative Research Program (NCHRP) Project 1-26[1], an extensive evaluation of ME procedures was performed, which led to the creation of a basic framework for future development of ME procedures. Subsequent work carried out in the late 1990s and early 2000s under NCHRP Project 1-37A led to the development of the Mechanistic-Empirical Pavement Design Guide (MEPDG) procedure. The objective of this project, which was completed in 2004, was to produce a state-of-the-practice tool for designing new and rehabilitated pavements using existing ME methods. A key to its success was the availability of data from one of the world's largest pavement test programs, the Long-Term Pavement Performance (LTPP) program, which collected and analyzed pavement performance data on more than 2,500 pavement sections starting in 1986.

The development of the MEPDG (including software documentation, user manual, and implementation and training materials) provided a major shift in pavement design by including site conditions (e.g., traffic, climate, subgrade, existing pavement) and construction conditions (month, year) to predict key pavement distress and smoothness. The MEPDG specifically

[1] Barenberg, E. J. and M. R. Thompson. 1992. "Calibrated Mechanistic Structural Analysis Procedure for Pavements-Phase 2," NCHRP 1-26 Final Report. Transportation Research Board, Washington, DC.

involved the designer in the analysis process requiring an iterative approach to determine the appropriate pavement structure to meet the site conditions and the distress and smoothness criteria. An iterative approach was conceived to provide the designer with other alternatives (e.g., asphalt binder type, unstabilized versus stabilized base layer) besides increasing the pavement layer thickness.

Since the rollout of the MEPDG 20 years ago, several State DOTs have adopted the methodology for some or all their pavement design applications. Moreover, most of the agencies that have not adopted it have been actively involved in transitioning to its use. In recent years, the progress of implementation by agencies has stagnated or even regressed, based on information shared in the annual Pavement ME User Group meetings. Consequently, there is a need to examine the experiences contributing to agency decisions about adoption and provide information on successful and unsuccessful practices for agencies to consider as they implement the MEPDG.

Synthesis Objectives

The objectives of this synthesis report are to document the progress made by highway agencies since 2014 in implementing the MEPDG and accompanying AASHTOWare Pavement ME Design (PMED) software (herein, collectively referred to as "AASHTO Pavement ME") and to highlight the implementation experiences—challenges, successful strategies, and lessons learned—of selected agencies. This information, along with background information on the MEPDG procedure and the evolution of the PMED software, will benefit agencies interested in adopting and formally using AASHTO Pavement ME in the future.

Synthesis Methodology

The methodology followed to achieve the synthesis objectives consisted of collecting and synthesizing relevant information through a detailed literature review, an online survey of U.S. State DOTs and Canadian provincial ministries of transportation (MOTs), and interviews with selected DOTs. Focusing on publications from the past 10 years (since the 2014 NCHRP Synthesis 457), the literature review included information about the research and development activities sponsored by highway agencies in support of AASHTO Pavement ME implementation. Activities of interest included asphalt and concrete material characterization, unbound layer and subgrade soil characterization, traffic characterization, climate data source assessment, global model verification and local calibration/validation, training and workshops, and input guides and design manuals.

Based on the findings of the literature review and building from the mini-surveys conducted as part of past Pavement ME User Group meetings, a questionnaire on AASHTO Pavement ME implementation was developed and distributed electronically by AASHTO to all 50 State DOTs and several provincial MOTs. The questionnaire was sent to the voting members of the AASHTO Committee on Materials and Pavements (COMP) or their designees. Responses were received from 37 agencies, including 32 DOTs and five MOTs. The survey questions, which are provided in appendix A, focused on the implementation status of AASHTO Pavement ME within highway agencies and the challenges and successes experienced by agencies during the implementation process. For clarity in completing the survey, the following terms and definitions were provided, and they serve as the basis for the information presented in this synthesis:

- Implemented—The AASHTO Pavement ME procedure is: (a) the agency's official design procedure (this could be sole use or primary parallel use, as defined below), (b) formally required as a design check on another design procedure that is the agency's primary procedure (this is secondary parallel use, as defined below), or (c) the basis for a design catalog (this could be sole use, primary parallel use, or secondary parallel use). Usage may pertain to any or all types of pavements and any or all types of applications.

  - Sole use—Pavement ME is the only design procedure used to design roadway pavements.
  - Primary parallel use—Pavement ME is used concurrently with another design procedure but is the primary basis for the design of roadway pavements. The other procedure is used as a design check, which may prompt further design analysis.
  - Primary secondary use—Pavement ME is used concurrently with another design procedure, but the other procedure is the primary basis for the design of roadway pavements. Pavement ME is used as a design check for the other procedure, which may prompt further design analysis.
- Shadow use—Pavement ME is used in the background for comparison testing with the official design procedure but has no bearing on the official design.

When all the completed questionnaires were received, the results were tabulated and analyzed and served as the basis for the development of this synthesis report. In the questionnaire, agencies were asked if they were willing to serve as implementation case studies. Among the 22 volunteer agencies, 3 were selected to participate in supplementary interviews: the Colorado DOT, the Florida DOT, and the Kentucky Transportation Cabinet. These States were selected because they represent different stages of implementation, exhibit different needs and priorities concerning implementation, portray unique environments and geographies, and have different experience levels and practices concerning pavements and materials.

The selected agency interviews concentrated on implementation triumphs and lessons learned, which could be beneficial to other implementing agencies. The case study summaries developed from these interviews (and reviewed and edited by each agency) are featured in appendix B. Similar dialogs with eight other DOTs as part of the 2022 Pavement ME implementation roadmap workshop have been combined with the interview summaries for an expanded set of case studies (chapter 5).

Synthesis Organization

This synthesis report includes six chapters. This current chapter provides the background, objectives, and approaches used to develop the document. The remaining chapters are organized in the following manner:

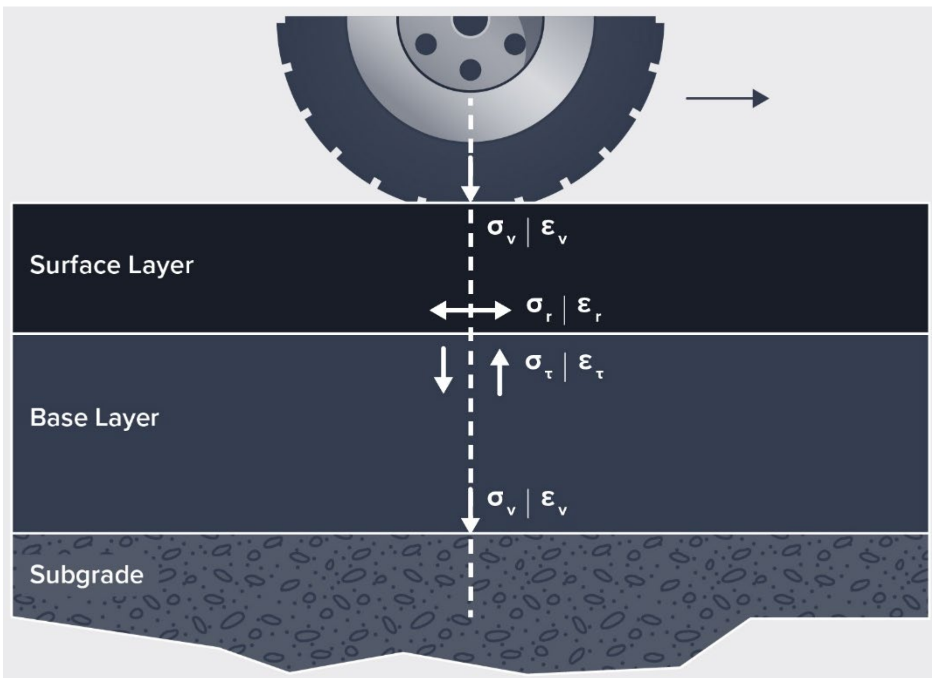
- Chapter 2–MEPDG and PMED software overview.
- Chapter 3–Implementation activities and history.
- Chapter 4–Agency implementation progress and status.
- Chapter 5–Selected agency implementation case studies.
- Chapter 6–Summary of key findings and conclusions as well as suggestions for future research.
- Appendix A– PMED Implementation Survey and Responses.
- Appendix B–Agency Implementation Case Studies.

CHAPTER 2. MEPDG AND THE AASHTOWARE PMED SOFTWARE

Introduction

ME Pavement Design Concept

Mechanistic pavement approaches quantify the pavement structural responses (stress, strain, and deflections) to loading. Simplistically, material properties needed to determine these responses include modulus of elasticity and Poisson's ratio for asphalt pavements and modulus of elasticity, Poisson's ratio, coefficient of thermal expansion, and temperature differential within the slab for concrete pavements. Computationally, layer thickness, loading conditions, and critical structural response locations are also needed. Using an asphalt pavement as an example, the typical critical locations are shown in figure 1.



Source: FHWA

Figure 1. Critical response locations in asphalt pavement (FHWA 2023).

In general, pavement damage calculation includes:

- Determining the daily and seasonal traffic loading conditions.
- Calculating daily and seasonal strains at critical locations.
- Calculating the number of cycles to failure.
- Calculating and summing the damage ratios.

$$D = \sum_{i=1}^{g} \frac{n_i}{N_i} \quad \text{Eq. 1}$$

where:

D = accumulated damage (when D=1, the damage has manifested itself).

n_i = actual loads due to condition i.

N_i = allowable loads due to condition i.

g = number of conditions evaluated (e.g., layer moduli, loading).

Given stresses, strains, and deflection, empirical models (those based on observations) are used to determine pavement performance based on a given set of conditions (e.g., traffic, climate, materials, layer configuration). For example, Finn et al. (1977) identified failure criteria for bottom-up (fatigue) cracking in asphalt pavements as:

$$logN_f = 15.947 - 3.291log\left(\frac{\varepsilon_t}{10^{-6}}\right) - 0.854log\left(\frac{E}{10^3}\right) \quad \text{Eq. 2}$$

where:

N_f = loads to failure.

ε_t = horizontal tensile strain at the bottom of the asphalt layer.

E = asphalt layer modulus.

The analysis for concrete pavements is similar but more complicated due to more critical locations within the slab related to slab geometry, joints with and without dowel bars, and temperature and moisture effects on the slabs.

Benefits

There are several benefits in moving from an empirical-based to an ME-based pavement design procedure, including:

- The ability to analyze different vehicle loads, load configurations, and tire characteristics.
- Improvement in incorporating available and new materials.
- Improvement in performance prediction reliability.
- The incorporation of the role of construction on pavement performance.
- Use of material properties that relate to actual pavement behavior and performance.
- The assessment of existing pavement layer properties.
- The consideration of the environmental and aging effects on materials.

Common Elements

Several fundamental aspects are needed to conduct an ME-based pavement design. These include estimating traffic loads, characterizing pavement materials and climate conditions, and predicting performance based on damage models and distress transfer functions. Pavement rehabilitation design also requires characterization of the existing pavement structure.

- Traffic Loads. ME-based pavement design methods typically estimate traffic loadings using the ESAL parameter. The ESAL concept was originally developed as part of the AASHO Road Test and is useful for expressing a mix of truck axle types and weights into a single value representing those combined traffic effects. However, AASHTO Pavement ME characterizes traffic loading according to axle load spectra. Axle load spectra are a more precise method and includes identifying the axle configuration and weights of different vehicle classes. Axle load spectra represent the hourly, daily, monthly, and seasonal distribution of axle type and load for 10 vehicle classes (typically, FHWA classes 4 through 13). Axle type and load data are collected through various traffic information systems, including weigh-in-motion (WIM), automated vehicle classification (AVS), and vehicle counts.

- Materials. Pavement material properties are determined through laboratory testing, field and nondestructive testing, historical knowledge, or based on engineering assumptions. Materials properties include (some properties are default values):
  - Asphalt layers: dynamic modulus, creep compliance and indirect strength, volumetric properties, asphalt layer coefficient of thermal expansion, unit weight, Poisson's ratio, and other thermal properties.
  - Concrete layers: elastic modulus, flexural strength, indirect tensile strength (continuously reinforced concrete only), coefficient of thermal expansion, unit weight, Poisson's ratio, and other thermal properties.
  - Unbound layers and subgrade: resilient modulus, classification and volumetric properties, moisture-density relationship, soil-water characteristics, saturated hydraulic conductivity, unit weight, Poisson's ratio, and other thermal properties.
- Climate. Pavement materials can be sensitive to changes in temperature and/or moisture (e.g., asphalt aging, freezing/thawing and shrinking/swelling subgrade soils). These changes are typically included as layer moduli adjustments. Climate parameters include temperature, wind speed, cloud cover, precipitation, and relative humidity.
- Performance. Performance prediction is typically conducted using regression equations to predict key pavement distress (e.g., cracking, faulting, punchouts) and smoothness.
- Existing Pavement Structure. It is essential to quantify the existing pavement structure for rehabilitation design. The existing structure is characterized through pavement condition surveys (distress and smoothness), coring (e.g., layer thickness, delamination, sampling), soil borings (e.g., subgrade type, depth to stiff layer or water table, sampling), and deflection testing (e.g., backcalculate layer modulus, load transfer efficiency at transverse joints and cracks, seasonal variation).

Data Needs

Data sources for obtaining input values for ME pavement designs include laboratory and field testing to quantify material properties; pavement management data to identify pavement performance criteria and for use in validation and calibration of the performance prediction models; and construction records, specifications, and plans for determining project-specific conditions. WIM, AVS, and vehicle counts are used to determine load spectra inputs at the project level or through clustering analysis (or other analysis methods) applied to other applicable locations. Ground-based weather stations (GBWS), the North American Regional Reanalysis (NARR), and the Modern Era Retrospective Reanalysis for Research and Applications (MERRA) are common sources for climate data.

MEPDG

As noted previously, the MEPDG is one of several ME design methods that have been developed and used over the past few decades. Its success can be attributed to many factors including, most notably, strong national interest and support, major computational improvements via computer hardware and software developments, advancements in laboratory and field testing, and comprehensive and robust data sources (e.g., LTPP, weather stations). While the MEPDG cannot be used to design a pavement structure (the AASHTOWare PMED software is required for this), it provides the needed information for establishing performance indicators, design criteria, reliability, and design details (e.g., material inputs, performance prediction equations) for new pavement and rehabilitation designs.

NCHRP Project 1-37A

The NCHRP Project 1-37A provided a framework for future improvements and incorporation of new models and changes in traffic loading, materials, construction practices, and design concepts. The design philosophy of the developed guide included (ARA 2004):

- Validated, state-of-the-practice technologies.
- Versatility to consider a wide variety of design and material options.
- Equitable designs by pavement type.
- New and rehabilitation design considerations.
- Hierarchical input levels allowing the designer to match the level of effort for obtaining design inputs to the importance of the project.

The resulting ME procedure incorporated climate impacts, material aging properties, and axle load spectra. The incorporation of these additional design features allowed for the prediction of specific distress types and smoothness including, for example, fatigue cracking (top down and bottom up), rutting, and thermal cracking for asphalt pavements; joint faulting and transverse cracking in jointed plain concrete pavements (JPCP); punchouts in continuously reinforced concrete pavement (CRCP); and the international roughness index (IRI) in asphalt and concrete pavements.

AASHTO MEPDG Manual of Practice

The AASHTO MEPDG MOP provides the necessary information related to the ME design approach developed under NCHRP Project 1-37A. As noted previously, the MEPDG MOP interim edition was balloted by AASHTO in 2007 and released in 2008 (AASHTO 2008). Updated versions of the manual were published and made available in 2015 (second edition), 2020 (third edition), and 2021 (2020 supplement) (AASHTO 2015; AASHTO 2020a; AASHTO 2021). The MEPDG MOP is updated in conjunction with AASHTOWare PMED software updates (e.g., incorporation of new models, recalibration efforts).

AASHTO Local Calibration Guide

The performance prediction models included in AASHTO Pavement ME were primarily developed and calibrated using the data obtained in the LTPP database. The availability of the LTPP database made developing a nationally calibrated ME pavement design method possible. However, each agency should validate the nationally calibrated pavement performance models to ensure their accuracy in predicting local conditions. In the event the validation process indicates the nationally calibrated models do not reflect local conditions, model calibration is recommended.

AASHTO released the *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide* in 2010 (AASHTO 2010). The Local Calibration Guide provides a step-by-step process for adjusting the model calibration coefficients to reflect the prediction of local conditions. Geary (2018) conducted an in-depth review and assessment of the Local Calibration Guide to provide a critical review of the guide from a general pavement practitioner viewpoint.

To assist agencies with the computational effort needed for local calibration, AASHTOWare released the calibration assistance tool (CAT) in 2019. The CAT is a semi-automated tool that follows the Local Calibration Guide procedures and expedites the process of determining optimal model coefficients.

AASHTO is currently updating the Local Calibration Guide to incorporate the current PMED version and provide examples of actual pavement distress model calibrations using the CAT for new asphalt, new concrete, semi-rigid pavements, and asphalt overlay designs.

