DISTRESS MODELING FOR DARWIN-ME

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16. ABSTRACT

Distress prediction models, or transfer functions, are key components of the Pavement M-E Design and relevant analysis. The accuracy of such models depends on a successful process of calibration and subsequent validation of model coefficients in the transfer functions with independent data sets. In this project, data needs for distress models in Pavement ME Design are investigated for the state of Oklahoma. Based on past research work at Oklahoma Department of Transportation (ODOT), various Pavement ME Design inputs, historical cracking, rutting, and roughness data are gathered for selected ODOT segments and Long Term Pavement Performance (LTPP) sites. Pavement ME Design test runs are performed, and precision and bias levels of rutting, cracking, and roughness data sets in the historical ODOT databases are studied. Finally a workflow for Pavement ME Design prediction model calibration in Oklahoma is established to assist ODOT in implementing Pavement ME in the next decade in a production environment.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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CHAPTER 1 PROJECT PROPOSAL

1.1 Background

DARWin (the acronym of pavement Design, Analysis and Rehabilitation for Windows) is the designation for and represents the series of AASHTO's computer software programs for pavement design and is an implementation of the 1993 AASHTO publication - *Guide for the Design of Pavement Structures* (AASHTO 1993). The basic framework of the pavement design procedures contained in the 1993 Guide was developed from data collected during the AASHO Road Test, a full-scale accelerated pavement testing carried out between 1957 and 1962 in Ottawa, Illinois. Therefore, the 1993 Guide is empirical in nature. That is, the procedures are based on observations of performance of various pavement structures under various loading conditions – namely, those conditions present at the AASHO Road Test. While the current AASHTO system has served the pavement community well, it has long been noted that the AASHO Road Test was limited in scope in terms of the variety of featured loads, subgrade support conditions, and environmental conditions. As the understanding has grown of how such factors affect pavement performance, the need for a pavement design guide based as fully as possible on mechanistic principles has been recognized.

Since 1996, NCHRP has sponsored projects to develop, test, revise and disseminate the new generation guide called Mechanistic-Empirical Pavement Design Guide (MEPDG). The first version of the design software was delivered in early 2004 under project 1-37A. 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 (ARA Inc., 2004).

Mechanistic-empirical pavement design is composed of three stages. First of all, a trial structure is proposed and the corresponding design parameters including traffic, climate and materials properties are input into a mechanistic model, which analyzes the structural responses (stress and strain) of the trial design. This is the mechanistic part. The second step is predicting the performance of the trial design using transfer functions, which convert stress and strain into cracking, rutting and smoothness. If the performance passes the pre-determined design criteria, the trial design is considered to be appropriate; otherwise, it is modified, and step one and step two are repeated until the predicted performance fulfills the requirements. This is the empirical part because transfer functions are developed using historical measurements of different pavements. Finally, more trial designs are proposed so that the best strategy could be selected based on life cycle cost analysis and other considerations.

