

Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide

November 2010



Preface

This guide is to provide guidance to calibrate the *Mechanistic-Empirical Pavement Design Guide* (MEPDG) software to local conditions, policies, and materials and to conduct the local calibration process. The guide does not provide guidance for determining the inputs and running the MEPDG software. A separate document, the *Mechanistic-Empirical Pavement Design Guide—A Manual of Practice*, provides guidance for using the MEPDG software to analyze and design new pavements and rehabilitation strategies. The *Manual of Practice* is referenced throughout this guide.

Version 1.0 of the MEPDG software is currently available. It should be noted that version 2.0 of the MEPDG software is in the process of being developed. Version 2.0 may include different transfer functions for selected distresses based on the results and recommendations from other on-going NCHRP projects. If any of the transfer functions are revised, the *Guide for Local Calibration* and the *Mechanistic-Empirical Pavement Design Guide—A Manual of Practice* for the MEPDG software may need to be revised accordingly.

Table of Contents

1.0 INTRODUCTION	1-1
2.0 TERMINOLOGY AND DEFINITION OF TERMS	2-1
2.1 Statistical Terms	2-1
2.2 MEPDG Calibration Terms	2-3
2.3 Hierarchical Input Level Terms	2-3
2.4 Distress or Performance Indicator Terms	2-4
3.0 SIGNIFICANCE AND USE	3-1
4.0 DEFINING ACCURACY OF MEPDG PREDICTION MODELS	4-1
4.1 Calibration	4-1
4.2 Validation	4-3
4.3 General Approach to Local Calibration-Validation	4-4
4.3.1 Traditional Approach—Split-Sample	4-4
4.3.2 Jack-knife Testing—An Experimental Approach to Refine Model Validation	4-4
5.0 COMPONENTS OF THE STANDARD ERROR OF THE ESTIMATE	5-1
5.1 Distress/IRI Measurement Error	5-2
5.2 Estimated Input Error	5-3
5.3 Model or Lack-of-Fit Error	5-3
5.4 Pure Error	5-3
6.0 STEP-BY-STEP PROCEDURE FOR LOCAL CALIBRATION	6-1
7.0 REFERENCED DOCUMENTS AND STANDARDS.....	7-1
7.1 Referenced Documents	7-1
7.2 Test Protocols and Standards	7-1
APPENDIX: EXAMPLES AND DEMONSTRATIONS FOR LOCAL CALIBRATION	A-1
A1. Background	A-1
A2. New Flexible Pavements and Rehabilitation of Flexible Pavements	A-2
A2.1 Demonstration 1—PMS Data and Local Calibration	A-2
A2.1.1 Description of PMS Segments	A-2
A2.1.2 Step-by-Step Procedure	A-2
A2.2 Demonstration 2—LTPP Data and Local Calibration	A-34
A2.2.1 Description of LTPP Test Sections Used in Demonstration.....	A-34
A2.2.2 Step-by-Step Procedure	A-35
A2.3. Summary for Local/Regional Calibration Values	A-62
A2.3.1 Comparison of Results: PMS Segments and LTPP SPS Test Sections	A-62
A2.3.1.1 Alligator (Fatigue) Cracking Transfer Function	A-63
A2.3.1.2 Rut Depth Transfer Function	A-64
A2.3.1.3 Thermal Cracking Transfer Function	A-65
A2.3.1.4 IRI Regression Model	A-66
A2.3.2 Application of Results from Local Calibration Process for Pavement Design	A-66

