Guidelines for Implementing NCHRP 1-37A M-E Design Procedures in Ohio

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Problem
The Ohio Department of Transportation (ODOT) uses the 1993 version of the American Association of State Highway Transportation (AASHTO) Guide for Design of Pavement Structures as a basis for designing new and rehabilitated highway pavements. In recognition of some of the widely accepted limitations of this Guide, AASHTO initiated two major research projects—National Cooperative Highway Research Program (NCHRP) Projects 1-37A and 1-40—to develop a modern design method. This effort resulted in the Mechanistic-Empirical Pavement Design Guide (MEPDG) and software. The MEPDG became an interim AASHTO pavement design standard in late 2007.

The MEPDG represents a paradigm shift in pavement design, and full implementation can take several years. However, the benefits of implementing the MEPDG appear to be significant, ranging from cost-effective designs to positive effects on mobility and congestion.

Objectives
The primary objective of this study is to develop guidelines for ODOT to implement the MEPDG procedure. The major items of interest include (1) an assessment of ODOT’s needs to implement the procedure, (2) establishment of default values (means and ranges) for those inputs that have adequate data from previous ODOT
research, and (3) validation of nationally calibrated distress and smoothness prediction model using readily available Ohio-specific pavement section data.

**Description**

Experience has shown that the flow of work for a successful MEPDG implementation effort should follow that depicted in figure 1. To ensure that the findings of this research readily integrate into ODOT’s implementation plans, the project team strived to perform the research tasks, interpret the data, and present the findings in a manner that is compatible with this model framework.

Key implementation activities included (1) defining the scope of the implementation, (2) developing a factorial of pavement sections for local validation/calibration of the MEPDG, (3) selecting readily available Ohio-specific pavement section data and literature to customize the MEPDG procedure inputs and to validate/calibrate MEPDG distress and smoothness models for Ohio conditions, inasmuch as possible, and (4) identifying gaps in the current body of work and recommending ways to overcome them through future research efforts.

**Scope of MEPDG Implementation in Ohio**

The MEPDG can be used to design 17 different new and rehabilitated pavement types. At a project kick-off meeting involving key ODOT stakeholders, it was determined that the following seven “families” of pavements and rehabilitations were of most interest to ODOT:

1. New or reconstructed jointed plain concrete pavement (JPCP)—high priority.
2. New hot-mix asphalt (HMA) pavements (all types)—high priority.
3. Unbonded JPCP overlays of existing portland cement concrete (PCC) pavements—high priority.
4. HMA overlays over rubblized PCC slabs (excluding continuously reinforced concrete pavement)—high priority.
5. HMA overlays over HMA pavement—moderate priority.
6. HMA overlays over JPCP—moderate priority.
7. Restoration, including concrete pavement restoration (CPR) and grinding—low priority.

The high priority pavement types were considered as part of this effort.

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Figure 1. Breakdown of work activities and work flow for implementing the MEPDG in Ohio.
Literature Review

Following the scope identification, a detailed review of national and Ohio-specific MEPDG literature was conducted to identify pertinent information that could be useful in the implementation effort. Over 200 relevant publications were found through a search of national literature. A majority of this body of work focused on the following:

- Characterization of input parameters such as traffic loading, layer material and subgrade foundation properties, climate, and other design features.
- Sensitivity of globally calibrated performance prediction models to agency-specific inputs.
- Validation and calibration of the performance prediction models.
- Agency business plans and strategies for local implementation of the MEPDG.

The literature review also identified important national research activities and state implementation activities that could have some bearing on ODOT’s implementation of the MEPDG.

ODOT has sponsored a number of research projects within the last decade to improve pavement performance standards. A majority of these projects focused on improved characterization of pavement materials and understanding the fundamental properties of various paving materials. A few of these studies also looked into traffic issues, pavement performance, and pavement construction and management databases.

As a result of these research efforts, some typical ODOT materials can be characterized as required by the MEPDG at one of its three hierarchical input levels: for example, HMA dynamic modulus (level 1 for most mixes), HMA creep compliance and tensile strength (level 2 for some mixes), PCC flexural strength and elastic modulus (level 3 for some mixes), and unbound base and subgrade materials (level 2 for most soil types). However, the literature review showed that a more coordinated testing program is required to establish Ohio-specific defaults for all materials for production-level use of the MEPDG. In addition, the literature review indicated that more comprehensive traffic and climatic input characterization studies are needed.

Sensitivity Analysis

The MEPDG includes several pavement distress and smoothness models for use in pavement design. Needless to say, the model outputs are affected by the design- and site-related inputs to the procedure. The degree to which a model is affected by a given input is largely a function of the phenomenological linkage between the two. These linkages have been well established in published MEPDG literature. The objective of the sensitivity analysis task performed under this study was to (1) establish the impact of Ohio-specific site- and design-related inputs on the key design types and models of interest to ODOT and (2) establish the relative importance of the various model inputs to the design process.