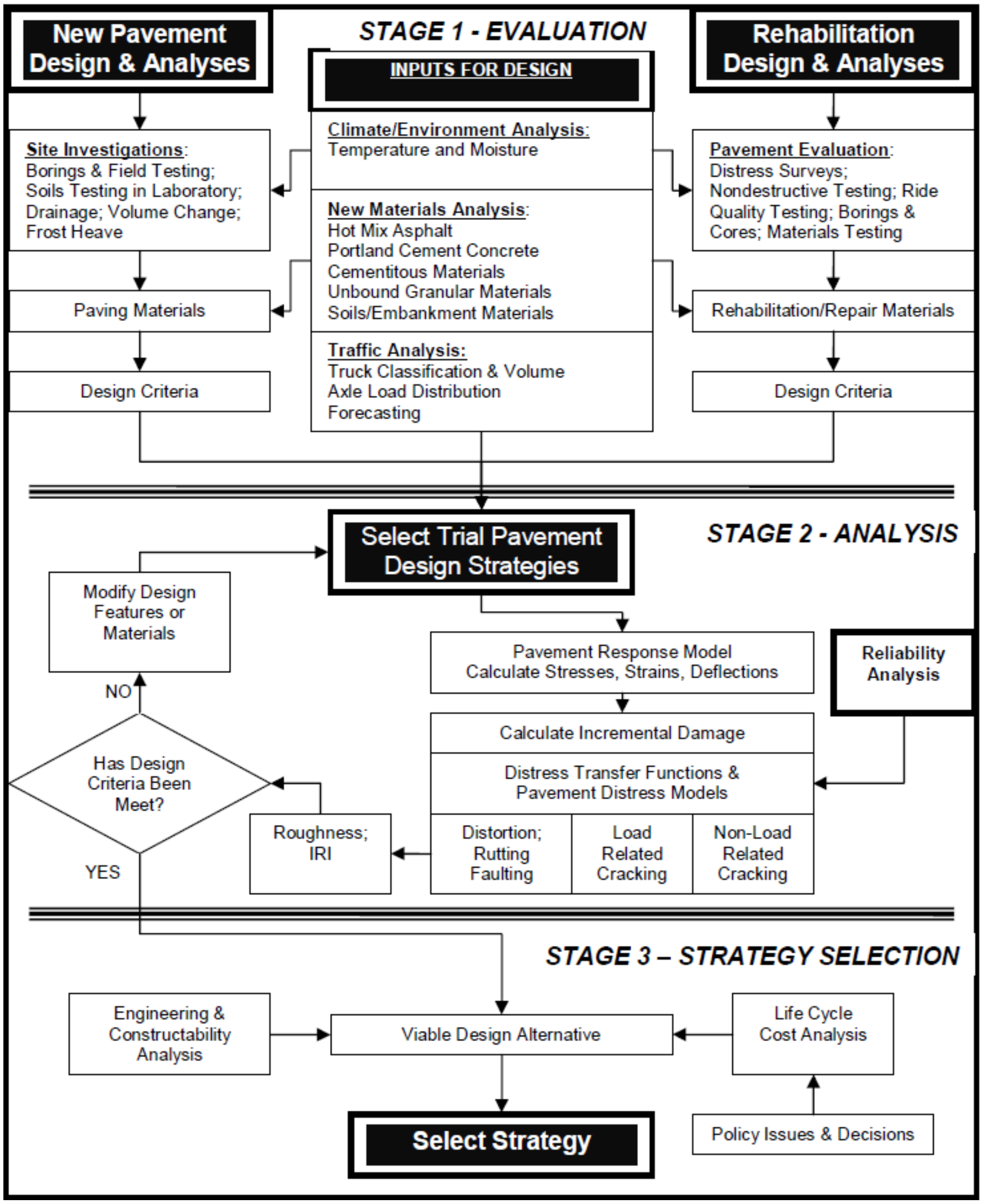


Figure 1.1 Conceptual Flow Chart for DARWin-ME (ARA Inc., 2004)

After the release of the first version of MEPDG, a large number of projects were initiated by NCHRP, FHWA and State Highway Agencies (SHA) to review, test, improve and implement the new design guide. The final product of MEPDG was delivered to AASHTO in 2008. DARWin-ME is the next generation of AASHTOWare® pavement design software which builds upon the MEPDG.

DARWin-ME, for many pavement engineers, will be a paradigm shift away from a nomograph-based design to one based on engineering principles and mechanics. Instead of entering basic site and project information into an equation and getting an empirically based pavement design output, the engineer will be able to use detailed traffic, materials and environmental information to assess the short and long-term performance of a pavement design using nationally and/or locally calibrated models. DARWin-ME is intended to be a comprehensive pavement design and analysis tool, capable of providing support and insights to highway decision-makers, academia and consultants through the entire pavement structure life cycle, from design through maintenance. This type of state-of-the-practice approach represents the current advancements in pavement design. The results of this design approach will be smoother, longer-lasting and more cost-effective pavements (AASHTO 2011).

DARWin-ME requires hundreds of data sets to analyze a pavement design. It may be impractical or unnecessary to collect all data from the field or laboratory testing. Therefore, DARWin-ME has a hierarchical approach which provides designers with a lot of flexibility in data acquisition based on the criticality of the project and the available resources. There are three levels for traffic, climate and material.

- **Level 1**: This level requires the highest quality of site specific data and would have the lowest level of uncertainty and error. Level 1 inputs require laboratory testing or field testing; therefore, it may only be affordable on roads with high volume traffic and importance. For traffic, site specific load spectra may be collected using portable WIM stations. Groundwater table depth could be measured by boring test in the site. Material properties such as dynamic modulus and resilient modulus have to rely on laboratory testing instead of empirical equations.

- **Level 2**: This is the intermediate level of quality and accuracy. Level 2 inputs typically would be user selected, possibly from an agency database, could be derived from a limited testing program, or could be estimated through correlations (ARA 2004). For example, if a designer did not have the resource to test resilient modulus of subgrade in laboratory, he/she may estimate the resilient modulus through simpler tests such as California Bearing Ratio (CBR) test or Dynamic Cone Penetration (DCP) test.
- **Level 3**: This is the level with the lowest quality, which is only recommended for low-volume roadways. Inputs typically would be user-selected values or typical averages for the region. For example, the default values of materials built in the software are Level 3 inputs, because they are just average values in a national level, which may be different from one region to another region.

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 essential that distress prediction models be properly calibrated prior to adopting and using them for design purposes.

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 U.S. 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 recommended practice is to investigate the data needs for the local calibration process and validate the global distress models in DARWin-ME for Oklahoma pavement design. MEPDG, DARWin-ME, and Pavement ME Design are interchangeably used in the report.

1.2 Proposal Tasks

The project focuses on the application of distress models for pavement design in DARWin-ME for ODOT. Historical cracking, rutting, and roughness data in ODOT is used as base data for local model calibrations. Studies will be made in the proposed project on data qualification of the three types of performance indices in ODOT. Recommendations will be made relating to data collection and analysis technologies, and precision and bias requirements for data's future use in DARWin-ME in ODOT.

The objective of this study will be to investigate data needs for distress models in the new DARWin-ME, based on past ODOT research work to establish a workflow in using local level data sets on cracking, rutting, and roughness for DARWin-ME prediction models, and to assist ODOT in implementing DARWin-ME in the next decade as part of ODOT long-term plan in studying and deploying DARWin-ME in a production environment.