AASHTOWare PMED

Implementation of the MEPDG design procedure is not possible without the accompanying computational software, AASHTOWare PMED. This program is a comprehensive pavement design and analysis tool that is synchronized with the MEPDG, represents the current state-of-the-practice in ME design procedures, and incorporates advances in materials, traffic loading, and climate conditions for site-specific conditions. It has dramatically evolved from the NCHRP Project 1-37A rudimentary analysis software to its current form as a web-based application.

New and Rehabilitation Design Types

Table 1 provides a summary of AASHTOWare PMED new and rehabilitation design strategies.

New and Rehabilitation Design Inputs

To allow the pavement designer more flexibility, input values for the AASHTOWare PMED are based on hierarchical levels and include:

- Level 1: Inputs are based on material testing (e.g., modulus, compressive strength), deflection testing to determine layer modulus, and site-specific traffic information.
- Level 2: Inputs are based on limited testing or correlations.
- Level 3: Inputs are based on regional averages or expert opinion.

Where appropriate, the highest input level should be used in AASHTOWare PMED. Level 1 inputs require the greatest level of effort to collect but can provide the highest level of accuracy. Therefore, the use of Level 1 data is recommended on the more critical roadways.

A summary of material properties by input level is shown in table 2. (Note: Many of the inputs, especially for Levels 2 and 3, are included in PMED as default values.)

Table 1. Summary of new and rehabilitation design types (AASHTO 2020a*).

Design Type	New	Rehabilitation/Restoration
Asphalt	• Conventional, < 6-inch asphalt over unbound aggregate base • Deep strength, > 6-inch asphalt over unbound aggregate base • Full-depth, thick asphalt (surface and/or base) layer directly on prepared embankment of subgrade soil	• First overlay: – Asphalt over asphalt – Asphalt over asphalt with seal coat – Asphalt over asphalt with interlayer – Asphalt over JPCP – Asphalt over CRCP – Asphalt over fractured JPCP – 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 – Short-jointed Plain Concrete Pavement (SJPCP) over asphalt • Multiple overlays: – Asphalt over asphalt – Asphalt over JPCP – Asphalt over CRCP • Asphalt over fractured JPCP
Concrete	• JPCP – With or without dowels at transverse joints • CRCP	• JPCP and CRCP overlays: – Intact JPCP, CRCP, and jointed reinforced concrete pavement (JRCP) – Existing asphalt pavement • JPCP restoration: – Diamond grinding • Surface repair
Semi-rigid	• Asphalt over cement treated base (CTB), lean concrete base (LCB), or cement aggregate mixture (CAM), with or without an unbound aggregate base	• Asphalt over semi-rigid (first overlay) • Asphalt over semi-rigid (multiple overlays)
Restoration	• Not applicable	• JPCP (diamond grinding, panel replacement)
Recycling	• Not applicable	• Cold in-place recycling • Full-depth recycling (restoration) • Hot in-place recycling • Asphalt over rubblized PCC • Asphalt over asphalt over rubblized PCC • Asphalt over asphalt over asphalt over rubblized PCC

* Based on information from *Mechanistic-Empirical Pavement Design Guide: Manual for Practice*, 2020, published by the American Association of State Highway and Transportation Officials, Washington, D.C.

Table 2. Summary of material inputs (AASHTO 2020a*).

Input	Level 1	Level 2	Level 3
Asphalt (new and overlay)	• Dynamic modulus: laboratory testing of binder and mix properties • Air voids, effective binder content by volume, percent asphalt content by weight of mix, aggregate gradation, unit weight, Poisson's ratio, dynamic modulus, dynamic modulus, binder category (Superpave, penetrations, MSCR), creep compliance, indirect tensile strength, heat capacity, thermal conductivity, and thermal contraction	• Dynamic modulus derived from binder properties and aggregate gradation of asphalt mixture • Air voids, effective binder content by volume, percent asphalt content by weight of mixture, aggregate gradation, unit weight, Poisson's ratio, asphalt binder category, creep compliance, indirect tensile strength, heat capacity, thermal conductivity, and thermal contraction	• Dynamic modulus derived from selected asphalt binder and aggregate gradation of asphalt mixture • Air voids, effective binder content by volume, percent asphalt content by weight of mixture, aggregate gradation, unit weight, Poisson's ratio, asphalt binder category, creep compliance, indirect tensile strength, heat capacity, thermal conductivity, and thermal contraction
Asphalt (existing)	• Dynamic modulus based on backcalculated "damaged" layer moduli • Air voids, effective binder content, percent asphalt content by weight of mixture, aggregate gradation, Poisson's ratio, unit weight, backcalculated layer modulus, and asphalt binder category	• Dynamic modulus derived from binder properties and aggregate gradation of asphalt mixture and "damage" based on extent of alligator cracking • Air voids, effective binder content, percent asphalt content by weight of mixture, aggregate gradation, Poisson's ratio, unit weight, indirect tensile strength, heat capacity, thermal conductivity, and thermal contraction	• Dynamic modulus derived from selected asphalt binder and aggregate gradation of asphalt mixture and "damage" based on overall pavement condition • Air voids, effective binder content, percent asphalt content by weight of mixture, aggregate gradation, Poisson's ratio, and unit weight, indirect tensile strength, heat capacity, thermal conductivity, and thermal contraction
Asphalt binder	• Superpave performance grade (temperature, complex modulus, and phase angle) • Penetration/viscosity grade (softening point, absolute viscosity, kinematic viscosity, specific gravity, penetration, and Brookfield viscosity) • Multiple stress creep recovery grade (MSCR) (temperature, complex modulus, phase angle, and recovery)	• Superpave performance grade (temperature, complex modulus, and phase angle) • Penetration/viscosity grade (softening point, absolute viscosity, kinematic viscosity, specific gravity, penetration, and Brookfield viscosity) • Multiple stress creep recovery grade (temperature, complex modulus, phase angle, and recovery)	• Binder category (Superpave, viscosity, penetration, or MSCR grade) • Binder type • Creep compliance • Thermal conductivity • Heat capacity

Table 2. Summary of material inputs (continued) (AASHTO 2020a).

Input	Level 1	Level 2	Level 3
Concrete	• Strength: direct input of elastic modulus and modulus of rupture at specified ages • Unit weight, Poisson's ratio, coefficient of thermal expansion, thermal conductivity, heat capacity, cement type, cementitious material content, water to cement ratio, aggregate type, set temperature, ultimate shrinkage, reversible shrinkage, time to develop 50% ultimate shrinkage, and curing method	• Strength: direct input of compressive strength at specified ages • Unit weight, Poisson's ratio, coefficient of thermal expansion, thermal conductivity, heat capacity, cement type, cementitious material content, water to cement ratio, aggregate type, set temperature, ultimate shrinkage, reversible shrinkage, time to develop 50% ultimate shrinkage, and curing method	• Strength: direct input of 28-day modulus of rupture, compressive strength, modulus of rupture and elastic modulus, or compressive strength and elastic modulus. • Unit weight, Poisson's ratio, coefficient of thermal expansion, thermal conductivity, heat capacity, cement type, cementitious material content, water to cement ratio, aggregate type, set temperature, ultimate shrinkage, reversible shrinkage, time to develop 50% ultimate shrinkage, and curing method
Chemically stabilized materials	• Damaged modulus: backcalculated layer moduli • Undamaged modulus: compressive strength of field cores • Poisson's ratio, unit weight, elastic/resilient modulus, modulus of rupture, thermal conductivity, and heat capacity	• Damaged modulus: estimated from undamaged modulus • Undamaged modulus: estimated from compressive strength of field cores • Poisson's ratio, unit weight, elastic/resilient modulus, modulus of rupture, thermal conductivity, and heat capacity	• Damaged modulus: estimated from undamaged modulus • Undamaged modulus: estimated from typical compressive strength • Poisson's ratio, unit weight, elastic/resilient modulus, modulus of rupture, thermal conductivity, and heat capacity
Unbound layers and subgrade	• Not applicable	• Resilient modulus: direct input or based on CBR, R-value, layer coefficient, DCP, or based on PI and gradation • Poisson's ratio, coefficient of lateral earth pressure, aggregate gradation	• Resilient modulus: direct input • Poisson's ratio, coefficient of lateral earth pressure, aggregate gradation
Bedrock	• Poisson's ratio, unit weight, and elastic/resilient modulus	• Poisson's ratio, unit weight, and elastic/resilient modulus	• Poisson's ratio, unit weight, and elastic/resilient modulus

* Based on information from *Mechanistic-Empirical Pavement Design Guide: Manual for Practice*, 2020, published by the American Association of State Highway and Transportation Officials, Washington, D.C.

Preventive Maintenance Options

A more recent revision to AASHTOWare PMED is the addition of maintenance strategies in the evaluation of pavement performance. At this time, the MEPDG and PMED help manual have yet to be revised to discuss the inclusion of maintenance strategies into the design process. The non-structural maintenance treatments (including month and year of treatment application and reset value for initial IRI) currently include:

- Flexible pavement.
  - Micromill.
  - Micromill with seal coat.
  - Micromill with microsurface.
  - Microsurface.
  - Ultra-thin overlay.
  - Scratch layer with non-structural surface.
- Rigid pavement.
  - Diamond grinding.
  - Ultra-thin overlay.

Performance

With the advent of ME performance prediction models, AASHTOWare PMED is able to predict several types of surface distress and smoothness. Smoothness prediction is based on initial smoothness (as measured by the IRI) and the type and severity of the predicted surface distress. Surface distress types for asphalt pavements include wheelpath alligator cracking (bottom-up), wheelpath longitudinal cracking (top-down), transverse (or thermal) cracking, reflection cracking (transverse and fatigue), and rutting (within the asphalt layer and total structure). For JPCP, distress types include mean transverse joint faulting and transverse cracking (bottom-up and top-down). For SJPCP, the predicted distress is bottom-up longitudinal cracking. For CRCP, the predicted distress is punchouts. Recommended threshold values by distress type are summarized in table 3.

Table 3. Summary of threshold values by distress type (AASHTO 2020a*).

Pavement Type	Performance Criteria	Interstate Highways	Primary Roads	Secondary Roads
Asphalt (new and overlays)	Alligator cracking (% lane area) Transverse cracking (ft/mile) Total rut depth (inches) IRI (inches/mile)	10 500 0.40 160	20 700 0.50 200	35 700 0.65 (< 45 mph) 200
JPCP (new, overlays, and CPR)	Mean joint faulting (inches) Transverse cracking (% slabs) IRI (inches/mile)	0.15 10 160	0.20 15 200	0.25 20 200
SJPCP (overlay)	Longitudinal cracking (% slabs)	10	15	20
CRCP (new and overlays)	Punchouts IRI (inches/mile)	10 160	15 200	20 200

* Based on information from *Mechanistic-Empirical Pavement Design Guide: Manual for Practice*, 2020, published by the American Association of State Highway and Transportation Officials, Washington, D.C.

PMED Software Version Summary

Introduction

AASHTOWare PMED has evolved from a rudimentary software developed as part of NCHRP Project 1-37A to a rigorous methodology that includes improved software user interfaces, design tools, and updated performance prediction models. Table 4 provides a chronology of the more significant software updates to AASHTOWare PMED, along with associated releases of applicable AASHTO publications. Software versions not listed in this table have either not been officially released or information related to the version was unavailable.

Table 4. Chronology of AASHTOWare PMED software versions.

Date	Description	Software Version	Software Supplements
Feb 1998	• Initiation of NCHRP 1-37A, Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II	---	---
Jun 2004	• Final report released, NCHRP 1-37A, *Guide for the Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*	MEPDG v0.7	---
Nov 2005	• Resolved software issues	MEPDG v0.8	---
Jul 2006	• Resolved software issues	MEPDG v0.9	---
Jul 2007	• Resolved software issues	MEPDG v1.0	---
Aug 2008	• Released, *AASHTO Mechanistic-Empirical Pavement Design Guide Manual of Practice (Interim Edition)*	---	---
Sep 2009	• Resolved software issues	MEPDG v1.1	---
Aug 2008	• Released, *AASHTO Mechanistic-Empirical Pavement Design Guide Manual of Practice (Interim Edition)*	---	---
Nov 2010	• Released, *AASHTO Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide*	---	---
Apr 2011	• Rudimentary software updated and released as AASHTOWare	DARWin-ME v1.1	---
Dec 2011	• Completed, NCHRP 20-07(288), *National Calibration of MEPDG Rigid Pavement Models Based on Corrected CTE Values*	DARWin-ME v1.1.33	---
Feb 2013	• DARWin-ME rebranded as PMED	PMED v1.0	---
Jul 2013	• Released educational version	PMED v1.5.08	
Jan 2014	• Calibration of rutting models based on NCHRP Project 9-30A, *Calibration of Rutting Models for HMA Structural and Mixture Design* • Allow input of special axle traffic information • Added layer-by-layer asphalt rutting coefficients	PMED v2.0.19	---
Jul 2014	• Use backcalculation results with thickness optimization • Incorporate subgrade moduli in sensitivity analysis	PMED v2.1.22	---

Table 4. Chronology of AASHTOWare PMED software versions (continued).

Date	Description	Software Version	Software Supplements
Aug 2015	• Added reflection cracking model based on NCHRP 01-41, *Models for Predicting Reflection Cracking of Hot Mix Asphalt Overlays* • New calibration coefficients for JPCP cracking, JPCP faulting, and CRCP punchout models based on NCHRP Project 20-07(327), *Developing Recalibrated Concrete Pavement Performance Models for Mechanistic-Empirical Pavement Design* • Added semi-rigid pavement type (replaced new AC over CTB design) • Added Level 1 and 2 input data for AC overlays of AC • Added Level 3 input data for AC overlays of JPCP • Added Level 1, 2, and 3 input data for PCC overlays of existing AC • Added Drainage Requirement in Pavements (DRIP) tool • Released MapME tool (geographical data linkage) Released, AASHTO MEPDG Manual of Practice (Second Edition)	PMED v2.2	DRIP v2.0 MapME
Jul 2016	• Added North American Regional Reanalysis (NARR) climate data • Added SJPCP analysis model • Updated MapME with SJPCP and NARR data	PMED v2.3	MapME update
2017	• Released, addendum for NCHRP Project 9-51, *Material Properties of Cold In-Place Recycled and Full-Depth Reclamation Asphalt Concrete for Pavement Design*	---	---
Jul 2017	• Backcalculation Tool (BcT) released	---	BcT v1.0
Jul 2018	• Integrated, *Mechanistic-Empirical Pavement Design Guide Manual of Practice (Interim Edition)* • Added ability for APADS to analyze 100-year designs. • Calibrated models for semi-rigid pavements based on NCHRP 4-36, *Characterization of Cementitiously Stabilized Layers for Use in Pavement Design and Analysis* • Added preventive maintenance function based on NCHRP Project 1-48, *Incorporating Pavement Preservation into the MEPDG* • Added Modern Era Retrospective Reanalysis for Research and Applications (MERRA-2) climate data for asphalt pavements • Added Level 1 tensile strength input data • Recalibrated new and rehabilitation asphalt models	PMED v2.5	---
Aug 2018	• Changed default level for AC rehabilitation to Level 2 • Updated asphalt fatigue damage beta f1 and bottom-up fatigue cracking C2 calibration coefficients	PMED v2.5.2	---
Oct 2018	• Corrected error in faulting module (bonded overlays) • Corrected error for steel depth in SI version	PMED v2.5.3	---
Apr 2019	• Corrected error in special traffic module that underpredicted rutting • Corrected error causing PADS seasonal moduli calculation to crash • Updated climate user interface	PMED v2.5.4	---
Jul 2019	• Analysis lift subsystem reworked to run independently of the file system • Updated climate user interface to use Google Maps • Included link to the RePave Tool developed as part of SHRP2 R23, *Using the Existing Pavement In-Place and Achieving Long Life* • Released Calibration Assistance Tool (CAT)	PMED v2.5.5	CAT v1.0
Jun 2020	• Resolved F25 format issue	---	BcT v1.0.4

Table 4. Chronology of AASHTOWare PMED software versions (continued).

Date	Description	Software Version	Software Supplements
Dec 2020	• Updated for compatibility with PMED v2.5.5 • Software functionality updates	---	BcT v1.06
Jul 2020	• Released, *Mechanistic-Empirical Pavement Design Guide Manual of Practice (Third Edition)* • Integrated the *Mechanistic-Empirical Pavement Design Guide Manual of Practice (Third Edition)* into PMED • Improved the performance of the Enhanced Integrated Climatic Model (EICM) and APADS • Added top-down cracking model based on NCHRP Project 1-52, *A Mechanistic-Empirical Model for Top-Down Cracking of Asphalt Pavement Layers* • Update climate map for educational users	PMED v2.6	---
Mar 2021	• Software functionality updates	---	BcT v1.1
Jul 2021	• Corrected error in the top-down cracking model of AC over JPCP/AC	PMED v2.6.1	---
Sep 2021	• Updated void detection calculation and plots	---	BcT v1.1.5
2021	• Released 2021 Supplement of *Mechanistic-Empirical Pavement Design Guide Manual of Practice (Third Edition)*	---	---
May 2022	• Updates unknown	---	BcT v1.1.6
Jul 2022	• Released PMED web-based application • Integrated NCHRP Project 1-51, *A Model for Incorporating Slab/Underlying Layer Interaction into the MEPDG Concrete Pavement Analysis Procedures* • MERRA-2 used for all pavement design strategies	PMED v3.0 PMED v2.6.2.2 (no changes)	---
Jul 2023	• Added analysis of multiple (up to 4) asphalt overlays • Automatically generate Level 2 creep compliance from Level 1 dynamic modulus (lab testing for creep compliance not required) • Corrected error in mean annual air temperature (MAAT) for temperatures below freezing	PMED v3.15	---
Jul 2024	• Sunset PMED Desktop v2.x (see Note below). • Incorporated, AASHTO M 332, Standard Specification for Performance-Graded Binder Using Stress Creep Recovery (MSCR) for Level 2 and 3 inputs	PMED v3.21	---

Note: All AASHTOWare technical support will cease on July 1, 2027.