A2.4 Attachments	A-68
A2.4.A Attachment A—Description of PMS Segments	A-68
A2.4.A.1 HMA Full-Depth New Construction/Reconstruction Projects	A-68
A2.4.A.2 HMA Overlay of Flexible Pavement Projects	A-72
A2.4.B Attachment B—Plots of Time-History Performance Data	A-73
A2.4.B.1 Full-Depth HMA, New Construction	A-74
A2.4.B.2 HMA Overlays of Flexible Pavements, Rehabilitation	A-80
A2.4.C Attachment C—Description of LTPP Projects	A-84
A2.4.C.1 Full-Depth and Conventional New Construction—LTPP SPS-1 Projects	A-84
A2.4.C.2 HMA Overlays of Flexible Pavement—LTPP SPS-5 Projects	A-85
A2.4.D Attachment D—Plots of Time-History Performance Data for the LTPP SPS Projects	A-86
A2.4.D.1 Full-Depth and Conventional HMA, New Construction	A-86
A2.4.D.2 HMA Overlays of Flexible Pavements, Rehabilitation	A-90
A3. New Rigid Pavements—Jointed Plain Concrete Pavements.....	A-94
A3.1 Demonstration 3—LTPP and PMS Data and Local Calibration.....	A-94
A3.1.1 Description of LTPP And PMS Segments.....	A-94
A3.1.2 Step-by-Step Procedure.....	A-94
A3.2 Attachments	A-117
A3.2.A Attachment A—Description of MODOT LTPP and PMS JPCP Segments	A-117
A3.2.A.1 Design (Analysis) Life	A-117
A3.2.A.2 Analysis Parameters	A-118
A3.2.A.3 Traffic	A-119
A3.2.A.4 Climate	A-124
A3.2.A.5 Pavement Surface Layer Thermal Properties	A-124
A3.2.A.6 Design Features for JPCP Sections	A-124
A3.2.A.7 Pavement Structure Definition	A-126
A3.2.B Attachment B—Plots of Time-History Performance Data	A-126

List of Figures

Figure 1-1. Conceptual Flow Chart of the Three-Stage Design/Analysis Process for the MEPDG..... 1-2

Figure 6-1. Flow Chart of the Procedure and Steps Suggested for Local Calibration; Steps 1 Through 56-2

Figure 6-2. Flow Chart of the Procedure and Steps Suggested for Local Calibration; Steps 6 Through 116-3

Figure A2-1. General Location of the Roadway Segments Selected for Demonstrating the Local Validation-Calibration Process Using Kansas PMS Data A-8

Figure A2-2. Comparison of Predicted and Measured Rut Depths Using the Global Calibration Values and Local Calibration Values of Unity A-16

Figure A2-3. Comparison of Predicted and Measured Fatigue Cracking Using the Global Calibration Values and Local Calibration Values of Unity..... A-17

Figure A2-4. Comparison of Predicted Thermal Cracking and Measured Transverse Cracking Using the Global Calibration Values and a Local Calibration Value of Unity..... A-17

Figure A2-5. Comparison of Predicted and Measured IRI Using the Global Calibration Values and Local Calibration Values of Unity A-18

Figure A2-6. Comparison of the Intercept and Slope Estimators to the Line of Equality for the Predicted and Measured Rut Depths Using the Global Calibration Values A-19

Figure A2-7. Comparison of the Intercept and Slope Estimators to the Line of Equality for the Predicted and Measured IRI Using the Global Calibration Values A-20

Figure A2-8. Comparison of Predicted and Measured Rut Depths Using the Subgrade and HMA Local Calibration Values for the PMS Segments .. A-26

Figure A2-9. Comparison of Measured and Predicted Values of Fatigue Cracking Using Different Value for the C_2 and β_{f1} Parameters for PMS Segments FDAC-C-3 and FDAC-S-4 A-27

Figure A2-10. Comparison of Predicted and Measured Fatigue Cracking Using the Local Calibration Values for the PMS Segments..... A-28

Figure A2-11. Comparison of Predicted Thermal Cracking and Measured Transverse Cracking Using the Local Calibration Value for the PMS Segments..... A-30

Figure A2-12. Comparison of Predicted and Measured IRI Values Using the Global Calibration Values A-31

Figure A2-13. Comparison of the Standard Error of the Estimate for the Global-Calibrated and Local-Calibrated Transfer Function A-32