More specifically, this project is intended to validate the national calibrated DARWin-ME performance models to Oklahoma' condition, and adjust the DARWin-ME model calibration coefficients to provide better predicted pavement distresses for the design of Oklahoma pavements. The following five sub-objectives are included:

Task 1 Perform Literature Review

There are a number of lead and active states in implementing MEPDG and DARWin-ME, which have conducted extensive research in distress and performance models. ODOT also commissioned a number of studies on MEPDG in recent years. The research team plans to write a synthesis as part of the literature review to understand and analyze the progresses of the agencies in their DARWin-ME research and implementation with the focus on distress and performance models.

Task 2 Gather Data for DARWin-ME Analysis

Under ODOT staff's direction and assistance, the research team will gather cracking, rutting, and roughness data from ODOT on selected routes and sites for testing. During this task, the research team will come up with a plan with selected sites for calibration and DARWin-ME runs. Design, materials, construction, and performance data are all needed from ODOT for calibration of DARWin-ME distress models.

Task 3 Conduct Data Analysis and Validate Distress Models

The research team will commence DARWin-ME test runs at the beginning of the task. As DARWin-ME has brand new relational and network database support, the initial work is to learn and study the functionality of the DARWin-ME database structure and tables. The core of the task then becomes the calibration of the models with data from the selected sites. A particular emphasis of the data analysis process is to study precision and bias levels of rutting, cracking, and roughness data sets in the historical ODOT databases. A particular emphasis of the data analysis process is to study precision and bias levels of rutting, cracking, and roughness data sets in the historical ODOT databases;

Task 4 Develop Distress Model Master Plan for ODOT Implementation

This task will pave the way for ODOT to establish a workflow to conduct the entire distress model calibration. In addition, recommendation will be made to ODOT in terms of data collection technologies for rutting, cracking, and roughness. Acceptable precision and bias levels for consistency and repeatability are critical for successful implementation of DARWin-ME distress models in a local setting. Data analysis on rigid pavements is not to be performed during the proposed study.

However, in this study provisions will be made for future project(s) on applying DARWin-ME for rigid pavement distress models. This task is to establish a step-by-step procedure to calibrate distress models;

Task 5: Submit Final Reports and DARWin-ME Training

In this task, the research team will prepare Final Report of the project. The team will compile our findings in the comprehensive final report at the end of the study. In addition the research team shall conduct a training session to ODOT pavement design staff on DARWin-ME.

1.3 Report Organization

Chapter 1 provides an introduction to the DARWin-ME design procedure and outlines the proposal tasks to be completed for this project.

Chapter 2 gives an overview current calibration and implementation practices by several state highway agencies.

Chapter 3 summarizes large amount of data that have been collected to prepare the DARWin-ME data inputs for 77 selected ODOT flexible pavement segments. These inputs are then used to validate the Pavement ME Design distress models for Oklahoma.

Chapter 4 provides a comprehensive evaluation of the Weigh-In-Motion data in Oklahoma and demonstrates how the data can be used for the preparation of DARWin-ME traffic loading spectra inputs..

Chapter 5 explores the data from the LTPP SPS sites in Oklahoma and Kansas for the usage of distress model validation for Oklahoma. LTPP and DARWin-ME adopts the same distress definitions.

Chapter 6 presents the DARWin-ME analysis results. Comparisons and statistical analysis are conducted between filed monitoring performance and DARWin-ME predictions, aiming to investigate whether the global DARWin-ME distress models need to be local calibrated in Oklahoma.

Chapter 7 establishes a workflow for Oklahoma to locally calibrate DARWin-ME distress prediction models based on the AASHTO Local Calibration Guideline (AASHTO 2010).

Chapter 8 presents the conclusions and future research recommendations.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Pavement performance prediction models contained in the current DARWin-ME were calibrated primarily based on data from the LTPP program. Because of potential differences between ‘national’ and ‘local’ conditions – including climate, material properties, traffic patterns, construction and maintenance activities – pavement performance predicted by the MEPDG should be compared to and verified against local experience.

In all, substantial efforts were attempted in the last few years in understanding data inputs and models used in MEPDG and the new DARWin-ME. Particularly, detailed distress information relating to loading damage and environmental impacts are integrated in the new design procedure.

States are reporting either a partial or full calibration of the MEPDG on a local level. Kang and Adams calibrated the longitudinal and alligator fatigue cracking models for Michigan, Ohio and Wisconsin (Kang and Teresa 2007). All models except top-down longitudinal cracking model were validated for Montana (Von Quintus and Moulthrop 2007). It was found that the MEPDG over predicted total rutting because significant rutting was predicted in unbound base and subgrade soil. Muthadi and Kim calibrated the rutting and bottom-up fatigue cracking model for North Carolina using a spreadsheet-based approach (Muthadi and Kim 2008). In an overview of selected calibration studies, Von Quintus found that the measurement error of the performance data has the greatest effect on the precision of MEPDG models (Von Quintus 2008). California utilized data from accelerated pavement testing (APT) to calibrate its mechanistic empirical pavement models (Ullidtz et al 2008). Although data from APT could be ideal for model calibration considering its advantages of controlled climate condition, precise loading, and testing until pavement fails, most of states that do not have APT facilities can only rely on in-service pavement sites. Texas was divided into five regions for the calibration of rutting models (Banerjee, Aguiar-Moya, and Prozzi 2009). Washington selected two representative calibration sections to calibrate all distress models (Li, Pierce and Uhlmeyer 2009). A national guideline for local calibration was also developed by NCHRP Project 1-40B (Von Quintus, Darter and Mallela 2009). Using Pavement Management Information System (PMIS), MEPDG were verified for Iowa (Kim et al 2010). Systematic difference was found for rutting and cracking models.