Supplemental PMED Tools

Over the course of AASHTOWare PMED software development, several supplemental software tools have been developed to aid the analysis and design process. These tools, which are briefly described below, are available at or accessible through the AASHTOWare PMED and Pavement ME Design websites.

- DRIP v2.0: The DRIP tool is a Microsoft Windows-based microcomputer program for the subsurface drainage analysis of pavements, including time-to-drain and depth-of-flow calculations for drainage layers, separator layer and permeable base design, and edgedrain design.
- MapME: With this web-based mapping tool, a designer can create and download an AASHTOWare PMED project .dgpx file containing climate, traffic, and subgrade soils data geospatially referenced to the subject project location. The application uses area of interest (AOI) and MapME project functions to extract the relevant data from five different data sources to populate the .dgpx file for a specific design type (e.g., new/reconstruction, overlay) and pavement type (e.g., flexible pavement, JPCP). The file can then be downloaded and uploaded into AASHTOWare PMED for use.
- RePave: This tool was developed under the Second Strategic Highway Research Program (SHRP2) R23 research project and is a web-based scoping tool for identifying long-life pavement renewal strategies for existing pavements. The AASHTOWare PMED and Pavement ME Design websites contain links that redirect the designer to the Pavement Renewal Solutions website, where the RePave tool and other resource information can be accessed.
- Backcalculation Tool (BcT): The BcT tool allows a designer to perform backcalculation analysis of falling weight deflectometer (FWD) data and use the results in AASHTOWare PMED for rehabilitation design. The tool follows a 3-stage process consisting of (1) pre-processing (importing and pre-processing the raw deflection data and establishing unique segments within a project for analysis), (2) backcalculation (defining the pavement layer structure and inputs for each segment and running the EVERCALC backcalculation), and (3) post-processing (exporting the analysis results into an AASHTOWare PMED rehabilitation design file). Although the BcT was developed as a stand-alone tool for the desktop versions of AASHTOWare PMED, it was integrated into the web-based version as an individual analysis module.
- Calibration Assistance Tool (CAT): The CAT was developed to expedite the process of conducting a local calibration of the AASHTOWare PMED performance models in accordance with the 2010 AASHTO *Guide for Local Calibration*. It uses AASHTOWare PMED design files and performance data to evaluate predicted versus measured distress and IRI data and statistically improve the global performance models by identifying model coefficients that eliminate bias and minimize standard error. Unlike the BcT, the CAT is not integrated into AASHTOWare PMED v3; however, it is accessible within the program.

CHAPTER 3. A HISTORY OF IMPLEMENTATION ACTIVITIES

The Early Years

As noted previously, the MEPDG was released in 2004 as a deliverable of NCHRP Project 1-37A and balloted into practice by AASHTO in 2007. In the period shortly before its release until 10 years after its release (2014), many national- and regional-level training activities took place to help highway agencies prepare for and adopt the new design procedure. Several State DOTs served as champions for the development and implementation of the MEPDG procedure and many engaged in research and development activities to facilitate implementation. A few DOTs were able to successfully adopt the procedure within a few years of its release. A summary of the events in the early years is provided in the sections below.

Lead States and Early Adoption

In 2004, a Lead States group was created consisting of representatives from DOTs that had an early interest in MEPDG implementation. The group was formed to share knowledge regarding the MEPDG, promote the growth of the procedure, and foster the development of short- and long-term implementation plans. The Lead States included Arizona, California, Florida, Kentucky, Maine, Maryland, Minnesota, Mississippi, Missouri, Montana, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Texas, Utah, Virginia, and Wisconsin (Timm et al. 2014).

Two of the Lead States (Missouri and Oregon) and one non-Lead State (Indiana) are considered the early adopters of the MEPDG procedure. A pavement design status survey conducted by the FHWA's Design Guide Implementation Team (DGIT) in 2006-07 indicated that Indiana and Oregon were using the MEPDG at that time (Crawford 2008). And, following the completion of a comprehensive research study by ARA (2009), the Missouri DOT officially adopted the MEDPG. No additional implementations were reported between 2009 and 2013.

State Implementation Efforts

As noted previously, many States sponsored research and development work in the early years to facilitate the implementation of the MEPDG. Although these efforts varied in scope and level of detail, they generally involved one or more of the following aspects:

- Evaluation of MEPDG functionality, use, and reasonableness of results: Overall functionality of the procedure and software, applicability and reasonableness of the procedure considering agency conditions and practices.
- Evaluation and/or characterization of MEPDG inputs: Availability and reasonableness of agency data (materials, traffic, climate, etc.) and compatibility of agency data with MEPDG input requirements.
- Sensitivity analysis: Impact of MEPDG input parameters (using data ranges typical for the agency) on design outputs.
- Database for MEPDG model verification and local calibration: Development of database or data files for use in evaluating overall functionality of MEPDG and its performance prediction models.
- MEPDG model verification: Comparative study of MEPDG performance predictions (using default/national calibration factors) with actual performance results.

- Local calibration of the MEPDG models: Adjustments made to performance prediction model calibration coefficients in order minimize standard error and correct for bias in the performance predictions.
- Validation of locally calibrated models: Comparative study of locally calibrated performance predictions with actual performance results.
- MEPDG overview or user guide information: General descriptions of the MEPDG process, inputs, performance models, and/or outputs. Detailed descriptions of how to develop inputs for the MEPDG, conduct an analysis using the MEPDG software, and/or analyze the outputs toward identifying a suitable pavement design.

National Collaboration and Training Activities

Prior to the completion of the NCHRP 1-37A in 2004, FHWA formed the DGIT to inform, educate, and assist State DOTs, FHWA Division Offices, and the pavement industry in MEPDG implementation efforts. A comprehensive listing of the activities and events sponsored by the DGIT can be found in NCHRP Synthesis 457 (Pierce and McGovern 2014) and the FHWA Pavements website. These included several in-person workshops and recorded webcasts conducted between 2004 and 2007, a series of recorded webinars on the AASHTOWare PMED software in 2013, and a series of recorded webinars on local calibration in 2014.

The FHWA DGIT also sponsored five regional MEPDG meetings designed to share the expertise, challenges, and accomplishments of the State participants toward successful implementation of the MEPDG (Heitzman 2011). These meetings took place in Ames, Iowa (2008); Mercer, New Jersey (2008); Corvallis, Oregon (2009); Las Vegas, Nevada (2009); and Nashville, Tennessee (2009).

NCHRP Synthesis 457 (Pierce and McGovern 2014) also details the MEPDG-related training courses that were developed and delivered in the early years through the National Highway Institute (NHI). These instructor-led or web-based courses covered different aspects of the MEPDG, including ME design concepts and procedures, geotechnical considerations, development of traffic data inputs, and use of the MEPDG software.

The FHWA Highway Materials Engineering Course (HMEC), developed and delivered for engineers and technicians in State DOTs and FHWA Division Offices, incorporated a MEPDG training module in 2014. Module E of the HMEC course included an introduction to the new design procedure, as well as instruction on the development of design inputs and the procedures for designing flexible and rigid pavements.

In Recent Years

State- and Province-Level Implementation Efforts

A comprehensive literature search and review of AASHTO Pavement ME implementation activities covering the years 2014 to 2023 was performed by the project team under the current study. The results of the review indicate that the primary focus in recent years has been on performance model verification and local calibration/validation. Some key findings from the literature obtained for 24 States and 2 Canadian provinces are as follows:

- Hot-mix asphalt (HMA) material characterization: Although one agency only recently embarked on the testing of HMA mixtures and the development of Level 1 or 2 inputs, four others have been focused on expanded testing and continued material property input development. This has included activities like characterizing modified HMA mixes, transitioning from Level 2 to Level 1 inputs (e.g., dynamic modulus, creep compliance), updating the HMA materials database, and developing XML material input files.
- PCC material characterization: The efforts of two agencies in this area have been focused on developing Level 1 inputs for key PCC properties, such as compressive strength, modulus of rupture (MOR), elastic modulus, and coefficient of thermal expansion.
- Unbound layer and subgrade soil characterization: Five agencies have been active in this area, and the main focus is the development or updating of the agency's unbound materials library and XML input files. Some of these agencies have pursued the development of correlations between laboratory-derived resilient modulus (Mr) values and in-place Mr values (C-factors) obtained through FWD testing.
- Traffic characterization: Four agencies have sponsored studies involving the development of Level 1 (site-specific), Level 2 (agencywide), and Level 3 (national) traffic inputs based on their in-service traffic data collection equipment.
- Climate data source assessment: While the development of hourly climate data (HCD) was the priority of one agency in 2015, the more recent focus of three agencies has been the evaluation of the effect of the different climate data sources (e.g., GBWS, NARR, MERRA1, and MERRA2) on AASHTOWare PMED performance predictions.
- Global model verification and local calibration/validation: Sixteen agencies have been engaged in analyzing the suitability of the AASHTOWare PMED global performance prediction models and, if needed, calibrating the models to their local conditions. For those agencies attempting this work for the first time, efforts were typically directed at both the HMA and PCC models for new design. In most cases, local calibrations were performed resulting in updated model coefficients that reduced the bias and/or standard error, thereby improving the accuracy of the models. In some cases where improved calibrated models could not be achieved, issues such as insufficient number of calibration sites or lack of data with higher levels of distress were cited.
- AASHTO Pavement ME implementation plans/roadmaps: Four agencies have been active with developing implementation plans, all in the 2014-to-2016 timeframe. One of these agencies updated its plan in 2023. Each plan includes details about the objectives and scope of the work, the data/information and sources needed to perform each activity, the schedule for conducting the various activities, and the agency offices/staff that should be involved in steering the implementation efforts.
- User guides and design manuals: AASHTOWare PMED user input guides have been a focus for six agencies. These documents typically include information and guidance in the selection of inputs pertaining to the overall design (design life, reliability, pavement type, performance criteria), design traffic, climate, pavement structure and materials, rehabilitation aspects (characterization of the existing pavement), and the AASHTOWare PMED performance model calibration coefficients.
- Training: Only one agency reported on its training efforts, which took place in 2015. The training sessions included agency staff and consultants and covered the fundamentals of the MEPDG procedure and project-specific design using the design software available at the time.

National Collaboration and Training Activities

In 2014, the FHWA, serving as the Lead for Transportation Pooled Fund Study TPF-5(305) (Regional and National Implementation and Coordination of ME Design), sponsored four regional peer exchange meetings to foster the sharing of highway agency experiences and to facilitate the AASHTO Pavement ME implementation effort. These meetings, which were prompted by a highly successful 2013 regional peer exchange hosted by the Wisconsin DOT, were held in Atlanta, Georgia (2014); Phoenix, Arizona (2015); Portland, Oregon (2015); and Albany, New York (2015). The results of the four peer exchange meetings were summarized in an FHWA technical report titled *AASHTO MEPDG Regional Peer Exchange Meetings* (Pierce and Smith 2015).

To continue the sharing of experiences and the dissemination of information related to AASHTO Pavement ME, and to facilitate its adoption, the FHWA also sponsored seven annual national Pavement ME User Group meetings and six training webinars, as summarized in table 5. In addition to these events, a 1.5-day implementation roadmap workshop was conducted in June 2022 to gather and document information on PMED implementation experiences and knowledge from selected States, industry groups, and universities. The reports, presentations, and other materials for each these events are available on the TPF-5(305) website.

Table 5. FHWA-sponsored Pavement ME User Group meetings and training webinars.

Pavement ME User Group Meetings	Pavement ME Training Webinars
(1) Indianapolis, Indiana (December 2016)	(1) HMA Overlays of Existing Flexible Pavement, Existing Intact Concrete Pavement, and Fractured Concrete Pavement (July 2021)
(2) Denver, Colorado (October 2017)	(2) FDR and CIR Design, PCC Overlay Options (October 2021)
(3) Nashville, Tennessee (November 2018)	(3) HMA Overlay Design Using Limited Available Data on the Existing Pavement, PCC Overlay Design Using Limited Available Data on the Existing Pavement (April 2022)
(4) New Orleans, Louisiana (November 2019)	(4) PMED Models and Calculations: A Journey Through the PMED Engine—HMA Fatigue Cracking, JPC Fatigue Cracking (September 2022)
(5) Virtual (December 2020)	(5) MEPDG Implementation RoadMap Workshop and Report (March 2023)
(6) Virtual (December 2021)	(6) Long-Life Renewal Design Using Pavement ME: Long-Life Asphalt Renewal and Concrete Renewal Design of Existing Flexible Pavement (November 2023)
(7) Salt Lake City, Utah (November 2022)	---

Since the time of the 2014 NCHRP Synthesis 457, AASHTO has sponsored many additional Pavement ME training webinars and, beginning in 2023, assumed responsibility for the Pavement ME User Group meetings. A listing of the webinars is provided in table 6, and the webinar materials are available at the AASHTO PMED website. The AASHTO-sponsored User Group meetings include:

- Madison, Wisconsin (September 2023).
- Atlanta, Georgia (September 2024).
- Richmond, Virginia (planned September 2025).

Table 6. AASHTO-sponsored Pavement ME User Group meetings and training webinars.

Pavement ME Training Webinars
Enhancements to AASHTOWare PMED v2.2 (September 2015)
Enhancements to AASHTOWare PMED v2.3 (August 2016)
FWD Deflection Data Analysis and Backcalculation Tool (BcT) v1.0 (August 2017)
PMED v2.5 Enhancements Part 1 (August 2018)
PMED v2.5 Enhancements Part 2 (August 2018)
PMED v2.5 Enhancements Part 3 (August 2018)
PMED v2.5.5 and CAT v1.0 Part 1 (October 2019)
PMED v2.5.5 and CAT v1.0 Part 2 (October 2019)
Top-Down Cracking Enhancement Released in PMED v2.6.0 (June 2020)
Getting Started with Local Calibration (FY21 webinar 1, December 2020)
Local Calibration Using the CAT Tool (FY21 webinar 2, December 2020)
Backcalculation Tool Enhancements (FY21 webinar 3, February 2021)
Rehabilitation Design of Fractured JPCP and an Asphalt Overlay (FY21 webinar 4, June 2021)
Use of Reflection Cracking Control Measures and Their Simulation in the PMED Software (FY22 Webinar 1, October 2021)
Use of Innovative Materials in PMED (FY22 Webinar 2, January 2022)
Composite Pavement Design and the AASHTOWare PMED Software (FY22 Webinar 3, May 2022)
PMED v3.0 Web Application—Part 1, Introduction (FY22 Webinar 4, June 2022)
PMED v3.0 Web Application—Part 2, Data Management (FY23 Webinar 1, August 2022)
Integration of NCHRP Product 1-51 in v3.0 AASHTOWare PMED Software and Recalibration of the Rigid Pavement Models (FY23 Webinar 2, September 2022)
Importance of Materials Testing and Libraries for Use in Pavement Design (FY23 Webinar 3, March 2023)
PMED Updates and Enhancements: Improving the User Experience in Pavement ME Design (FY23 Webinar 4, June 2023)
PMED Feature Enhancement: Overview of the Implementation of Multiple Asphalt Overlays (FY24 Webinar 1, August 2023)
Input Level 2 Creep Compliance (FY24 Webinar 2, September 2023)
Designing Semi-Rigid Pavements (FY24 Webinar 3, February 2024)
Creating XML Input Files in PMED (FY24 Webinar 4, June 2024)
Implementation of MSCR Binder Grade and Initial Damaged Dynamic Modulus Mastercurve (FY25 Webinar 1, September 2024)
PMED Feature Enhancement: Integration and Use of Recycling Options for Rehabilitation Design (December 2024)

Finally, in 2025, AASHTO made available an E-Learning training course, entitled Fundamental Concepts of the Mechanistic-Empirical Pavement Design Guide (MEPDG). The course can be accessed at the AASHTO Store website.

CHAPTER 4. AGENCY IMPLEMENTATION PROGRESS AND EXPERIENCES

AASHTO Pavement ME Implementation Survey

On behalf of the project team, AASHTOWare staff administered a 2024 online survey of State DOTs and provincial MOTs designed to identify the status of PMED implementation, the challenges and issues each has encountered with respect to implementation, and any successful implementation practices or policies that were instituted. The project team drafted a list of survey questions and worked with AASHTO and the Pavement ME Task Force to finalize the questions. The team also supported AASHTO by suggesting who the recipients of the survey should be and what mailing lists could be used to distribute the survey.