Figure A2-14. Rut Depths Measured Over Time for the Kansas SPS-1 Project A-38

Figure A2-15. Determination of the Resilient Modulus of the Subgrade
Using Laboratory Test Data Included in the LTPP Database A-41

Figure A2-16. Determination of the Resilient Modulus of the Unbound
Aggregate Base Layer Using Laboratory Test Data Included in
the LTPP Database..... A-41

Figure A2-17. Comparison of Predicted and Measured Rut Depths Using the
Global Calibration Values..... A-43

Figure A2-18. Comparison of Predicted and Measured Fatigue Cracking
Using the Global Calibration Values..... A-44

Figure A2-19. Comparison of Predicted Thermal Cracking and Measured
Transverse Cracking Using the Global Calibration Values..... A-45

Figure A2-20. Comparison of Predicted and Measured IRI Using the
Global Calibration Values..... A-46

Figure A2-21. Comparison of Predicted and Measured Rut Depths Using
the Local Calibration Values for the Subgrade, Unbound
Aggregate, and HMA Layers..... A-53

Figure A2-22. Comparison of Measured and Predicted Values of Fatigue
Cracking for Specific Test Sections A-54

Figure A2-23. Comparison of Predicted and Measured Fatigue Cracking Using a
Local Calibration Values for the HMA Mixture That Is Air Void Dependent A-55

Figure A2-24. Comparison of Predicted Thermal Cracking and
Measured Transverse Cracking Using the Local Calibration
Values for the HMA Mixture..... A-57

Figure A2-25. Comparison of Predicted and Measured IRI Values
Using the Global Calibration Values..... A-59

Figure A2-26. Comparison of the Standard Error of the Estimate from
the Global and Local Calibration Process A-60

Attachments

Figure A2.4.B.1-1. Full-Depth HMA, New Construction..... A-74

Figure A2.4.B.2-1. HMA Overlays of Flexible Pavements, Rehabilitation. A-80

Figure A2.4.D.1-1. Rut Depth Measurements and Predictions with the
Global Calibration Values..... A-86

Figure A2.4.D.1-2. Fatigue Cracking Measurements and Predictions
with the Global Calibration Values..... A-87

Figure A2.4.D.1-3. Transverse Cracking Measurements and Thermal Cracking
Predictions with the Global Calibration Values..... A-88

Figure A2.4.D.1-4. IRI Measurements and Predictions with the Global Calibration Values..... A-89

Figure A2.4.D.2-1. Rut Depth Measurements and Predictions with
the Global Calibration Values..... A-90

Figure A2.4.D.2-2. Fatigue Cracking Measurements and Predictions with the
Global Calibration Values..... A-91

Figure A2.4.D.2-3. Transverse Cracking Measurements and Thermal Cracking
 Predictions with the Global Calibration Values..... A-92

Figure A2.4.D.2-4. IRI Measurements and Predictions with the Global Calibration Values A-93

Figure A3-1. General Location of the Missouri LTPP and PMS Roadway Segments
 Selected for Demonstrating the Local Validation-Calibration Process A-96

Figure A3-2. LTPP Transverse Cracking A-101

Figure A3-3. Illustration of Initial IRI Backcasting for G01-S-S1 A-105

Figure A3-4. Illustration of Field Measurement of Permanent Curl/Warp
 Effective Temperature A-106

Figure A3-5. Comparison of Predicted and Measured Transverse Joint
 Faulting Using the Global Calibration Values A-109

Figure A3-6. Comparison of Predicted and Measured IRI Using the
 Global Calibration Values A-110

Figure A3-7. Different Stages of Faulting Development..... A-112

Figure A3-8. Effect of Parameter C_1 on Faulting Prediction..... A-112

Figure A3-9. Effect of Parameter C_3 on Faulting Prediction..... A-113

Figure A3-10. Effect of Parameter C_7 on Faulting Prediction..... A-113

Figure A3-11. Effect of Parameter C_8 on Faulting Prediction..... A-114

Figure A3-12. Comparison of Predicted and Measured Faulting Using the New
 Faulting Local Calibration Values for MODOT LTPP and PMS Segments A-116