2.2 LTPP

The DARWin-ME models were nationally calibrated using LTPP data collected from many pavement sections across United States and Canada (ARA Inc., 2004). These performance models were calibrated for flexible pavement:

- Rutting model or permanent deformation models, including rutting in asphalt mixture and rutting in unbound materials (base and subgrade);
- Fatigue cracking models, including bottom-up or alligator cracking and top-down or longitudinal cracking;
- Thermal (transverse) cracking model; and
- Smoothness (IRI) model.

Initially, 80% of LTPP data were used for calibration and the left 20% data were used for verification. Because a reasonable verification was found, all LTPP data were combined to obtain a comprehensive national model.

Figure 2.1 shows 94 LTPP sites used to calibrate new constructed flexible pavement. It is obvious that the national calibration cannot represent every location in the country. For example, only three General Pavement Sections (GPS) were used in this process in the State of Oklahoma. Therefore, a statewide or regional calibration is recommended for any agency that wants to implement MEPDG with good confidence (ARA Inc., 2004).

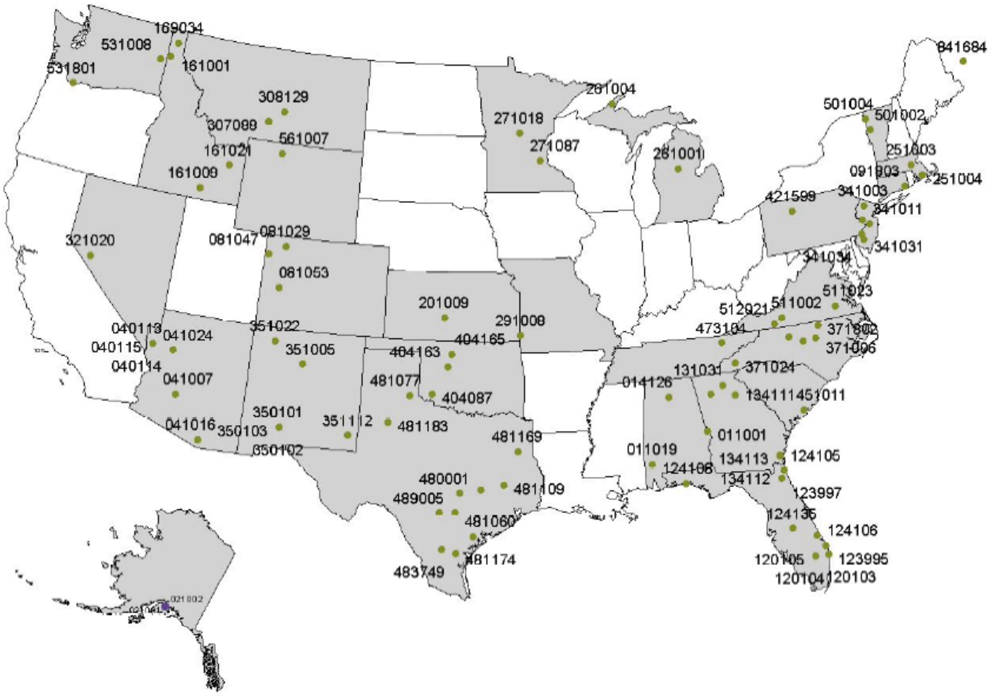


Figure 2.1 LTPP sites for new flexible pavement (ARA Inc., 2004)

2.3 State Practices

Most states in US have a plan to implement MEPDG, in which validation and calibration are necessary steps. There is a large amount of literature available including research reports, published papers and presentations. Experiences from the following states are summarized.

Arkansas

Many efforts have been invested in Arkansas to implement the new design guide. An initial sensitivity analysis was conducted to determine the most significant parameters of the MEPDG (Hall and Beam, 2005). Selected primary inputs required by the MEPDG, were then analyzed – including hot-mix asphalt (HMA) dynamic modulus, various aspects of the traffic load spectra, and the coefficient of thermal expansion of Portland cement concrete (PCC) (Tran and Hall, 2007). In addition, a comprehensive database software named PrepME was developed to manage data sets for MEPDG (Wang et al, 2009). Currently, a local calibration effort is progressing to allow the routine use of the MEPDG in Arkansas.

Florida

Florida started the research of MEPDG by implementing the dynamic modulus test of HMA (Birgisson et al, 2004). In 2007, the Phase I of MEPDG implementation program in Florida was completed (Fernando, Oh and Ryu, 2007). The project produced a database of performance and materials information on in-service pavement sections for calibrating the performance models. Specifically, it was found that the predominant distress on Florida pavements was top-down cracking. While a conceptual framework for calibration was reported, no further report on the calibration result was found. Recently, MEPDG was incorporated into the *Rigid Pavement Design Manual* as an alternate to the AASHTO 1993 and 1998 (Florida DOT, 2009).