The survey was distributed by AASHTOWare using the SurveyMonkey online survey platform and provided the project team with the final survey responses. In total, 37 agencies responded to the survey, including 32 DOTs and 5 MOTs. The responses to the survey are summarized below, and appendix A contains the tabulated responses to each survey question.

Implementation Status

Since the availability of the first version, agencies have slowly implemented AASHTO Pavement ME over the last 20 years. For asphalt pavement designs, the rate of implementation for new construction was slightly greater than for asphalt overlay designs, as shown in figure 2. Several agencies noted implementation is anticipated for new asphalt (three agencies) or asphalt overlay (seven agencies) designs over the next 10 years.

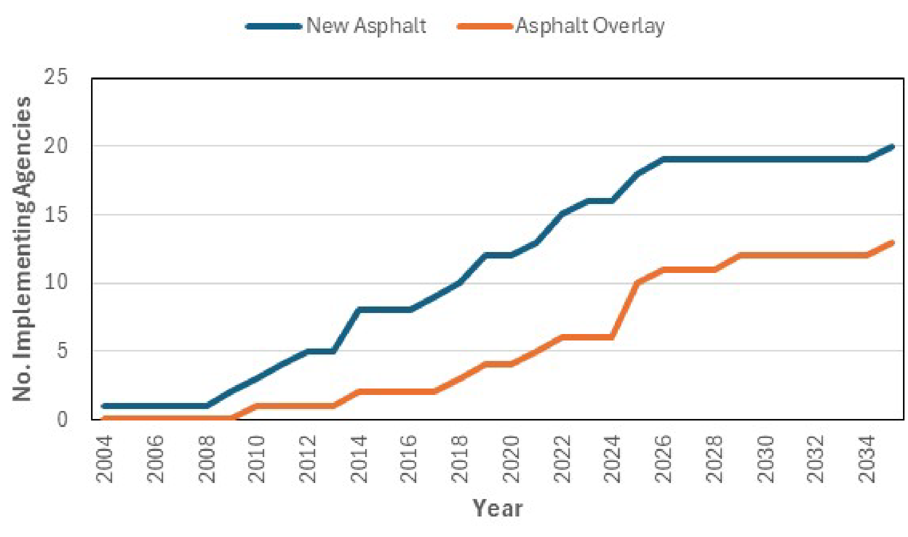


Figure 2. Agency implementation of AASHTO Pavement ME asphalt pavement designs.

Similarly, for concrete designs, the rate of implementation for new construction is slightly higher than for overlay designs (see figure 3). Moreover, only two agencies anticipate the adoption of new construction and concrete overlay designs over the next 10 years.

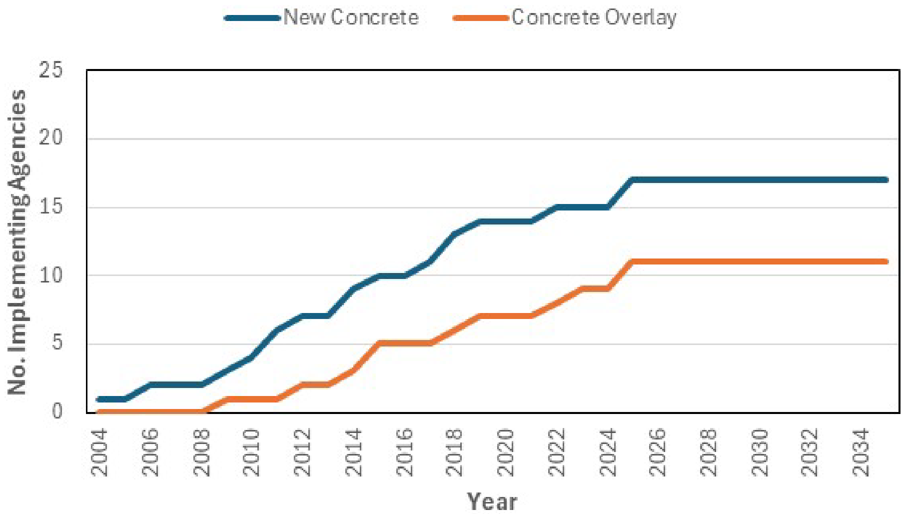


Figure 3. Agency implementation of AASHTO Pavement ME concrete pavement designs.

Of the 37 responses, 16 agencies indicated implementing AASHTO Pavement ME for the design of new asphalt pavements, 6 agencies for asphalt overlays, 15 for new concrete pavements, and 9 for concrete overlays. Breakdowns of specific asphalt and concrete designs that agencies have implemented or are planning to implement are illustrated in figure 4 and figure 5, respectively.

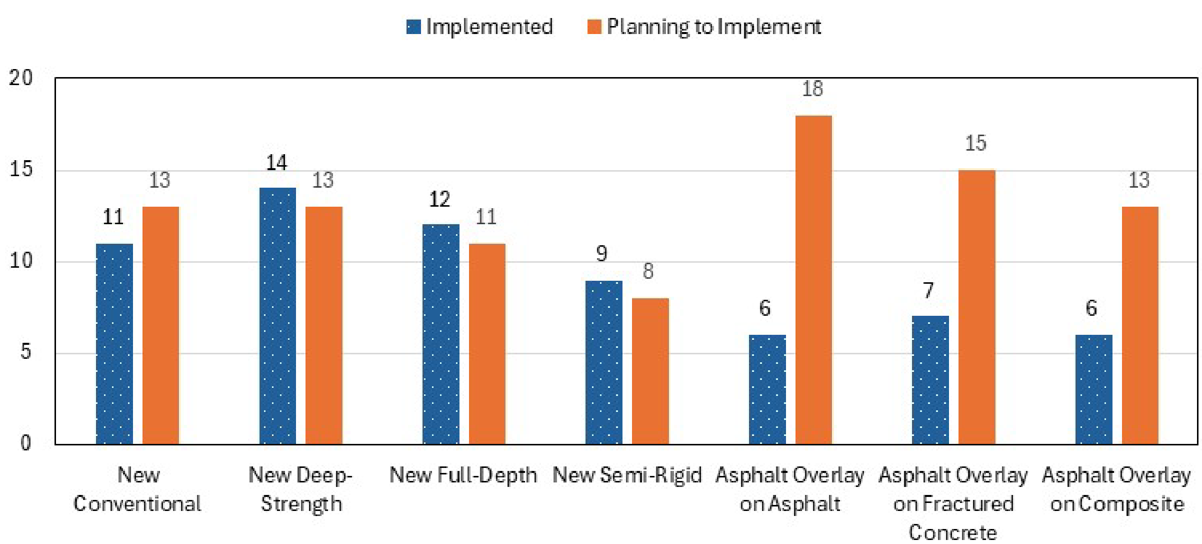


Figure 4. Agency implementation of specific asphalt pavement designs.

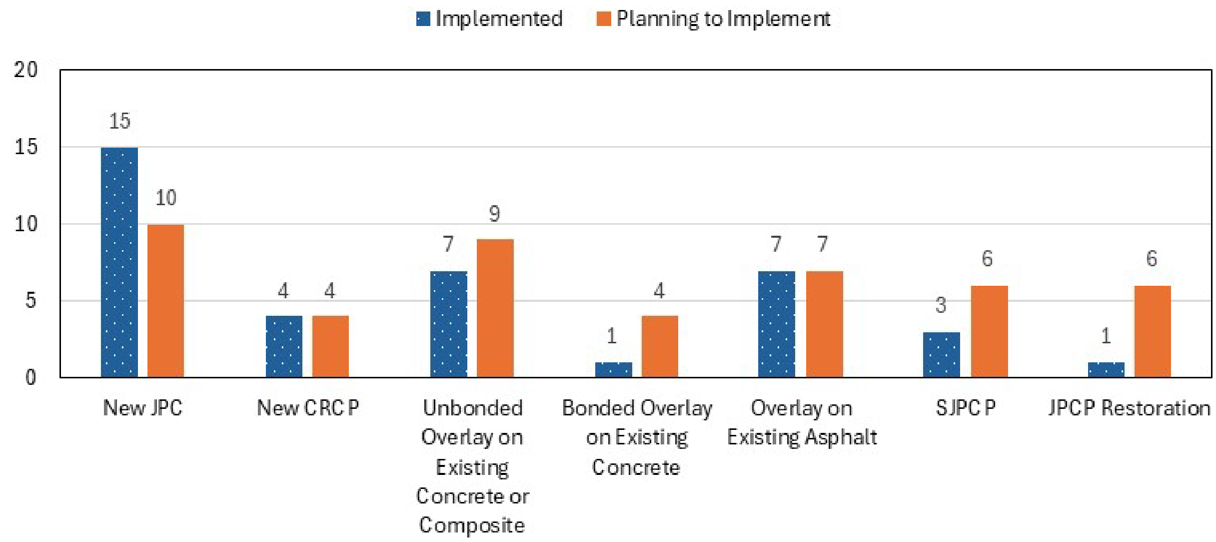
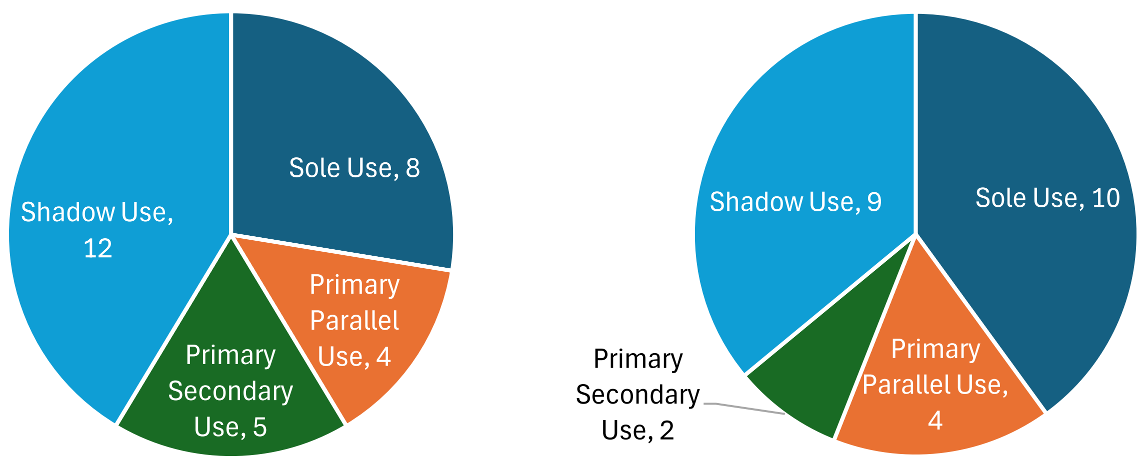


Figure 5. Agency implementation of specific concrete pavement designs.

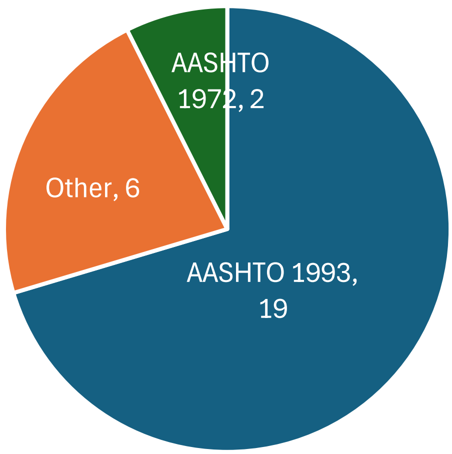
Agencies were also asked to indicate how AASHTO Pavement ME was being used for asphalt and concrete pavement design and analysis, in terms of sole use, parallel use, or shadow use. As figure 6 illustrates, 8 agencies indicated using it as the sole design procedure for asphalt pavement types and 10 agencies for concrete pavement types, whereas 12 and 9 agencies reported using it on a shadow basis for asphalt and concrete, respectively. Additionally, 9 and 6 agencies use it in parallel with or as a secondary design procedure for asphalt and concrete, respectively.



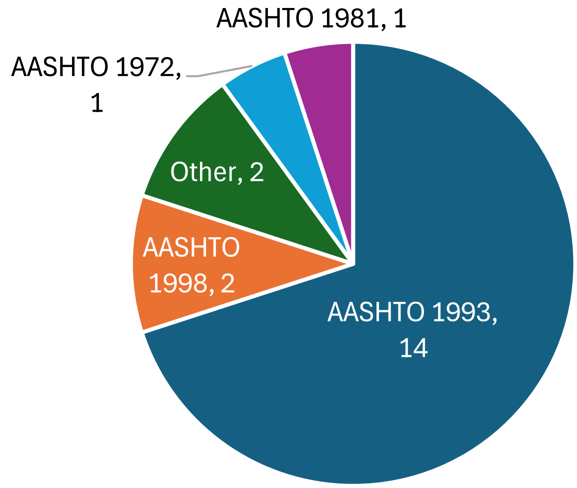
a. Asphalt pavements. b. Concrete pavements.

Figure 6. Agency use of AASHTO Pavement ME.

For agencies that indicated AASHTO Pavement ME was not being used, 19 reported using the AASHTO 1993 Guide, 6 agencies indicated using "other" methods, and 2 agencies indicated using the AASHTO 1972 Guide for the design of asphalt pavements (figure 7). Other methods for asphalt pavement design include, for example, the Idaho Gravel Equivalency, Caltrans ME, and remaining life for overlay design. For concrete pavements, 14 agencies indicated using the AASHTO 1993 Guide, 2 agencies used the AASHTO 1998 Supplement, 2 agencies used other empirical design procedures (remaining service life for overlays and bonded concrete overlay of asphalt pavement method for thin whitetopping), and 1 agency each used the AASHTO 1972 Guide or the AASHTO 1981 Guide.



a. Asphalt pavements.



b. Concrete pavements.

Figure 7. Agency use of other pavement design methods.

Several agencies indicated that they have no intent to implement AASHTO Pavement ME. Among the reported reasons for not pursuing implementation were: (a) the calibration effort is too expensive, time-consuming, and/or requires an outside entity with expertise in performing calibrations (three agencies), (b) the ongoing model recalibration and incorporation of new models (two agencies), (c) the lack of good quality data (two agencies), and (d) the lack of management support and/or coordination between agency offices (one agency).

Local Calibration and Validation

From 2004 to 2014, 13 agencies conducted local calibration on the asphalt pavement performance models, and 12 agencies conducted local calibration on the concrete pavement performance models (see figure 8). Over the last 10 years, significantly more local calibration efforts have been conducted, with 24 agencies calibrating the asphalt pavement performance prediction models and 15 agencies calibrating the concrete performance models.

For the agencies who have calibrated the AASHTO Pavement ME asphalt pavement performance models, 12 have recalibrated once, 3 have recalibrated two times, and 1 agency has recalibrated three times. Similarly, for the concrete pavement performance models, eight agencies have recalibrated once, and three agencies have recalibrated twice.

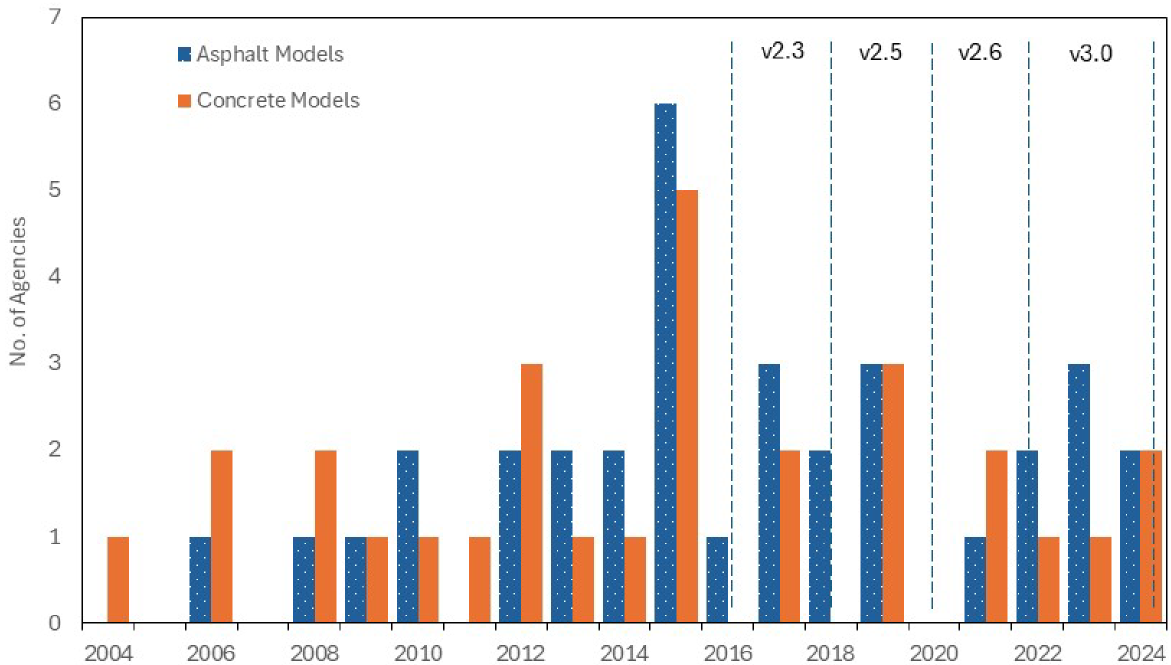


Figure 8. Agency local calibration efforts.