Figure A3-13. Locations of WIM Sites in Missouri from Which Traffic Data
 Were Obtained for Validation-Recalibration A-121

Figure A3-14. Summary of Years of WIM Data Available..... A-122

Figure A3-15. Monthly Truck Volume Adjustment Factors for 29-1005..... A-122

Figure A3-16. Cumulative Single Axle-Load Distribution for Class 5 Trucks on
 MODOT Heavy Duty Pavements Pertaining to TTC 1 A-123

Figure A3-17. Cumulative Tandem Axle-Load Distribution for Class 9 Trucks on
 MODOT Heavy Duty Pavements Pertaining to TTC 1 A-123

Figure A3-18. Lateral Truck Wander and Mean Number Axles/Truck for 29-1005 A-124

Attachments

Figure A3.2.B.-1. PMS Sites..... A-127

List of Tables

Table 5-1.	Summary of Major Components of Calibration Error Dependency.....	5-2
Table 6-1.	Recommendation for the Flexible Pavement Transfer Function Calibration Parameters to Be Adjusted for Eliminating Bias and Reducing the Standard Error	6-13
Table 6-2.	Recommendation for the Rigid Pavement Transfer Function Calibration Coefficients to Be Adjusted for Eliminating Bias and Reducing the Standard Error	6-13
Table A2-1.	General Structure Information for the Selected Kansas PMS Projects	A-3
Table A2-2.	General Project Information for the Kansas PMS Segments.....	A-5
Table A2-3.	Material Types and Layer Thicknesses for the Kansas PMS Segments.....	A-6
Table A2-4.	Simplified Sampling Template for the Demonstration Using PMS Data	A-8
Table A2-5.	Estimated Number of PMS Segments Needed for the Local Validation-Calibration Process.....	A-9
Table A2-6.	Summary of the Maximum Values of Different Performance Indicators in Comparison to the Design Criteria or Trigger Values (Number of Sites = 16)	A-11
Table A2-7.	Summary of the Statistical Parameters—Global Calibration Values Used for Predicting Performance Indicators for the Kansas PMS Sections.....	A-14
Table A2-8.	Summary of the Statistical Parameters—Local Calibration Values Used for Predicting the Performance Indicators for the Kansas PMS Sections.....	A-24
Table A2-9.	Thermal Cracking Local Calibration Values	A-29
Table A2-10.	LTPP SPS-1 and SPS-5 Site Locations.....	A-34
Table A2-11.	Sampling Template for the Demonstration Using LTPP Data	A-35
Table A2-12.	Summary of the Maximum Values of Different Performance Indicators in Comparison to the Design Criteria or Trigger Values (Number of Sections = 56).....	A-37
Table A2-13.	Summary of the Statistical Parameters—Global Calibration Values Used to Predict the Performance Indicators of the LTPP SPS-1 and SPS-5 Projects.....	A-42
Table A2-14.	Summary of the Performance Indicator Predictions Using the Global Calibration Values	A-47
Table A2-15.	Local Calibration Parameter of Unbound Layers.....	A-51
Table A2-16.	An Analysis of Residual Errors from the Use of Global Calibration Values	A-51
Table A2-17.	Summary of the Statistical Parameters—Local Calibration Values Used for Predicting.....	A-52
Table A2-18.	Local Calibration Values for Ranges of Air Voids in Relation to Thermal Cracking	A-56
Table A2-19.	Comparison of the Two Demonstrations for Flexible Pavements and HMA Overlays	A-63
Table A2-20.	HMA Layers/Mixture Local Calibration Parameters, β_{f1} , C_2	A-64
Table A2-21.	Subgrade/Unbound Layer Local Calibration Parameter, β_{s1}	A-65
Table A2-22.	HMA Layers/Mixture Local Calibration Parameters, β_{r1} , β_{r3}	A-65