Montana

A comprehensive implementation and calibration of MEPDG was conducted for the Montana Department of Transportation (MDT) by Applied Research Assoc. Inc. and Fugro Consultants, Inc. (Von Quintus & Moulthrop, 2007). The project made use of 89 LTPP sections and 13 non-LTPP sites. Moreover, not only LTPP sites in Montana, but also some LTPP sites in the adjacent states were used. Consequently, it was possible to compare the data between Montana and near states to check if any bias exists. It also increased the data points which made the calibration process more statistically robust.

Field and laboratory testing were conducted in non-LTPP sites to obtain the material properties. Pavement performance including deflection using FWD, distress, rutting and smoothness was routinely monitored.

Moreover, all required data for MEPDG prediction and calibration are managed in a specially designed database for this project. The database was developed to permit future data entries so that MEPDG could be recalibrated in the future when more performance data are available. This is extremely important because data required for MEPDG calibration are enormous. The database is based on Microsoft Access 2000, similar to the standard data releases of LTPP (DataPave 3.0).

With the available data, MEPDG was calibrated with Montana’s traffic, material and climate condition. MEPDG Version 0.9 was used for prediction and calibration. It was found that MEPDG significantly over predicted the total rut depth. The average rutting measured in Montana was 0.29 in. For fatigue cracking model, the project found that the MEPDG over predicted the area of alligator cracks (bottom-up cracking) of new construction or in place pulverization of flexible pavements. For longitudinal (top-down) cracking, the difference between the measured and predicted values was significant. Therefore, the top-down cracking model was not recommended for use in Montana. The average length of longitudinal cracking per project in Montana was 965 ft/mi. On the contrary, good correlation was found for non-load related transverse cracking (thermal cracking). The average length of transverse cracks measured on the Montana test sections was 479 ft/mi. The same trend was also obtained for the smoothness model.

Minnesota

A study on MEPDG initiated by the Minnesota Department of Transportation (MnDOT) and the Local Road Research Board (LRRB) was completed (Velasquez, et al., 2009). With the same goal of local calibration, the researchers made use of field performance data obtained from MnROAD pavement sections as well as other pavement sections located in Minnesota and neighboring states.

For flexible pavement, rutting model, alligator cracking model and thermal cracking model were calibrated successfully to match Minnesota’s condition. However, the longitudinal cracking model, rutting model for base and subgrade, and IRI model were not able to be calibrated. For rigid pavement, it was found that the MEPDG model predictions agreed well with field monitoring observations. No adjustment of the faulting model was recommended, and the cracking model could be calibrated. Therefore, the study suggested that the MEDPG can be implemented completely for the design of rigid pavements and partially (without the longitudinal cracking and IRI models) for the design of flexible pavements.

Moreover, the study compared the prediction from different versions of MEPDG. Big difference was found because bugs are solved and models are improved in the new version software. Therefore, it is suggested to repeat the calibration process in the future when new version of MEPDG is released.

Missouri

Missouri is one of the first states to complete its local calibration and the first state to use the MEPDG to design its pavements. Missouri DOT has let more than $1 billion in construction contracts for pavements designed using the new guide (NCHRP, 2008). As early as in 2005, a design manual using mechanistic-empirical method was developed (Missouri DOT, 2005). The manual identified the needs to implement MEPDG and defined the design life, distress criteria and inputs based on Missouri’s condition. In addition, Missouri DOT conducted other research projects to develop a statewide input database such as resilient moduli of typical Missouri soils and unbound granular base materials (Richardson et al. 2009), and creep compliance and indirect tensile (IDT) strength of HMA (Richardson and Lusher, 2008). However, no publication about the calibration was found.

Ohio

Ohio used a limited number of LTPP projects to calibrate the new HMA and JPCP design models of MEPDG (Mallela et al. 2009). For flexible pavement, only the total rutting and IRI model were validated and calibrated. It was found that about

90% of the measured transverse cracking was between 0 to 20 ft/mi. Therefore, recommendations were provided such as selecting more calibration sites, developing statewide material and traffic database, and performance data collection.

2.4 Summary

State highway agencies are making the best use of available data from LTPP and local pavement management systems. Some states only analyzed LTPP sites; some incorporated a few LTPP sites in the neighbor states to increase the sample size; while some selected a few sites from their pavement management system.

Load spectra have to rely on weigh-in-motion (WIM) stations. Many states have research projects analyzing WIM data and prepare traffic data for MEPDG. States that don't have statewide traffic data use default values (Level 3) in the calibration.

Material data are first assembled from design and construction record. For missing data, some states used common values based on engineering experience; some states conducted field tests using FWD, dynamic cone penetrometer (DCP) and nuclear gauge, and laboratory tests on cores taking from the field to obtain material properties such as HMA volumetric properties, tensile strength, and creep compliance. Trenching is needed to extract base and subgrade materials from which resilient modulus, sieve analysis, Atterberg limits and moisture-density are tested. The ground water table depth could be determined by boring adjacent to the trench location. Coring through cracks is also suggested to verify the type of cracking (top-down or bottom-up).