In total, 21 agencies have conducted a local calibration of the AASHTO Pavement ME asphalt pavement performance prediction models. Most agencies have calibrated the bottom-up, transverse thermal, and reflective cracking models; the asphalt and total rutting models; and the IRI model (see table 7).

Table 7. Summary of agency calibration efforts for the asphalt performance models.

Distress / Condition	No. of Agencies Calibration #1	No. of Agencies Calibration #2	No. of Agencies Calibration #3	No. of Agencies Calibration #4
Bottom-up cracking	17	7	4	2
Top-down cracking	8	4	3	1
Transverse thermal cracking	13	5	5	2
Reflective cracking	9	6	5	1
Rutting-asphalt layer	13	7	5	2
Rutting-total	17	8	6	2
IRI	16	5	4	2

Similarly, 15 agencies have conducted a local calibration of the AASHTO Pavement ME concrete pavement performance prediction models. As shown in table 8, agencies have primarily calibrated the transverse cracking, faulting, and JPCP IRI models. Four agencies have calibrated the CRCP IRI model, three agencies have calibrated the CRCP punchout model, and one agency has calibrated the SJPCP longitudinal cracking model.

Table 8. Summary of calibration efforts for the concrete performance models.

Distress / Condition	No. of Agencies Calibration #1	No. of Agencies Calibration #2	No. of Agencies Calibration #3	No. of Agencies Calibration #4
Transverse slab cracking	12	8	4	1
Mean joint faulting	12	8	3	1
CRCP punchouts	3	0	0	0
SJPCP longitudinal cracking	1	0	0	0
JPCP IRI	10	7	3	2
CRCP IRI	4	1	1	1

Keys to Implementation

Agencies were asked to rank several elements considered beneficial to successfully implementing AASHTO Pavement ME. The resulting rankings, based on 24 responding agencies, are provided in table 9. As can be seen, the highest ranked elements included achieving upper management support/adequate funding, having strong leadership/champion, having experienced and knowledgeable staff, and having a well-conceived and documented implementation plan.

Table 9. Summary of keys to implementation.

Key Element	Weighted No. of Responses	Ranking
Upper management support/adequate funding	20.7	1
Strong leadership/champion	19.6	2
Experienced and knowledgeable technical staff	18.8	3
Well-conceived and documented implementation plan	16.2	4
Sufficient and good quality data to drive the PMED process	13.5	5
Comprehensive training	12.8	6
Successful local calibration of performance models	11.6	7
External support (industry, university, consultants)	11.3	8
Successful characterization of design inputs	11.1	9
Strong interaction between offices	9.9	10
Effective steering/oversight committee	9.8	11
Compatibility between agency and PMED performance measures/thresholds and test standards/specifications	6.2	12

Implementation Challenges

Agencies identified several technical challenges with implementation of AASHTO Pavement ME. A summary by pavement type included:

- Asphalt pavements:
  - Conducting local calibration/validation (12 agencies).
  - Transitioning from the previous design procedure and reaching an acceptable comfort level with Pavement ME (eight agencies).
  - Other responses (two agencies each) included:
    - Training.
    - Compatibility between agency and Pavement ME performance measures.
    - Sufficient funding for implementation.
    - Inconsistency in predicted distresses.
- Concrete pavements:
  - Conducting local calibration/validation (nine agencies).
  - Transitioning from the previous design procedure and reaching an acceptable comfort level with Pavement ME (eight agencies).
  - Training (two agencies).
  - Compatibility between agency and Pavement ME performance measures (two agencies).
  - Other responses (one agency each) included:
    - Developing traffic inputs.
    - Insufficient number of concrete sections.
    - Properly characterizing existing pavement structure and conditions.
    - Inconsistency of predicted distresses.

In addition to the technical challenges, agencies also provided non-technical challenges with AASHTO Pavement ME implementation. The primary challenges included:

- Limited resources and time (16 agencies).
- Retirement/turnover and staff training (3 agencies each).
- Funding restrictions, internal agency resistance, and external agency resistance (2 agencies each).

These challenges were further expanded when agencies were asked to identify additional efforts to assist with implementation. Such efforts included:

- Determining the benefits of Pavement ME versus existing procedures (six agencies).
- Developing an implementation plan (three agencies).
- Evaluating the economic impact of alternative designs, applicability to current conditions, and obtaining approval from upper management (two agencies each).

Implementation Advantages

Responding agencies indicated several advantages with the successful implementation of AASHTO Pavement ME. Most of these agencies cited advantages related to the ability to conduct designs based on local conditions and the opportunity to optimize designs (six agencies each). Other advantages included:

- Keeping pace with the state-of-the-practice in pavement design methods (four agencies).
- Ability to characterize local materials (three agencies).
- Climatic effects, truck loading conditions, having greater confidence in the design results, and pavement and rehabilitation type decisions (one agency each).

Of the responding agencies, none noted being dissatisfied with the previous design methodology.

Implementation Efforts

Among the agencies who indicated plans to implement AASHTO Pavement ME, the activities cited the most were determining benefits over existing procedure (six agencies) and developing an implementation plan (three agencies). Two agencies each reported evaluating an economic impact of alternative designs, obtaining approval from upper management, and evaluating applicability to current conditions.

CHAPTER 5. IMPLEMENTATION HIGHLIGHTS OF SELECTED AGENCIES

Introduction

This chapter highlights the experiences of several State DOTs who have been at the forefront of AASHTO Pavement ME implementation. The agencies include CDOT, FDOT, and KYTC, which were interviewed as part of the current study, and eight other DOTs who shared their efforts in the 2022 Pavement ME implementation roadmap workshop. The summaries presented are derived from the three case studies featured in appendix B and from the Mechanistic-Empirical Pavement Design Guide (MEPDG) Implementation Roadmap workshop report and PMED User Group meeting notes.

Colorado

In 2015, the Colorado DOT (CDOT) became one of the first agencies to fully adopt AASHTOWare PMED v2.1 for the design and analysis of asphalt and concrete pavements. CDOT saw the implementation of PMED as a logical improvement in their pavement design method as AASHTO moved toward the implementation of ME pavement design. The agency had the staffing, funding, and management support to enable that implementation.

A considerable effort was conducted to locally calibrate the performance prediction models to Colorado conditions, compile weather station information, and develop an extensive materials library. Most of CDOT's implementation has been in-house and through AASHTO's support consultant. Some initial material testing for AASHTOWare PMED was conducted by outside laboratories. CDOT was very satisfied with this initial implementation, which resulted in nominal concrete pavement thicknesses decreasing by about 2 inches and nominal asphalt pavement thicknesses increasing by about 2 inches.

In moving toward the implementation of AASHTOWare PMED v2.6 and v3.0, CDOT has uncovered issues with its materials library and climatic data. AASHTO has recommended that CDOT rebuild their materials library with additional testing data for satisfactory results. With limited staffing and laboratory testing equipment, this may be problematic for the Department.

CDOT is working toward the implementation of AASHTOWare PMED v3.0, but this will require considerable effort to update the materials library and calibrate to local conditions. CDOT is also updating its *Pavement Design Manual* to reflect the implementation of AASHTOWare PMED v3.0. The goal is to have the implementation and updated manual in place by July 2025. Funding and staffing for this activity are more limited now than in the original implementation.

Florida

The Florida DOT (FDOT) started its AASHTO Pavement ME implementation journey around 2007. While the JPCP calibration efforts moved along and ultimately resulted in published calibration factors for Florida, FDOT had concerns with Pavement ME for asphalt pavements.

The initial JPCP calibration started in 2008 using AASHTOWare PMED v1.0, with a second calibration completed in 2015 using v2.2. FDOT had limited JPCP sections and used LTPP sections from adjacent States to complete the calibration. By 2009, the Department was using AASHTO Pavement ME as an option aligned with the 1993 *AASHTO Guide* for new or reconstructed JPCP designs. In 2018, FDOT moved exclusively to Pavement ME designs of new and reconstructed JPCP.

The *FDOT Rigid Pavement Design Manual 2022* uses a catalog approach for JPCP designs developed with AASHTOWare PMED v2.2.6 (FDOT 2022). The designer uses a map developed from MERRA climatic data to determine the climate region. Then, traffic loading and reliability are used to select the slab thickness. The catalog assumes 15-ft joint spacings and a 13-ft widened lane with an erosion-resistant base. If a district cannot construct the 13-ft wide slab, then a customized PMED design is required.

While FDOT is comfortable with its present approach and calibration, the agency is anticipating the adoption of AASHTOWare PMED v3.0 as support for the desktop versions is phased out. They are in the process of obtaining additional technical support in the Central Office pavement design section to perform an in-house recalibration using the CAT. FDOT believes AASHTOWare PMED v3.0 is a better platform and would simplify computer and network issues with server permissions for the software and data files. The agency is relying heavily on using the CAT with the hope that the experience facilitates the implementation of Pavement ME for asphalt pavements.

In preparation for the adoption of newer versions and recalibration, FDOT constructed a 2.5-mile concrete test road which has been under traffic since March 2023. The concrete test road contains 52 experimental sections to study structural, drainage, and calibration variables. FDOT also constructed a parallel asphalt test road that was opened to traffic in September 2024. The asphalt test road includes 12 experimental sections to evaluate the base type, lift thickness, reflective cracking mitigation, alternative mix design protocol, and open-graded friction course.

Kentucky

Since the late 1990s, the Kentucky Transportation Cabinet (KYTC) has used a pavement design catalog to enable its staff and consultants to quickly and effectively develop pavement designs for its roads. The original design catalog was developed in 1999 using the 1981 Kentucky pavement design process (Graves 2022), which included layer coefficients from the *AASHTO Guide for Design of Pavement Structures*. Around 2016, KYTC management wanted to implement AASHTO Pavement ME. The Department believed that the 1999 catalog was conservative and that a mechanistic approach could produce more economical designs. During the initial phase of AASHTO Pavement ME implementation, KYTC worked with the University of Kentucky Transportation Center and queried other State DOTs implementing the procedure for information on their activities and strategies.

KYTC did not undertake an extensive calibration study, rather, it concentrated on a calibration/verification approach given its history with its existing catalog and pavement performance data. Through its sensitivity analysis and DOT survey, the Department determined that AASHTO Pavement ME performance prediction was most sensitive to subgrade stiffness and traffic levels; therefore, those parameters were used by KYTC to update its 1999 catalog.

Results from the AASHTO Pavement ME verification resulted in the nominal pavement thickness for a given set of subgrade and traffic levels being reduced by 1 to 1.5 inches. Some combinations resulted in a more significant reduction, but KYTC was not comfortable with that great of a change. Kentucky also varied the failure thresholds, such as using a 10 percent limit for fatigue cracking.

The online design catalog is available for use by agency engineers and consultants engaged in developing pavement designs. KYTC also developed a *Pavement Design Guide, January 2018 Update for Full Depth Projects*.

For AASHTO Pavement ME rehabilitation applications, customized designs were developed based on pavement forensics using input templates for AASHTOWare PMED v3.0. Multiple alternatives are provided to the Department's Pavement Branch and/or the project design team for alternative selection. Rehabilitation design using Pavement ME is reserved for in-house design at present and has not been released to consultants. KYTC has not applied a catalog approach for rehabilitation since the designs are unique and complex compared to new and reconstructed pavements.

KYTC has become an enthusiastic user of AASHTOWare PMED v3.0. They appreciated the improved accessibility, speed, and library features. KYTC was anticipating moving toward client-side processing to reduce queueing. KYTC's concern with v3.0 was that changes could be made to the software without the user's knowledge. Although there was a protocol for testing these changes before they were deployed, KYTC was aware of an instance where the change resulted in an error in the design. KYTC believed the protocols were not robust enough at present. In addition, KYTC noted that there needs to be better publicly available documentation on all changes made to the software.

Indiana

The Indiana DOT (INDOT) was an early adopter (circa 2009) of the NCHRP 1-37A study and the MEPDG procedure and AASHTOWare PMED software that followed. As part of this adoption, INDOT developed detailed procedures for its application into Part 6 – Pavement Design of the Indiana Design Manual. The adoption includes templates for use by INDOT designers and consultants to ensure the correct parameters are applied to the design. INDOT developed files that are available on its Pavement Design webpage for various asphalt mixes, binder grades, gradations, and districts. INDOT has used AASHTOWare PMED to design 400 to 700 projects per year, ranging from new construction to rehabilitation to preservation.

INDOT conducted its first major calibration in 2017 for asphalt pavement rutting and later for the cracking model using AASHTOWare PMED v2.6. INDOT continues its verification process using its extensive pavement management data. As part of its transition from AASHTOWare PMED v2.3 to 2.6, INDOT observed:

- Significant increases in truck traffic and changes in hourly distribution due to more extensive traffic data collection.
- The global coefficients for the rutting model were overpredicting subgrade rutting and underpredicting the rutting in the pavement structure.
- PMED v2.6 predicted substantially more bottom-up cracking than v2.3.

Recently, INDOT developed a design catalog for short sections of pavement associated with structure replacement. Pavement designs of this type represented about 20 percent of the pavement designs performed by INDOT. The designer can now select a pavement design based on average annual daily truck traffic, ESAL categories, road class, district, and traffic speed.

INDOT is currently conducting research that will pave the way for adopting AASHTOWare PMED v3 in 2025. The research study includes the development of Level 1 and Level 2 HMA input files, based on the collection and analysis of data on HMA mixes with multiple stress creep recovery (MSCR) binders. A check of the globally recalibrated performance prediction models for PCC design is also being performed in the study.

Iowa

The Iowa DOT (IDOT) had traditionally designed its pavements using the *1993 AASHTO Guide* for asphalt pavements and the PCA's *Thickness Design for Concrete Highway and Street Pavements* (Packard 1984) for concrete pavements. IDOT began its calibration of the AASHTO Pavement ME approach shortly after the national calibration was completed in 2004. The Department was supported in this effort by Iowa State University's Institute for Transportation (InTrans). Due to initial results and changing deterioration models, IDOT and InTrans completed two formal local calibrations.

The calibration studies by InTrans recommended a mix of national and local calibration coefficients—primarily national coefficients for asphalt pavements and local calibration coefficients for concrete pavements. From 2019 through 2021, IDOT performed a verification study to examine the application of AASHTOWare PMED v2.6 for asphalt and concrete pavement designs along with using its present design methods and the PerRoad software (perpetual asphalt pavement designs) as a design check. After the verification study, the agency moved forward with the implementation of AASHTO Pavement ME for:

- Asphalt pavements using AASHTOWare PMED and the 1993 *AASHTO Guide*, with PerRoad as a design check to limit thickness.
- Concrete pavements using AASHTOWare PMED and the PCA design method with a minimum 9-inch slab thickness.

IDOT is planning to implement AASHTOWare PMED v3.0 over the next year as support for v2.6 is sunset.

Maryland

The Maryland State Highway Administration (MDSHA) undertook a four-phase approach to the implementation of AASHTO Pavement ME that included:

1. Verification of the national models.
2. Sensitivity analysis.
3. Local calibration using AASHTOWare PMED v2.6.
4. Updates.

In Phases 1 and 2, which were completed in 2016, MDSHA used selected Maryland LTPP and pavement management sections to verify Maryland's measured pavement data against the values predicted by AASHTOWare PMED and a sensitivity matrix, respectively. The results of Phase 1 showed a need for the MDSHA to complete a calibration.

With the exception of the fatigue cracking model for asphalt overlays of existing flexible pavement, MDSHA used the CAT in Phase 3 to calibrate the performance prediction models.

The calibration study was completed in 2022. Under Phase 4, Maryland is developing traffic and materials libraries and updating its pavement design guide with the local calibration coefficients.

Michigan

The Michigan DOT (MDOT) first implemented AASHTO Pavement ME in 2015 and published its initial user guide (*Michigan DOT User Guide for Mechanistic-Empirical Pavement Design – Interim Edition*) in the same year. An updated version of this guide was released in January 2025. A critical step in MDOT's implementation journey was the formation of an "ME Oversight Committee," comprising both internal and external stakeholders in the pavement design process. That group serves to evaluate the best practices and develop MDOT design standards for Pavement ME.

MDOT currently uses AASHTOWare PMED v2.6 with locally calibrated coefficients for reconstruction projects of both asphalt and concrete pavements. Additionally, it uses the *1993 AASHTO Guide* design results to establish the initial designs for PMED. Accordingly, MDOT enforces rules to restrict AASHTOWare PMED final pavement design thickness to within 1 inch of the AASHTO 1993 final design thickness for both flexible and rigid pavements. While most AASHTOWare PMED designs fall within that thickness range, this restriction ensures that designs are not excessively thick or thin due to unique design aspects that cannot yet be comprehensively interpreted by PMED.