Table A2-23. Summary β_{fi} Values from Kansas PMS and LTPP Data	A-66
Table A3-1. General Information for the Selected Missouri LTPP and PMS Projects	A-95
Table A3-2. Material Types and Layer Thicknesses for the Missouri LTPP and PMS Segments .	A-96
Table A3-3. Design Features for the Missouri LTPP and PMS Segments.....	A-99
Table A3-4. Simplified Sampling Template for the Demonstration Using LTPP and PM Data .	A-99
Table A3-5. Estimated Number of PMS Segments Needed for the Local Validation-Calibration Process	A-100
Table A3-6. Summary of the Maximum Values of Different Performance Indicators in Comparison to the Design Criteria or Trigger Values (Number of Sites = 24)	A-102
Table A3-7. Summary of the Statistical Parameters—Global Calibration Values Used for Predicting Performance Indicators for the Missouri LTPP and PMS Sections.....	A-107
Table A3-8. Comparison of Measured and Predicted Transverse Slab Cracking (Percentage of All Data Points)	A-108
Table A3-9. Summary of New Local Coefficients for Faulting Model.....	A-115
Table A3-10. Summary of the Statistical Parameters—Global Calibration Values Used for Predicting Performance Indicators for the Missouri LTPP and PMS Sections .	A-115
Table A3-11. Summary of Construction Dates and Analysis Periods for All New JPCP	A-117
Table A3-12. Summary of Backcast Initial IRI Values	A-118
Table A3-13. Summary of Traffic Inputs for All New JPCP Projects	A-120
Table A3-14. JPCP Project Design Features	A-125



1.0 Introduction

The overall objective of the *Mechanistic-Empirical Pavement Design Guide* (MEPDG) is to provide the highway community with a state-of-the-practice tool for the design of new and rehabilitated pavement structures, based on mechanistic-empirical (M-E) principles. This means that the design procedure calculates pavement responses (stresses, strains, and deflections) and uses those responses to compute incremental damage over time. The procedure empirically relates the cumulative damage to observed pavement distresses. This M-E based procedure is shown in flowchart form in Figure 1-1. “MEPDG,” as used in this guide, refers to the documentation and software package (NCHRP 2007).

Pavement distress prediction models, or transfer functions, are the key components of any M-E design and analysis procedure. The accuracy of performance prediction models depends on an effective process of calibration and subsequent validation with independent data sets. Pavement engineers gain confidence in the procedure by seeing an acceptable correlation between observed levels of distress in the field and those levels predicted with the performance model or transfer function. The validation of the performance prediction model is a mandatory step in their development to establish confidence in the design and analysis procedure and facilitate its acceptance and use. It is also necessary to establish the design reliability procedure. It is essential that distress prediction models be properly calibrated prior to adopting and using them for design purposes.

The term calibration refers to the mathematical process through which the total error (often termed residual) or difference between observed and predicted values of distress is minimized. The term validation refers to the process to confirm that the calibrated model can produce robust and accurate predictions for cases other than those used for model calibration. A successful validation process requires that the bias and precision statistics of the model for the validation data set be similar to those obtained during calibration. This calibration-validation process is critical for potential users to have confidence in the design procedure.

All performance models in the MEPDG were calibrated on a global level to observed field performance over a representative sample of pavement test sites throughout North America. The Long Term Pavement Performance (LTPP) test sections were used extensively in the calibration process, because of the consistency in the monitored data over time and the diversity of test sections spread throughout North America. Other experimental test sections were also included such as

MnRoad and Vandalia. However, policies on pavement preservation and maintenance, construction and material specifications, and materials vary across the United States and are not considered directly in the MEDPG. These factors can be considered indirectly through the local calibration parameters included in the MEPDG. The purpose of this guide is to provide guidance in calibrating the MEPDG to local conditions and materials that may not have been included in the global calibration process.