Issues of incompatible data format have been reported. Researchers have to convert the format to MEPDG's requirement which is based on the *LTPP Distress*

Identification Manual. This process sacrifices the accuracy and brings uncertainty into calibration.

After all available data and predicted performance from MEPDG are assembled in a database, prediction and measurement are compared using statistical methods such as regression and hypothesis tests: (1) interception of the linear regression line is zero; (2) slope of the linear regression line is one; and (3) prediction minus measurement is zero. Bias and variation are determined and model calibration is conducted by changing the calibration coefficients.

CHAPTER 3 DATA COLLECTION FOR ODOT SITES

3.1 Pavement Sites for Local Calibration

The AASHTO Local Calibration Guide (AASHTO 2010) provides guidance for the minimum number of total test sections for each distress.

- Distortion (Total Rutting or Faulting)—20 roadway segments
- Load-Related Cracking—30 roadway segments
- Non-Load-Related Cracking—26 roadway segments
- Reflection Cracking (H MA surfaces only)—26 roadway segments

A listing of some factors that should be considered in selecting roadway segments for use in the local validation-calibration refinement plan (AASHTO 2010):

- Roadway segments should be selected with the fewest number of structural layers and materials (e.g., one PCC layer, one or two HMA layers, one unbound base layer, and one subbase layer) to reduce the amount of testing and input required for material characterizations. The roadway segments used to define the standard error of the estimate should include the range of materials and soils that are common to an area or region and the physical condition of those materials and soils.
- Roadway segments with and without overlays are needed for the validation-calibration sampling template. Those segments that have detailed time-history distress data prior to and after rehabilitation should be given a higher priority for use in the experiment because these

segments can serve in dual roles as both new construction and rehabilitated pavements.

- Roadway segments that include non-conventional mixtures or layers should be included in the experimental plan to ensure that the model forms and calibration factors are representative of these mixtures. Many of the LTPP test sections included in the NCHRP Project 1-37A calibration factorial were built with conventional HMA and PCC mixtures.
- It is recommended that at least three condition surveys be available for each roadway segment to estimate the incremental increase in distress over time. The interval between the distress measurements should be similar between all of the test sections. It is also suggested that this time history distress data represent at least a 10-year period, if available. This time period will ensure that all time-dependent material properties and the occurrence of distress are properly taken into account in the determination of any bias and the standard error of the estimate.
- If available, repeat condition surveys should be planned for those roadway segments that exhibit higher levels of distress to reduce the inherent variability of distress measurements and estimate the measurement error for a particular distress. A similar number of observations per age, per project should be considered in selecting roadway segments for the sampling template.

According to the above requirements, 77 HMA sites were identified by ODOT pavement engineers for the local calibration of distress models for DARWin-ME. The locations of these sites are demonstrated in Figure 3.1. The detailed geographic information is provided in Appendix A.