The models evaluated include:

- New HMA pavements and HMA overlays of rubblized PCC pavement.
  - Alligator (bottom-up fatigue) cracking.
  - Longitudinal (top-down fatigue) cracking.
  - Rutting.
  - Transverse (thermal) cracking.
  - Smoothness expressed as International Roughness Index (IRI).

- New JPCP and unbonded JPCP overlays.
  - Transverse (bottom-up and top-down fatigue) cracking.
  - Mean joint faulting.
  - Smoothness.
Version 1.000 of the MEPDG was used to perform the sensitivity study.

The sensitivity study showed the distress predictions trending on expected lines with the design and site variables. However, there were a few notable exceptions:

1. The longitudinal (top-down) cracking model seems to be affected only by thickness, and that effect is significant. All other factors (e.g., climate and climate-materials interaction) seem to have little influence.
2. The HMA rutting model seems to depend greatly on HMA thickness.
3. The HMA alligator cracking model is affected significantly by HMA thickness, asphalt binder content and base type.
4. The HMA thermal cracking model seems to be moderately sensitive to HMA thickness and highly sensitive to climate.
5. The JPCP fatigue cracking model seems to be very sensitive to seemingly small changes in climate.

Some of these findings merit further investigation during local calibration of the MEPDG models.

**Model Validation and Calibration**

The backbone of the design methodology proposed in the MEPDG is its ability to predict distress and smoothness accurately. The prediction models in the MEPDG were calibrated using data mostly from the Long Term Pavement Performance (LTPP) database, which contains pavement design, materials, climate, traffic, and performance data from several thousand flexible and rigid pavement projects from across the country, including in Ohio. These models are known as “nationally” or “globally” calibrated models.

It has been recognized in the MEPDG that these nationally calibrated models may need to be locally validated and calibrated.

Validation is the first step to determine if the nationally calibrated models are accurate when used to predict the performance of pavements in a local area. Calibration follows thereafter, whereby any identified model deficiencies are adjusted statistically.

A limited validation and calibration exercise was conducted as part of this study using Ohio’s LTPP sections. The LTPP Specific Pavement Studies (SPS) sites are excellent for this type of validation because they have been subject to extensive research since their construction and contain high-quality input data. Also, since a majority of these sections were either new HMA pavements or JPCP, the validation and calibration were limited to these pavement types. Figure 2 shows the geographic distribution of these projects within Ohio.

Results of the validation exercise for new HMA pavement models showed the following:

- As the alligator cracking data on the LTPP SPS-1 and SPS-2 projects were confounded with construction-related cracking, the model was not evaluated or recalibrated due to a lack of adequate data for analysis.
- Based on the data from a limited number of SPS-1 and SPS-9 projects, the nationally calibrated transverse cracking model seems to be adequate. However, it is recommended that ODOT reassess the model using data from Northern Ohio sites before making a final decision.
- Although there is a fair correlation between the measured and predicted rutting, the HMA rutting model overpredicts the measured rutting with significant bias in the predictions.
- The nationally calibrated HMA IRI model exhibited poor correlation and significant bias in predictions.
Results of the validation exercise for the JPCP models showed the following:

- Although the transverse cracking model predicts reasonably well, there is a need for additional analysis using data from moderate to highly distressed pavements.
- There is a very good correlation between measured and MEPDG predicted faulting; however, this model needs to be recalibrated using data from sections with greater amounts of faulting distress.
- The nationally calibrated JPCP IRI model exhibited excellent correlations but with significant bias.

The validation exercise indicated that the nationally calibrated models for HMA rutting, HMA IRI and JPCP IRI were deficient. These models exhibit significant bias in their predictions for Ohio conditions. The project team performed local calibration of all the deficient models using the Ohio-specific LTPP section data. The recalibration was completed successfully, with the models showing much improved goodness-of-fit statistics and reduced overall model errors.

**Conclusions and Implementation Plans**

The model validation effort demonstrated that local calibration of the globally calibrated models may be necessary and that it can be done. However, caution is recommended when using the locally calibrated models derived in this study for production work because of the limited inference space from which the data were derived. A majority of the sections used to validate the models (approximately 95 percent) were from one site. Therefore, the recalibration efforts were biased to the prevailing site conditions at this location.

A more thorough validation/calibration effort is recommended using a broader dataset. The research provides specific recommendation in this regard. The items covered in the detailed implementation plan include:
• An experimental factorial consisting of key rigid and flexible pavement factors covering the pavement design inference space of interest for ODOT.
• The minimum number of sections required to populate each cell and the desirable section attributes.
• Materials, traffic, climate, and foundation data needs assessment and recommendations to obtain additional data.
• Data collection plans and database needs.

• Model refinement.
• Costs and resources for implementation.

It is recommended that the implementation plan be a well-coordinated approach even if it is done in a piecemeal fashion so that work products developed in each increment add to the existing knowledge base and can be easily integrated. It is anticipated that the proposed MEPDG implementation effort could take between 3 to 5 years to complete and could cost between $100,000 and $200,000 each year.