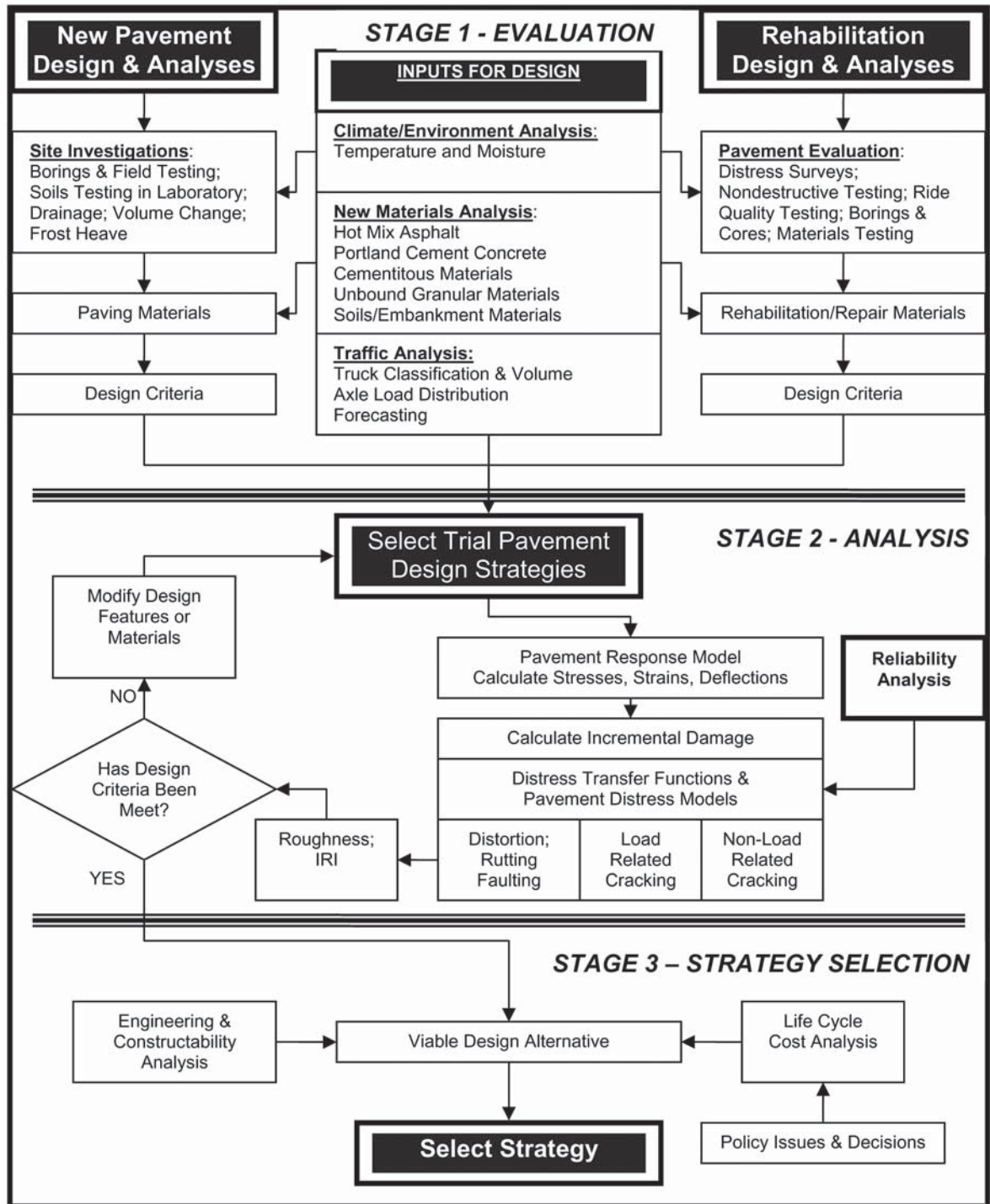


Figure 1-1. Conceptual Flow Chart of the Three-Stage Design/Analysis Process for the MEPDG