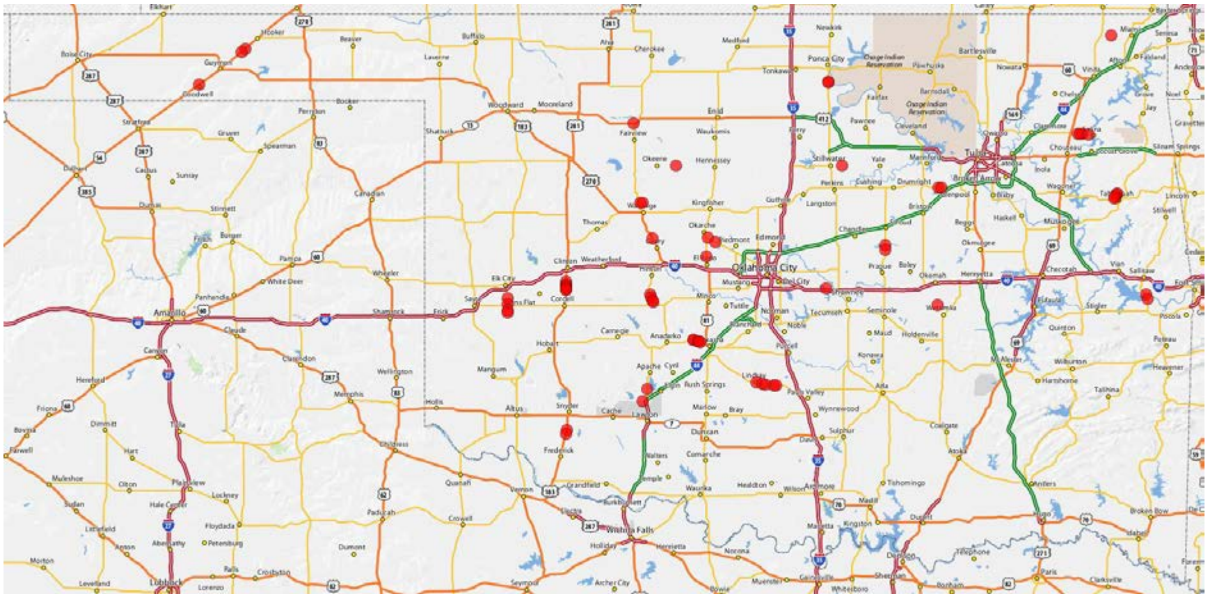


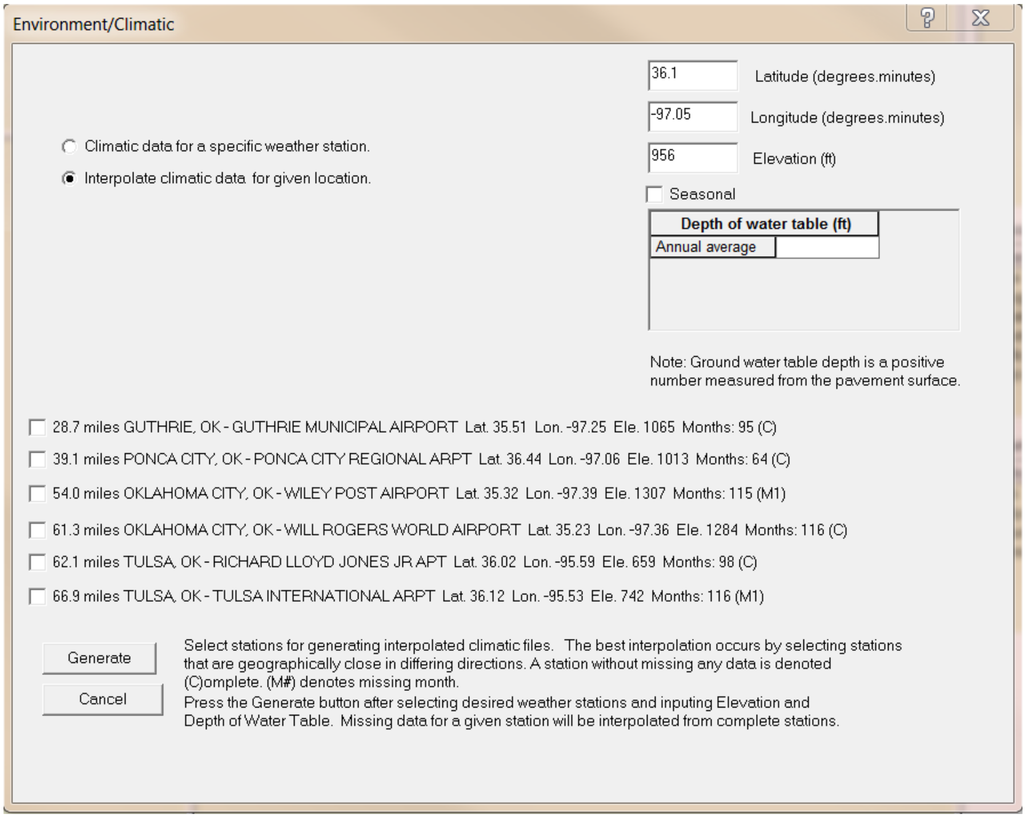
Figure 3.1 HMA Local Calibration Sections for ODOT

3.2 Climatic Data

To accomplish the climatic analysis required for incremental damage accumulation, MEPDG requires five weather-related parameters on an hourly basis over the entire design life for the design project (*ARA, 2004*):

- Hourly air temperature
- Hourly precipitation
- Hourly wind speed
- Hourly percentage sunshine (used to define cloud cover)
- Hourly relative humidity

In DARWin-ME, the weather-related information is primarily obtained from weather stations located near the project site. The DARWin-ME software provides over 800 weather stations containing hourly data across the United States from the National Climatic Data Center (NCDC) database. The climatic database can be tapped into by simply specifying the latitude, longitude, and elevation of the project site in MEPDG software. Once the GPS coordinates and elevation are specified for the design project site, the MEPDG software will highlight the six closest weather stations to the site from which the user may select any number of stations to generate a virtual project weather station. After selecting the climate stations and inputting the water table depth for the design, click “generate” button and all the climatic data sets required are saved in a file with an ‘icm” extension through the EICM numerical engine. The climate generating screen window is shown in Figure 3.2.



○ Climatic data for a specific weather station.
● Interpolate climatic data for given location.

36.1 Latitude (degrees.minutes)
-97.05 Longitude (degrees.minutes)
956 Elevation (ft)
☐ Seasonal

Depth of water table (ft)	
Annual average	

Note: Ground water table depth is a positive number measured from the pavement surface.