MDOT has conducted several research projects to refine AASHTOWare PMED inputs, including studies on traffic characterization, unbound materials and subgrade soil characterization, HMA characterization, and Michigan-specific climate data for AASHTOWare PMED designs. Most notably, MDOT has performed three local calibration studies, the most recent being titled *Testing Protocol, Data Storage, and Recalibration for Pavement-ME Design (Report SPR-1723)*, in collaboration with Michigan State University. This study supported the adoption of AASHTOWare PMED v2.6 as the primary design tool. Furthermore, to support calibration, this research used the CAT to calibrate the rutting and faulting performance prediction models. Other models, such as those for thermal cracking and IRI in flexible pavements and transverse cracking and IRI in rigid pavements, were calibrated using other statistical and computational tools outside AASHTOWare PMED and without the CAT. The calibration process involved key steps, including the determination of global model prediction bias (verification), the assessment of bias causes (investigation), the adjustment of model calibration factors to eliminate bias and minimize error (calibration), and the confirmation of the adequacy of the adjustment factors (validation).

Additionally, the latest recalibration research project included several notable investigations and findings to improve the MDOT local calibration. One enhancement involved adjusting the input for concrete widened slabs, using different theoretical widths to represent 14-ft slab configurations. Another focus was eliminating gaps in the MDOT performance data and improving the accuracy of its conversions to AASHTOWare PMED formatting. This included the backcasting of IRI values to obtain an initial IRI when the data were unavailable. Additionally, a comparison of MERRA climate data with the MDOT improved ground-based data revealed that the latter data source was better suited for MDOT use at this time. This research project also explored other aspects that were not found to improve the calibration at this time. This included the possible calibration of the AASHTOWare PMED empirical spalling calculation, MDOT asphalt mixture-specific fatigue calibration coefficient adjustment, and use of the mean average air temperature dependency for the AASHTOWare PMED thermal cracking coefficient (finding that a single value was better suited for the thermal cracking coefficient). Ultimately, the latest recalibration research project increased the number of historical MDOT sections used for calibration from 280 to 537 total pavement sections, expanded the catalog of tested materials for AASHTOWare PMED inputs, and validated the calibration by using past MDOT PMED designs to ensure their practicality.

Missouri

The Missouri DOT (MoDOT) was one of the early adopters (circa 2004) of AASHTO Pavement ME. It completed its initial local calibration in 2009 using the initial release of the research software. The initial calibration was focused on calibration for new and reconstructed pavements. In 2016, MoDOT started another local calibration using AASHTOWare PMED v2.5.5 for new and rehabilitated asphalt and concrete pavements. Data from MoDOT's pavement management system and LTPP sections in Missouri were the source of the data for the calibration. The calibration was completed in 2019 and published in 2020.

In 2024, MoDOT began making the transition from the AASHTOWare PMED desktop version (v2.5.5) to the web application (v3). The first part of this transition entailed setting up the web-based program (i.e., establishing users and permissions, configuring workspaces, and defining libraries) and training its users in the operation of the software. This part of the transition is expected to be completed in the first half of 2025. The second part of the transition involves recalibration of the performance prediction models. This effort is planned to start in the second half of 2025.

MoDOT has a long-standing policy of promoting innovation and fostering competition in highway construction. A major way of affecting this policy is using alternate pavement bidding on large projects involving new full-depth pavement and pavement rehabilitation. With MoDOT's Pavement ME implementation, it has successfully developed equivalent asphalt and concrete designs for hundreds of alternate design / alternate bid (ADAB) projects. Additional information on this practice can be found on Missouri DOT's optimal and alternate pavement designs webpage.

New Jersey

The New Jersey DOT (NJDOT) uses the latest available web version, AASHTOWare PMED v3.21, to design new and reconstructed asphalt pavements and to perform parallel designs with the *1993 AASHTO Guide* for asphalt overlays. A Material Catalog for most of the asphalt mixes used in New Jersey was developed under the NJDOT's Pavement Support Program through its work with Rutgers University and it is available on the Pavement and Drainage Management and Technology website. Under the Pavement Support Program, Rowan University is working on developing Level 1 material input for CIR, FDR, and CCPR layers. NJDOT has found that material properties of specialized mixes, such as SMA, bottom-rich base course, CIR, FDR, and CCPR, can be modeled using AASHTO Pavement ME, thus allowing pavement engineers to predict the performances of pavements with these mixes. A calibration study is also going on under the NJDOT Pavement Support Program.

Average annual daily traffic (AADT) with truck percentages is available on the NJDOT Traffic Monitoring System (TMS) website. The growth factor is calculated by an in-house database using census data. Vehicle class distribution has a significant effect on predicted pavement performance. Thus, having the best possible estimates for commercial truck volumes, truck class distributions, axle load configurations, and other traffic characteristics is critical to ensuring a suitable pavement thickness design. The NJDOT has developed traffic clusters for regions and functional classification. The traffic clusters are based on approximately 90 WIM sites and include axle load spectra, vehicle class distribution, and axle truck ratio. The traffic input files are available for use by in-house staff and design consultants on the NJDOT Pavement and Drainage Management and Technology website.

NJDOT's pavement management system database and as-built information are available for general information input, construction history, and the condition of existing pavement.

Utah

The Utah DOT (UDOT) has been conducting pavement designs using AASHTO Pavement ME since 2011. An initial local calibration for new asphalt pavement and overlays (focusing on the bottom-up fatigue cracking, transverse cracking, rutting, and IRI models) was performed in 2009. This was followed by a second local calibration in 2013 that focused on the rutting models.

With the agency's transition to AASHTOWare PMED v2.5, a third calibration involving all the above models was needed and was performed in 2019. Under this calibration, the predicted developments of rut depth were significantly reduced, however, the UDOT pavement engineers believe that value is still being overpredicted. Corresponding reductions in the IRI trends were also observed. Bottom-up cracking varied compared to those predicted using the earlier calibrated models, but generally, the predicted cracking was increased. Transverse cracking trends, on the other hand, were significantly increased because of the 2019 calibration.

The 2019 recalibration resulted in an increased pavement thickness of 2 to 4.5 inches for interstate pavements designed with 95 percent reliability. For non-interstate pavements designed with 90 percent reliability, reductions up to 2 inches and increases up to 1.5 inches were observed. The thickness increases were attributed to the changes in the bottom-up cracking model coefficients. UDOT has adopted the new calibration factors and updated its *Pavement Design Manual of Instruction* to reflect this. The increase in transverse cracking trends did not have an impact on pavement thickness, however, UDOT is exploring higher quality asphalt mixes to reduce the transverse cracking.

Virginia

The Virginia DOT (VDOT) was 1 of 15 lead agencies in MEDPG implementation and began planning its implementation efforts around 2007. VDOT completed several research projects to support the development of materials, traffic, and climate inputs for the design procedure and provided extensive training for its pavement designers.

Proceeding into the calibration stage, VDOT determined that a staged approach to implementation would be appropriate, with the initial focus on calibrating new asphalt and CRCP located on interstate, primary, and high-volume secondary routes, and a subsequent focus on rehabilitation design for pavements on these routes. The goal of implementing AASHTOWare PMED v2.2.6 for new construction, reconstruction, and lane widening projects on January 1, 2018, was successfully achieved. Now, recognizing the upcoming sunset of all desktop versions by AASHTO, the agency has shifted its focus from implementation of the rehabilitation design procedure to developing a plan to adopt the web-based version for new design. To facilitate this, the agency is working on upgrading AASHTOWare PMED to the latest web-based version.

Recognizing the tremendous shift from using the *1993 AASHTO Guide* and corresponding DARWin software to the MEPDG and AASHTOWare PMED, the agency developed the *AASHTOWare Pavement ME User Manual* for use by VDOT staff, consultants, and contractors. The document provides an overview of ME pavement design; guidance in selecting the many design inputs; and information and illustrations for entering the inputs, running the design analysis, and evaluating the outputs from the AASHTOWare PMED software. The user manual is posted on the Department's business webpage, along with AASHTOWare PMED materials, traffic, and climate input files.

In the adoption of AASHTO Pavement ME, VDOT executed a specific implementation plan. The plan contained goals, target dates, and weekly team meetings were used to discuss progress and problems. Monthly teleconferences were also conducted with stakeholders, including the FHWA and industry groups.

Challenges that VDOT faced during implementation included:

- Characterization of specialized materials (e.g., recycled asphalts, polymer-modified asphalts, SMA). VDOT developed guidance for AASHTOWare PMED users for modeling recycled materials, FDR, and CCPR in the pavement design process.
- Development of Virginia-specific design input XML files and AASHTOWare PMED software resources (i.e., materials, traffic, climate). Current versions are available in VDOT databases and webpages for external software users.
- Development of policy guidance on the minimum layer thickness for asphalt and aggregate base materials.
- Amount of time required for local calibration and implementation as well as the need for recalibration corresponding to software and model updates. The 2015 calibration effort focused on the bottom-up fatigue cracking and total rutting models for asphalt design and the punchout model for CRCP design (local calibration for JPCP was not performed due to the lack of calibration sites). Although attempts were made to calibrate the IRI models, the lack of initial IRI data prevented the development of acceptable calibrated models.
- Achievement of buy-in from management and stakeholders.
- Achievement of balance between perfection and excellence.

CHAPTER 6. SUMMARY AND CONCLUSIONS

More than 2 decades have passed since the MEPDG design procedure was first introduced and detailed as part of NCHRP Project 1-37A (ARA 2004). While the procedure is much more complicated than the 1993 *AASHTO Guide* and requires tremendously more data and information, many of the design concepts are consistent with those in the 1993 *AASHTO Guide*. Moreover, although the models encompassed by the procedure require periodic calibration to account for changes in materials, technologies, and environmental conditions, the expected outcome of these refinements is more accurate and reliable pavement designs.

Like the empirical design procedure featured in the 1993 *AASHTO Guide*, widespread implementation of the MEPDG procedure and accompanying software has only gradually occurred. This is because a vast amount of time is needed by a highway agency to learn about the methodology, evaluate its feasibility for use under its local conditions, assemble the required data and information, test and verify the acceptability of designs, and train the design personnel. Additionally, it takes time to adapt to the periodic updates and fixes in the PMED software.

The objective of this synthesis was to document the latest progress made by highway agencies in implementing AASHTO Pavement ME and to highlight the implementation experiences—challenges, successful strategies, and lessons learned—of selected agencies. The information presented in this synthesis was obtained through a comprehensive literature review, an AASHTO web-based survey of State DOTs and provincial MOTs, and case-study interviews with three selected DOTs. A summary of the key findings of these activities is presented below, followed by a list of actions or strategies to aid implementation and a list of suggestions for future research.

Literature Review

A review of recent literature (2014–present) indicates that highway agencies have been mostly focused on AASHTO Pavement ME performance model verification and local calibration/validation. These efforts include both first-time calibrations, as well as one or more recalibrations corresponding to PMED software updates. Agencies have also continued their material characterization efforts. Most notable among these efforts have been the attempted transitions from Level 2 to Level 1 inputs for HMA and PCC mixes, the characterization of modified mixes, and updates to the material libraries and XML material input files.

Agency Survey

Ten years following the release of the MEDPG in 2004, only 3 agencies (out of 41 U.S. States and 8 Canadian provinces) had reported adoption of the procedure, while 46 others reported being in the process of implementation (Pierce and McGovern 2014). Since 2014, the number of implemented agencies has increased to 17 and 15 for design of new asphalt pavements and new concrete pavements, respectively, based on 2024 survey responses from 32 DOTs and 5 MOTs. Approximately half of these agencies use AASHTO Pavement ME solely for production design, whereas the others use it in parallel or as a secondary method with another design procedure. The number of agencies that have implemented Pavement ME for asphalt and concrete overlay designs are 7 and 8, respectively.

The vast majority of agencies that have not implemented AASHTO Pavement ME are using the *AASHTO 1993 Guide* to design their pavements. Agencies that do not intend to implement Pavement ME have different reasons for this but most commonly cite the time and expense of the calibration effort and the challenges of keeping calibrations in pace with the current version of the AASHTOWare PMED software. Of the 37 total agencies surveyed, 21 and 15 have performed at least one local calibration of the asphalt and concrete pavement performance prediction models, respectively.

Highway agencies credit many different factors in the successful implementation of AASHTO Pavement ME. Chief among these are obtaining upper management support and adequate funding, having strong leadership and/or a champion, and having experienced and knowledgeable staff. Major challenges to implementation noted by highway agencies include conducting local calibrations and transitioning from the previous design procedure to an acceptable comfort level with Pavement ME.

Case Studies

Case studies for 11 DOTs highlighted several lessons learned for the successful implementation of AASHTO Pavement ME. The case-study agencies had performed a combination of verification of the national models and local calibration in their implementation process. Most found verifying national models much simpler than a full-scale calibration. Many of the agencies used a catalog approach that simplified the implementation and did not require the typical pavement designer to operate the AASHTOWare PMED software. The development of libraries for material properties, traffic, and climatic data also facilitated the use of the software. The DOTs noted that continuous training was required due to staff turnover. Finally, commitment by the implementation team and management was key to a successful implementation.

The case-study agencies also noted items that hindered their implementation. Continued updates to the methodology and software required multiple calibrations, which can be major undertakings. The agencies are hoping that the use of the CAT will simplify the calibration and recalibration process. Users have looked forward to AASHTOWare PMED v3.0 with anticipation and trepidation as the software moves to a web-based version. Some DOTs are concerned with the queueing of the execution and receiving timely results, while others worry that changes could be made to the software without the user’s knowledge.

Implementation Strategies

The following suggestions are provided as a means of facilitating the adoption of AASHTO Pavement ME within a highway agency and ensuring its successful long-term use.

- Obtain and sustain upper management support and adequate funding.
- Provide upper management with justification for implementation via complete and accurate analysis of benefits.
- Designate and sustain a long-term champion, along with steering and technical support committees to assist the champion.
- Ensure adequate staffing and resources are available for making the transition to AASHTO Pavement ME and for using it on a production basis.
- Develop and execute an implementation plan that includes specific goals, action items, target dates, assigned leads, and pertinent information sources.
- Conduct regular meetings of the core and expanded implementation teams to monitor progress and make adjustments to the implementation plan.

- Involve and solicit the inputs of various internal and external stakeholders, such as agency materials, construction, and pavement management staff and representatives from pavement industry, consultants, academia, and other highway agencies.
- Provide continual support and training for both internal and external design staff, covering all technical aspects, including the AASHTOWare PMED software and the local calibration procedures and tool (CAT).
- Use Pavement ME in its current form on actual projects on a shadow basis to continuously assess its reasonableness, identify shortcomings, and establish needs for further development.
- Use a staged approach to implementation that focuses on simpler and more readily attainable designs first, followed by more complex designs requiring longer durations to complete. Examples include implementation of new design followed by rehabilitation design and implementation of designs using conventional materials first followed by designs using modified materials.
- Focus calibration efforts on only those pavement performance parameters that typically come into play in design (i.e., minimize efforts in developing calibration coefficients for parameters that do not drive performance for the agency). For instance, if concrete pavement joint faulting is not a problem for an agency, it will be difficult to calibrate the model effectively and that distress could be removed from design consideration as long as the agency continues its practices to minimize faulting.
- Consider the development and use of a State-specific Pavement ME-based design catalog, suitable for common sets of conditions defined by geography, terrain, soils, traffic, district practices, and other factors.
- Expand and update source data used to characterize materials and traffic and to calibrate/validate the AASHTOWare PMED models. Develop libraries for materials, traffic, and other inputs to make the implementation an operation easier.
- Continually evaluate the reasonableness and suitability of agency-defined and default design inputs as well as climate source data.

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APPENDIX A. PMED IMPLEMENTATION SURVEY AND RESPONSES

1. Respondent information (name, title, organization, phone number, email address).

2. Has your agency implemented Pavement ME Design for the design of new asphalt pavements?

Response Option	No. Responses	Response Percent
Yes	16	43.2
No	21	56.8

3. If yes, what was the year of implementation?

Response Option	No. Responses
2004	1
2005	0
2006	0
2007	0
2008	0
2009	1
2010	1
2011	1
2012	1
2013	0
2014	3
2015	0
2016	0
2017	1
2018	1
2019	2
2020	0
2021	1
2022	2
2023	1
2024	0

4. If No, by what Year does your agency plan to be implemented?

Response Option	No. Responses
2024	0
2025	2
2026	1
2027	0
2028	0
2029	0
2030	0
2031	0
2032	0
2033	0
2034	0
2035	1
Unknown/Undecided/Undetermined	10
Others[1]	1

[1] Others cited: Local calibration of v3.0 anticipated in 2026, results will determine direction.

5. Has your agency implemented Pavement ME Design for the design of asphalt overlays?

Response Option	No. Responses	Response Percent
Yes	6	16.7
No	30	83.3

6. If yes, what was the year of implementation?

Response Option	No. Responses
2004	0
2005	0
2006	0
2007	0
2008	0
2009	0
2010	1
2011	0
2012	0
2013	0
2014	1
2015	0
2016	0
2017	0
2018	1
2019	1
2020	0
2021	1
2022	1
2023	0
2024	0

7. If No, by what Year does your agency plan to be implemented?

Response Option	No. Responses
2024	0
2025	4
2026	1
2027	0
2028	0
2029	1
2030	0
2031	0
2032	0
2033	0
2034	0
2035	1
Unknown/Undecided/Undetermined	13
Others[1]	0

[1] Others cited: None.

8. For which types of new asphalt pavements and asphalt overlays has your agency implemented or plan to implement Pavement ME Design (select all that apply)?

Response Option	No. Responses—Implemented	No. Responses—Planning to Implement
New Conventional Asphalt Pavement	11	13
New Deep-Strength Asphalt Pavement	14	13
New Full-Depth Asphalt Pavement	12	11
New Semi-Rigid Pavement	9	8
Asphalt Overlay on Existing Asphalt Pavement	6	18
Asphalt Overlay on Existing Intact or Fractured Concrete Pavement	7	15
Asphalt Overlay on Existing Composite Pavement	6	13

9. If your agency is using Pavement ME Design for new asphalt pavements or asphalt overlays, in what capacity is it being used (select one)?

Response Option	No. Responses	Response Percent
Sole Use	8	28
Primary Parallel Use	4	14
Primary Secondary Use	5	17
Shadow Use	12	41

10. If your agency is not using Pavement ME Design for new asphalt pavements or asphalt overlays, or is using it in a secondary or shadow capacity, what pavement design methodology is being used?

Response Option	No. Responses
AASHTO 1972 (Interim Guide)	2
AASHTO 1986	0
AASHTO 1993	19
Asphalt Institute	0
Other empirical design procedure or ME design procedure[1]	6

[1] Others cited: Idaho Gravel Equivalence method. AASHTO 93 for new pavements, but in-house remaining service life method for overlays. CalME design procedure has been used since 2004. For overlays, PMED is used as a secondary design and the primary design is to remove/replace in kind plus 0.5 inches of asphalt. Saskatchewan method.

11. If your agency has implemented (or is deeply engaged in implementing) Pavement ME Design for new asphalt pavements or asphalt overlays, what was the biggest technical challenge?

Response Option	No. Responses
Getting design staff and/or consultants trained in the process	2
Transitioning from the previous design procedure and reaching an acceptable comfort level with Pavement ME Design	8
Conducting a local calibration/validation	12
Developing traffic inputs	0
Developing material inputs	0
Properly characterizing the existing pavement structure and conditions	0
Developing compatibility between agency performance measures and Pavement ME Design measures	2
Obtaining and loading software	0
Conducting design analyses and interpreting the results	0
Others[1]	2

[1] Others cited: All of the above plus obtaining sufficient funding to do so. Inconsistency in predicted distress, impractical results.

12. Has your agency conducted a local calibration of the Pavement ME Design asphalt pavement performance prediction models?

Response Option	No. Responses	Response Percent
Yes	20	60.6
No	13	39.4

13. If your agency has conducted a local calibration, please indicate your agency's local calibration history by filling out the year the calibration was performed.

Open-Ended Response Option	No. Responses			
	Calibration #1	Calibration #2	Calibration #3	Calibration #4
2004	0	0	0	0
2005	0	0	0	0
2006	1	0	0	0
2007	0	0	0	0
2008	0	0	1	0
2009	1	0	0	0
2010	2	0	0	0
2011	0	0	0	0
2012	2	0	0	0
2013	2	0	0	0
2014	1	1	0	0
2015	4	2	0	0
2016	1	0	0	0
2017	1	1	1	0
2018	1	1	0	0
2019	0	3	0	0
2020	0	0	0	0
2021	0	1	0	0
2022	1	1	0	0
2023	1	0	1	1
2024	1	1	1	0

14. If your agency has conducted a local calibration, please indicate your agency's local calibration history by filling out what PMED software version was used.

Open-Ended Response Option	No. Responses			
	Calibration #1	Calibration #2	Calibration #3	Calibration #4
MEPDG	0	0	0	0
DARWin-ME v1.0	0	0	0	0
DARWin-ME v1.1	1	0	0	0
v0.6	1	0	0	0
v0.9	0	1	0	0
v1.0	1	0	1	0
v1.1	1	0	0	0
v1.2	0	0	0	0
v1.3	0	0	0	0
v2.0	3	0	0	0
v2.1	3	1	0	0
v2.2	1	0	0	0
v2.3	1	1	1	0
v2.3.1	3	1	0	0
v2.4 (NOTE: There is no v2.4)				
v2.5	0	5	0	0
v2.5.1	0	0	0	0
v2.5.2	0	0	0	0
v2.5.3	0	0	0	0
v2.5.4	0	0	0	0
v2.5.5	0	0	0	0
v2.6	1	1	1	1
v2.6.1	0	0	0	0
v2.6/v3.0	0	2	0	0
v3.0	0	0	0	0
Unknown	3	0	0	0
Other[1]	1	1	1	0

[1] Others cited: CalME.

15. If your agency has conducted a local calibration, please indicate your agency's local calibration history by filling out which models were included in each calibration effort:

Open-Ended Response Option	No. Responses			
	Calibration #1	Calibration #2	Calibration #3	Calibration #4
HMA Bottom-Up Cracking	16	6	4	2
HMA Top-Down Cracking	8	4	3	1
HMA Transverse Thermal Cracking	12	4	5	2
HMA Reflective Cracking	9	5	5	1
HMA Rutting-Asphalt layer	12	6	5	2
HMA Rutting-Total	16	7	6	2
HMA Smoothness (IRI)	16	5	4	2

16. If your agency has conducted a local calibration(s), how would you characterize the outcome of that effort(s)?

Response Option	No. Responses	Response Percent
Very Successful	5	25.0
Moderately Successful	8	40.0
Inconclusive	7	35.0
Failure	0	0.0

17. Has your agency implemented Pavement ME Design for the design of new concrete pavements?

Response Option	No. Responses	Response Percent
Yes	15	48.4
No	16	51.6

18a. If yes, what was the year of implementation?

Response Option	No. Responses
2004	1
2005	0
2006	1
2007	0
2008	0
2009	1
2010	1
2011	2
2012	1
2013	0
2014	2
2015	1
2016	0
2017	1
2018	2
2019	1
2020	0
2021	0
2022	1
2023	0
2024	0
Not sure	0

18b. If No, by what Year does your agency plan to be implemented?

Response Option	No. Responses
2024	0
2025	2
2026	0
2027	0
2028	0
2029	0
2030	0
2031	0
2032	0
2033	0
2034	0
2035	0
Unknown/Undecided/Undetermined	4
Others	0

19. Has your agency implemented Pavement ME Design for the design of concrete overlays?

Response Option	No. Responses	Response Percent
Yes	9	28.1
No	23	71.9

20a. If yes, what was the year of implementation?

Response Option	No. Responses
2004	0
2005	0
2006	0
2007	0
2008	0
2009	1
2010	0
2011	0
2012	1
2013	0
2014	1
2015	2
2016	0
2017	0
2018	1
2019	1
2020	0
2021	0
2022	1
2023	1
2024	0
Not sure	0

20b. If No, by what Year does your agency plan to be implemented?

Response Option	No. Responses
2024	0
2025	2
2026	0
2027	0
2028	0
2029	0
2030	0
2031	0
2032	0
2033	0
2034	0
2035	0
Unknown/Undecided/Undetermined	7
Others	0

21. For which types of new concrete pavements and concrete overlays has your agency implemented or plan to implement Pavement ME Design (select the status of all that apply)?

Response Option	No. Responses—Implemented	No. Responses—Planning to Implement
New Jointed Plain Concrete (JPC) Pavement	15	10
New Continuously Reinforced Concrete (CRC) Pavement	4	4
Unbonded JPC or CRC Overlay on Existing Concrete or Composite Pavement	7	9
Bonded Portland Cement Concrete (PCC) Overlay on Existing Concrete Pavement	1	4
PCC Overlay on Existing Flexible Pavement	7	7
Short Jointed Plain Concrete Pavement (SJPCP) Overlay on Existing Flexible Pavement (aka Bonded Concrete Overlay on Asphalt Pavement [BCOA])	3	6
JPC Pavement Restoration	1	6

22. If your agency is using Pavement ME Design for new concrete pavements or concrete overlays, in what capacity is it being used (select one)?

Response Option	No. Responses	Response Percent
Sole Use	10	40.0
Primary Parallel Use	4	16.0
Primary Secondary Use	2	8.0
Shadow Use	9	36.0

23. If your agency is not using Pavement ME Design for new concrete pavements or concrete overlays, or is using it in a secondary or shadow capacity, what pavement design methodology is being used?

Response Option	No. Responses
AASHTO 1972 (Interim Guide)	1
AASHTO 1981 (revised 1972 Interim Guide)	1
AASHTO 1986	0
AASHTO 1993	14
AASHTO 1998 (rigid supplement to 1993 Guide)	2
PCA	0
Other empirical design procedure or ME design procedure[1]	3

[1] Others cited: AASHTO 93 for new pavements, but in-house remaining service life method for overlays. Concrete design is performed by different office-answers provided are tentative only. For thin whitetopping, the BCOA program is used.

24. If your agency has implemented (or is deeply engaged in implementing) Pavement ME Design for new concrete pavements or concrete overlays, what were the biggest technical challenges?

Response Option	No. Responses
Getting design staff and/or consultants trained in the process	2
Transitioning from the previous design procedure and reaching an acceptable comfort level with Pavement ME Design	8
Conducting a local calibration/validation	9
Developing traffic inputs	1
Developing material inputs	0
Properly characterizing the existing pavement structure and conditions	1
Developing compatibility between agency performance measures and Pavement ME Design measures	2
Obtaining and loading software	0
Conducting design analyses and interpreting the results	0
Others[1]	5

[1] Others cited: Not having a sufficient number of sections. All of the above and also obtaining sufficient funding to do so. Not deeply engaged with implementation at this time. Inconsistent predicted distresses. Have not implemented yet.

25. Has your agency conducted a local calibration of the Pavement ME Design concrete pavement performance prediction models?

Response Option	No. Responses	Response Percent
Yes	16	50.0
No	16	50.0

26. If your agency has conducted a local calibration, please indicate your agency's local calibration history by filling out the year the calibration was performed.

	No. Responses			
Open-Ended Response Option	**Calibration #1**	**Calibration #2**	**Calibration #3**	**Calibration #4**
2004	1	0	0	0
2005	0	0	0	0
2006	2	0	0	0
2007	0	0	0	0
2008	1	1	0	0
2009	1	0	0	0
2010	1	0	0	0
2011	0	1	0	0
2012	2	1	0	0
2013	1	0	0	0
2014	1	0	1	0
2015	4	0	0	0
2016	0	0	0	0
2017	1	1	0	0
2018	0	0	0	0
2019	1	2	0	0
2020	0	0	0	0
2021	0	2	0	0
2022	1	0	0	0
2023	0	0	1	0
2024	0	1	1	0

27. If your agency has conducted a local calibration, please indicate your agency's local calibration history by filling out what PMED software version was used.

Open-Ended Response Option	No. Responses			
	Calibration #1	Calibration #2	Calibration #3	Calibration #4
MEPDG	2	0	0	0
DARWin-ME v1.0	0	1	0	0
DARWin-ME v1.1	0	0	0	0
v0.6	0	0	0	0
v0.9	1	0	0	0
v1.0	1	1	0	0
v1.1	1	0	0	0
v1.2	0	0	0	0
v1.3	0	0	0	0
v2.0	2	0	0	0
v2.1	2	0	0	0
v2.2	1	0	1	0
v2.3	1	1	0	0
v2.3.1	3	0	0	0
v2.4 (NOTE: There is no v2.4)				
v2.5	0	2	0	0
v2.5.1	0	0	0	0
v2.5.2	0	0	0	0
v2.5.3	0	0	0	0
v2.5.4	0	0	0	0
v2.5.5	0	1	0	0
v2.6	1	0	1	0
v2.6.1	0	0	0	0
v2.6/v3.0	0	0	0	0
v3.0	0	2	1	0
Unknown	0	0	0	0
Other	0	0	0	0

28. If your agency has conducted a local calibration, please indicate your agency's local calibration history by filling out which models were included in each calibration effort:

Open-Ended Response Option	No. Responses			
	Calibration #1	Calibration #2	Calibration #3	Calibration #4
JPC Transverse Slab Cracking	13	9	4	1
JPC Mean Joint Faulting	12	8	3	1
CRC Punchouts	3	0	0	0
SJPCP Longitudinal Cracking	1	0	0	0
JPC Smoothness (IRI)	10	7	3	2
CRC Smoothness (IRI)	4	1	1	1

29. If your agency has implemented (or is deeply engaged in implementing) Pavement ME Design, what were the biggest non-technical challenges?

Response Option	No. Responses
Funding restrictions	2
Limited resources and time	16
No strong leader/champion	0
Internal agency resistance	2
External resistance	2
Retirements/turnover	3
Inexperienced or inadequately trained staff	3
Others[1]	7

[1] Others cited: Cost and time of re-calibrations. Collaboration between pavement design and pavement management. Not deeply engaged with implementation at this time. Contracting. Have not implemented it yet.

30. If your agency has implemented (or is deeply engaged in implementing) Pavement ME Design, what were the key elements in achieving implementation (rank each from 1 to 12, with 1 being most important and 12 being least important)?

Response Option	Weighted Average Score	Ranking
Upper management support / adequate funding	20.7	1
Strong leadership/champion	19.6	2
Experienced and knowledgeable technical staff	18.8	3
Well-conceived and documented implementation plan	16.2	4
Strong interaction between offices	9.9	10
Effective steering/oversight committee	9.8	11
Comprehensive training	12.8	6
External support (industry, university, consultants)	11.3	8
Sufficient and good quality data to drive the Pavement ME Design process	13.5	5
Successful characterization of design inputs	11.1	9
Successful local calibration of performance models	11.6	7
Compatibility between agency and Pavement ME Design performance measures/thresholds and test standards/specifications	6.2	12

31. If your agency has implemented (or is deeply engaged in implementing) Pavement ME Design, what was the biggest implementation advantage?

Response Option	No. Responses
Current AASHTO method (i.e., keeping pace with the state-of-the-practice)	4
Conducting appropriate designs given local conditions (i.e., minimizing over and under designs)	6
Ability to characterize local and advanced materials	3
Ability to characterize local climatic affects	1
Ability to characterize local truck loading conditions	1
Dissatisfaction with the old method	0
Greater confidence in design results and subsequent decision-making regarding pavement/rehabilitation type	1
Expanded opportunities to optimize designs	6
Others[1]	3

[1] Others cited: None-the program is too complicated, and not enough research has been done to ensure the prediction models are correct. In addition, so many versions since 2014, with each version giving a different response to the same project/traffic loads, etc. Have not implemented it yet.

32. If your agency plans to implement Pavement ME Design, what additional work is required to assist with implementation?

Response Option	No. Responses
Evaluate economic impact of alternative designs	2
Determine benefits over existing procedure	6
Evaluate applicability to current conditions	2
Establish an oversight committee to evaluate/approve the procedure	1
Develop an implementation plan	3
Develop a training plan	1
Obtain buy-in from other agency divisions	0
Obtain approval from upper management	2
Others[1]	10

[1] Others cited: VDOT implemented Pavement ME for new design-to update to new software version, additional calibration work is needed. Obtain approval from upper management-concerns over reduced life with reduced thickness. Needs to be a value-added implementation. Significant funding needs and additional time resources. Not sure we will implement. None-we are fully implemented but do not trust the program due to its numerous inconsistencies. Satisfaction with software outputs. Evaluate predicted performance from v3.0 with field performance. Set up inputs and use the software.

33. If your agency does not intend to implement Pavement ME Design, what are the contributing factors?

Response Option	No. Responses
Calibration is too expensive, time-consuming, and/or requires an outside entity with expertise in performing calibrations	3
On-going model recalibration and new models	2
On-going software revisions and enhancements	1
Insufficient staffing and expertise	1
Lack of management support and/or coordination among agency units	1
Models do not reflect the performance of agency pavements	0
Development of inputs, assumptions, and criteria is too expensive and time consuming	1
Lack of good quality data for existing pavement structure (layer types and thicknesses), materials, traffic, and/or conditions	2
Others[1]	5

[1] Others cited: VDOT implemented Pavement ME for new flexible and rigid design. Have implemented PMED for concrete designs but have not made a decision on implementing for asphalt designs due to calibration needs and the learning curve associated with moving from AASHTO 93 to PMED. Inconsistent and impractical outputs.

34. Would you be willing to participate in a follow-up interview of less than 30 minutes to provide more details about your agency's implementation activities and progress?

Response Option	No. Responses	Response Percent
Yes	22	66.7
No	11	33.3

35. Please provide any additional thoughts or comments related to the implementation and use of Pavement ME Design that were not covered in the preceding questions.

- Training/Support is needed for agencies to conduct local calibration. This will help agencies to perform local calibration on their own and help them to understand the design process and calibration for future updates/enhancements.
- I think v3.0 will greatly assist in implementation given the ability of the root admin user to customize the experience for the DOT.
- Ohio had a local calibration effort completed in 2009 on the research version of the software and provided the next steps that were followed to gather additional local data for a future calibration planned to be completed in 2026 on V3.0 of AASHTOWare PMED Software. This was not noted in the survey since it was the older version prior to becoming the AASHTOWare product.
- California has implemented PMED for concrete pavements but has its own ME design method for asphalt pavements called CalME. Calibration performed in 2021 for concrete pavements showed that the results were very similar (less than 0.5 inches) compared to the use of global calibration so global calibration was used to develop catalog tables for general use. For major projects, the actual PMED can be used in lieu of catalog tables.
- Local calibration and staff willing to switch to a new system are the key components to a successful implementation.
- Currently working on the verification for rigid to move from 2.6 to 3.0. For us, the software developer made calibration possible without their direction we could not have done it.
- Do your homework on traffic and Material input before implementation.
- The program has been wrought with inconsistencies. When we contact the software developer for an explanation or to determine if we are doing something wrong, we very rarely get an answer; 6 months later we ask the same question and get the opposite answer. We waited 4.5 years for the software developer to provide us with calibrations for version 2.6.2. We have yet to receive the final report. But the calibrations were wrong, and we had to go back to version 2.3.1. Except now that version gives erroneous designs. A template is sent to 20 computers to run, 15 of the computers will have different answers, some pass at 6 inches, others never pass at 30 inches. The software developer will not discuss the issue since 'they have moved on to a new version' CDOT has not been able to run any designs since July of 2023, we are dead in the water. The software developer wants us to move to version 3.0, but all soils, HMA, PCCP mixes in our library must be redone because the new version is either sensitive to creep compliance or soils need optimum moisture content - variables that were not needed prior, so our database with 100+ mixes is useless now and it will take many months to redevelop our libraries and we have limited staff. In the meantime, we have no reliable program to run designs since version 2.3.1 is no longer stable and the 2.6.2 calibrations were incorrect, so CDOT is struggling immensely.
- NJDOT has started using Web Version of Pavement ME from 2024.
- Canadian User Group (TAC ME Pavement Design Subcommittee) is conducting systematic evaluation of the software outputs, papers are published, and any issues are being brought forward to the Task Force.

APPENDIX B. AGENCY IMPLEMENTATION CASE STUDIES

When all the completed surveys were received, the results were tabulated and analyzed and became the basis for the development of this synthesis report. In the questionnaire, agencies were asked if they were willing to serve as implementation case studies. From the 22 volunteer agencies, 3 were selected to participate in supplementary interviews: Colorado DOT, Florida DOT, and Kentucky Transportation Cabinet. These States were selected as they represent different stages implementation, have different needs and priorities concerning implementation, have unique environments and geographies, and have different experience levels and practices concerning pavements and materials.

The interviews concentrated on triumphs and lessons learned by these agencies in their MEPDG implementation journey that could be applied by other agencies. Two-page case studies of the interviews were prepared and provided to the interviewees for their review. The final versions of Colorado, Florida, and Kentucky case studies are presented in the sections below.

Colorado

In 2015, the Colorado Department of Transportation (CDOT) became one of the first agencies to fully adopt AASHTOWare PMED v2.1 for the design and analysis of asphalt and concrete pavements. CDOT saw the implementation of PMED as a logical improvement in their pavement design method as AASHTO moved toward the implementation of ME pavement design. CDOT had the staffing, funding, and management support to enable this implementation.

A considerable effort was conducted to locally calibrate the performance prediction models to Colorado conditions, compile weather station information, and develop an extensive materials library. Most of CDOT's implementation has been in-house and through AASHTO's support consultant. Some initial material testing for AASHTOWare PMED was conducted by outside laboratories. CDOT was very satisfied with this initial implementation, which resulted in concrete pavement thickness decreasing by about 2 inches and asphalt pavement thickness increasing by about 2 inches.

CDOT and the consultant calibrated/validated each subsequent version as they were released. CDOT's calibration/validation for AASHTOWare PMED v2.5 did not go smoothly and resulted in a hybrid of v2.6 and v3.0.

In moving toward the implementation of AASHTOWare PMED v2.6 and v3.0, CDOT has uncovered issues with its materials library and climatic data. AASHTO has recommended that CDOT rebuild their materials library with additional testing data for satisfactory results. With limited staffing and laboratory testing equipment, this may be problematic for the Department.

CDOT is working toward the implementation of AASHTOWare PMED v3.0 and is updating its *Pavement Design Manual* to reflect the implementation of AASHTOWare PMED v3.0. The goal is to have the implementation and updated manual in place by July 2025. Funding and staffing for this activity are more limited now than in the original implementation.

Florida

The Florida Department of Transportation (FDOT) started its AASHTO Pavement ME implementation journey around 2007. While the JPCP calibration efforts moved along and ultimately resulted in published calibration factors for Florida, FDOT had concerns with Pavement ME for asphalt pavements including:

- FDOT-developed designs using the *1993 AASHTO Guide* performed well, and there were no significant savings with AASHTOWare PMED adoption.
- Predominant asphalt pavement distress is top-down cracking. In 2007, there was no top-down cracking model in AASHTOWare PMED.
- Research by Goehl and Nyamuhokya (2022) recommended delaying the implementation of AASHTOWare PMED v2.6 until additional research and model calibrations are performed.

The initial JPCP calibration started in 2008 using AASHTOWare PMED v1.0, with a second calibration completed in 2015 using v2.2. FDOT had limited JPCP sections and used LTPP sections from adjacent States to complete the calibration. The 2015 calibration modified five calibration factors as shown in table 10.

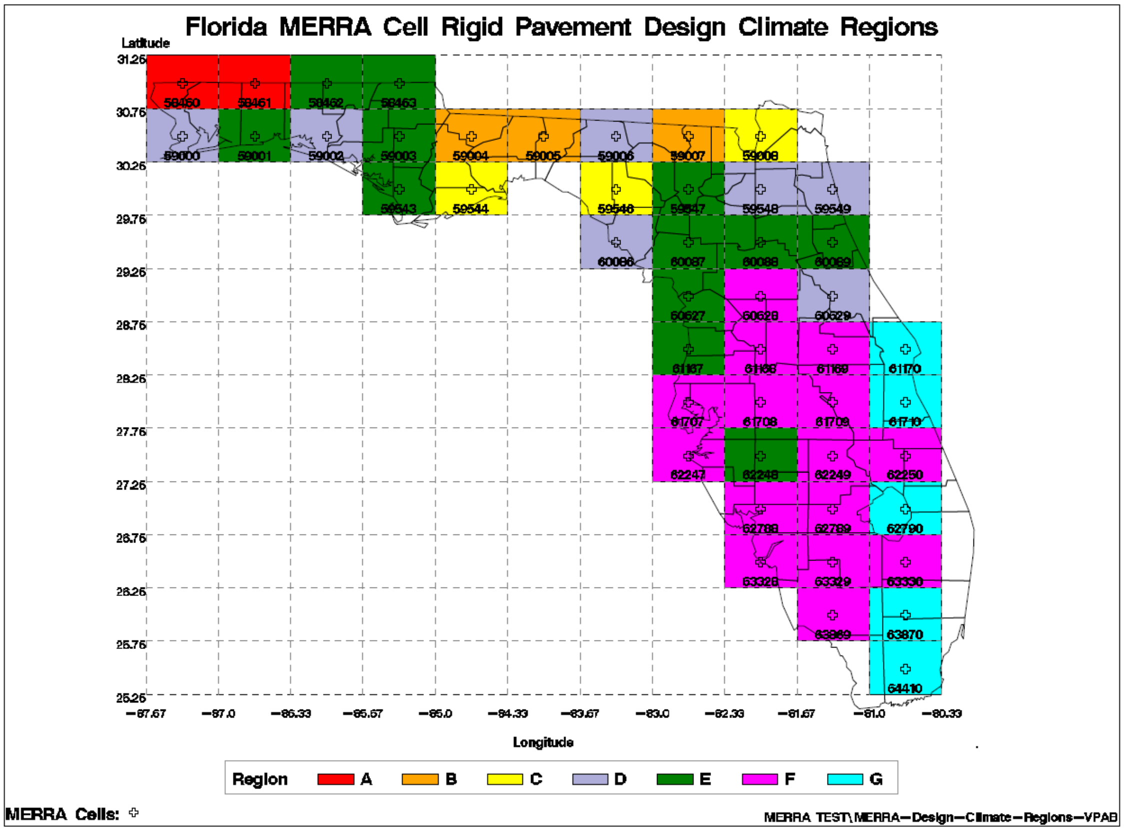
Table 10. FDOT 2015 JPCP calibration factors.[2]

Calibration Parameter	2015 AASHTO *MEPDG Manual of Practice* Global Calibration Factor (AASHTO 2015)	FDOT 2015 Calibration Factor
PCC Cracking C4	1.0	1.38E-07
PCC Cracking C5	-1.98	-3.633
PCC Faulting C1	1.0184	4.0472
PCC Faulting C6	0.4	0.0790
PCC IRI-JPCP C3	1.4929	2.2555

By 2009, FDOT was using AASHTOWare PMED as an option in parallel with the 1993 *AASHTO Guide* for new or reconstructed JPCP designs. In 2018, FDOT moved exclusively to AASHTOWare PMED designs of new and reconstructed JPCP.

The *FDOT Rigid Pavement Design Manual 2022* uses a catalog approach for JPCP designs developed with AASHTOWare PMED v2.2.6. The designer uses a map (figure 9) developed from MERRA climatic data to determine the climate region, and then, traffic loading and reliability are used to select the slab thickness. The catalog assumes 15-ft joint spacings and a 13-ft widened lane with an erosion-resistant base. If a district cannot construct the 13-ft wide slab, then a customized AASHTOWare PMED design is required.

[2] Table data obtained from project interview with Florida DOT representative.



Source: Florida DOT

Figure 9. Florida rigid pavement design climate regions (FDOT 2022).

While FDOT is comfortable with its present approach and calibration, it is anticipating the adoption of AASHTOWare PMED v3.0 as support for the desktop versions is phased out. They are in the process of obtaining additional technical support in the Central Office pavement design section to perform an in-house recalibration using the CAT. FDOT believes v3.0 is a better platform and would simplify computer and network issues with server permissions for the software and data files. FDOT is relying heavily on using the CAT with the hope that the experience may facilitate the implementation of AASHTOWare PMED for asphalt pavements.

In preparation for the adoption of newer versions and recalibration, FDOT constructed a 2.5-mile concrete test road which has been under traffic since March 2023. The concrete test road contains 52 experimental sections to study structural, drainage, and calibration variables. FDOT also constructed a parallel asphalt test road that was opened to traffic in September 2024. The asphalt test road includes 12 experimental sections to evaluate the base type, lift thickness, reflective cracking mitigation, alternative mix design protocol, and open-graded friction course.

Staffing and training have been significant challenges for FDOT during the implementation and operation of AASHTOWare PMED, especially in the area of knowledge transfer. There are a limited number of people within FDOT who have access to the program. The State Pavement Design Engineer position has changed three times during the evaluation and implementation phases. Project-level pavement designs are performed in FDOT's seven districts and the Florida Turnpike office. Likewise, District/Turnpike pavement design positions have experienced a high turnover rate in recent years as well. Recently, FDOT has cooperated with the Florida Concrete and Products Association and the American Concrete Pavement Association to provide training using AASHTOWare PMED for the design of new and reconstructed JPCP.

Kentucky

Since the late 1990s, the Kentucky Transportation Cabinet (KYTC) has used a pavement design catalog to enable its staff and consultants to quickly and effectively develop pavement designs for its roads. The original design catalog was developed in 1999 using the 1981 Kentucky pavement design process (Graves 2022), which included layer coefficients from the AASHTO *Guide for Design of Pavement Structures*. KYTC prefers a catalog approach to maintain consistency across the agency since most designs for new and reconstructed pavements were completed in the districts or by consultants.

Around 2016, KYTC management wanted to implement the AASHTO Pavement ME. The Department believed the 1999 catalog was conservative and that a further mechanistic approach may produce a more economical design. During the initial phase of AASHTO Pavement ME implementation, KYTC worked with the University of Kentucky Transportation Center and queried other implementing State DOTs for information on their activities and strategies.

KYTC did not undertake an extensive calibration study, rather, it concentrated on a calibration/verification approach given its history with its existing catalog and pavement performance data. Through its sensitivity analysis and DOT survey, KYTC determined that AASHTO Pavement ME performance prediction was most sensitive to subgrade stiffness and traffic levels; therefore, these parameters were used by KYTC to update its 1999 catalog.

As part of the AASHTO Pavement ME implementation, the agency conducted thousands of design runs using AASHTOWare PMED v2.3 covering the spectrum of Kentucky's new pavement structures, traffic levels, and subgrade conditions. The designs used Kentucky-specific design inputs and performance criteria as well as the global calibration coefficients used by other DOTs. Verification of the updated design catalog was performed in 2017 using approximately 30 calibration/verification sites across Kentucky along with a comparison to historical pavement designs.

Results from the AASHTO Pavement ME verification resulted in the pavement thickness for a given set of subgrade and traffic levels being reduced by 1.0 to 1.5 inches. Some combinations resulted in a more significant reduction, but KYTC was not comfortable with that great of a change. Kentucky also varied the failure thresholds, such as using a 10 percent limit for fatigue cracking.

The initial verification concentrated on fatigue cracking, rutting, and pavement smoothness for asphalt pavements, as those were the best developed models at the time. Verification of concrete pavements was more difficult due to the limited use of this pavement type in Kentucky. The verification process concentrated on reasonable performance thresholds compared to the prior catalog moving to 10 percent fatigue cracking and 0.25 inches of rutting for asphalt pavement and 0.10 inches of faulting for concrete pavements. The application of engineering judgment to the verification process resulted in adopting the global calibration factors for the performance prediction models except for subgrade rutting. Subgrade rutting was not a common pavement distress in Kentucky. The subgrade rutting model global calibration coefficient was overpredicting rutting; therefore, the coefficients were adjusted to reflect field performance better.

KYTC's online design catalog is available for use by agency engineers and consultants engaged in developing pavement designs. KYTC also developed a *Pavement Design Guide, January 2018 Update for Full Depth Projects*. The KYTC considers the catalog quick to use and easy for new users to train on. The agency is currently in the process of updating its manual to include AASHTOWare PMED v3.0. KYTC's catalog approach has bridged multiple turnovers in personnel at the central office, 12 districts, and consultants. On average, the districts see a turnover of pavement design leads every 1 to 2 years.

In addition to developing a software catalog, KYTC developed material libraries for common pavements, aggregates, and subgrades and a traffic library. KYTC used its extensive volumetric mix data for its asphalt mixtures to define mix properties. The AASHTO Pavement ME correlations were verified with limited modulus testing. Since KYTC predominantly performed Level 3 designs, they believed using Level 3 data in the correlation/verification was the most appropriate. The traffic library provided vehicle class breakdown by roadway functional class.

KYTC believed this implementation method allowed them to build confidence in AASHTO Pavement ME for the design of new and reconstructed pavements. Since the Pavement ME design thicknesses were compared to the 1999 catalog and controlled through the online design catalog, this was a low-risk approach to implementation. With this confidence level, KYTC has applied AASHTO Pavement ME to rehabilitation analysis and design.

For pavement rehabilitation applications, customized AASHTO Pavement ME designs were developed based on pavement forensics using input templates for AASHTOWare PMED v3.0. Multiple options are then provided to the Pavement branch and/or the project designer for alternative selection. Rehabilitation design using Pavement ME is currently reserved for in-house design and has not been released to consultants. KYTC has not applied a catalog approach for rehabilitation since the designs are unique and complex compared to new and reconstructed pavements.

KYTC continues to refine its pavement design catalog and is initiating a more robust calibration procedure using AASHTOWare PMED v3.0, along with the sites used in the past and pavement management data. They are waiting for the sensitivity analysis to be included in AASHTOWare PMED v3.0 and have started exploring the CAT.

In the initial AASHTO Pavement ME calibration/verification effort, KYTC believed it did not have as much traffic data as it would have liked, since it has limited WIM data. Better traffic data may lower the risk of thinner pavement designs.

Another KYTC calibration concern was the lack of uniformity with distress identification between AASHTO Pavement ME and agency standards. Quantification and types of distress used by Pavement ME differed from those used by most pavement management systems and pavement distress collection equipment vendors. Kentucky posited that a standard crosswalk could be built to assist DOTs in consistently translating the data for AASHTO Pavement ME calibration.

KYTC has become an enthusiastic user of AASHTOWare PMED v3.0. They appreciated the improved accessibility, speed, and library features. The major benefits of AASHTO Pavement ME implementation cited by KYTC include decreased cost (thinner pavements), consistent application, and an improved catalog.

KYTC was anticipating moving toward client-side processing to reduce queueing. KYTC's concern with AASHTOWare PMED v3.0 was that changes could be made to the software without the user's knowledge. Although there was a protocol for testing these changes before they were deployed, KYTC was aware of an instance where the change resulted in an error in the design. KYTC believed the protocols were not robust enough at present. In addition, KYTC noted that there needs to be better publicly available documentation on all changes made to the software.

KYTC was also aware that numerous white papers had been developed over the years to answer unique questions about AASHTO Pavement ME and AASHTOWare PMED applications. Presently, access to these documents is only available by querying AASHTOWare PMED support staff. KYTC believed incorporating these documents into a knowledge-based tool would lessen user frustration. KYTC also found that locating information and changes in the AASHTO *MEPDG MOP* could be difficult, and a tool to assist users with that would be helpful.