☐ 28.7 miles GUTHRIE, OK - GUTHRIE MUNICIPAL AIRPORT Lat. 35.51 Lon. -97.25 Ele. 1065 Months: 95 (C)
☐ 39.1 miles PONCA CITY, OK - PONCA CITY REGIONAL ARPT Lat. 36.44 Lon. -97.06 Ele. 1013 Months: 64 (C)
☐ 54.0 miles OKLAHOMA CITY, OK - WILEY POST AIRPORT Lat. 35.32 Lon. -97.39 Ele. 1307 Months: 115 (M1)
☐ 61.3 miles OKLAHOMA CITY, OK - WILL ROGERS WORLD AIRPORT Lat. 35.23 Lon. -97.36 Ele. 1284 Months: 116 (C)
☐ 62.1 miles TULSA, OK - RICHARD LLOYD JONES JR APT Lat. 36.02 Lon. -95.59 Ele. 659 Months: 98 (C)
☐ 66.9 miles TULSA, OK - TULSA INTERNATIONAL ARPT Lat. 36.12 Lon. -95.53 Ele. 742 Months: 116 (M1)

Select stations for generating interpolated climatic files. The best interpolation occurs by selecting stations that are geographically close in differing directions. A station without missing any data is denoted (C)omplete. (M#) denotes missing month.
Press the Generate button after selecting desired weather stations and inputing Elevation and Depth of Water Table. Missing data for a given station will be interpolated from complete stations.

Figure 3.2 Climatic Generating Window in MEPDG

The MEPDG software identifies 15 weather stations from the NCDC database for Oklahoma and many others in neighboring states that can be used for Oklahoma, as presented in Figure 3.3. The detailed locations of the Oklahoma weather stations are in Table 3.1.

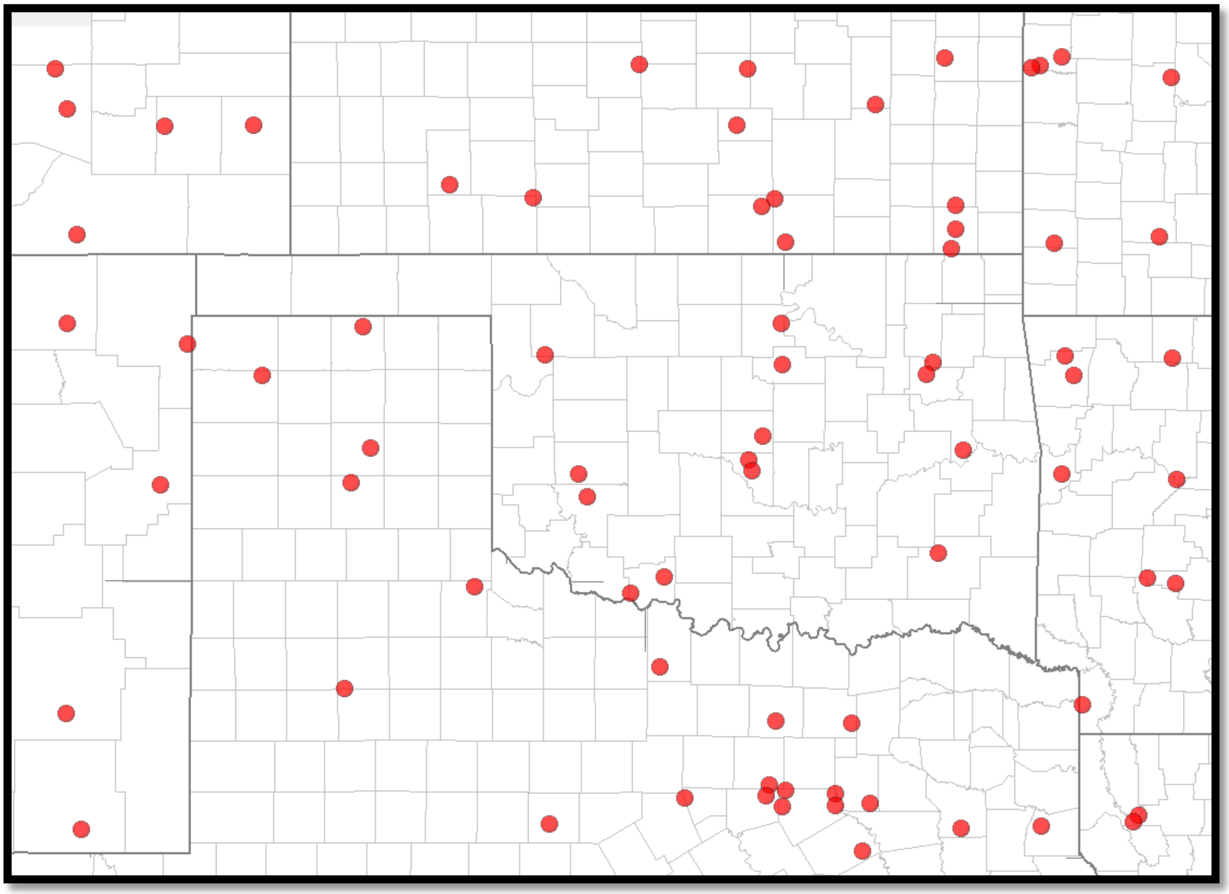


Figure 3.3 Weather Stations Used for Oklahoma

3.3 Structure and Materials

The structural layer data of pavement segments and the type of materials used are obtained from ODOT. Two data sources are provided: the ODOT PMS database and the design plans for each site. Both data sets are examined and it is found that they generate very consistent results. The structural and material data for the 77 sites are summarized in Appendix B. It should be noted that the layer structural data for some segments are missing.

In DARWin-ME, Level 1 material characterization inputs for hot-mix asphalt (HMA) require a dynamic modulus (E*) value from laboratory tests while level 2 and 3 HMA inputs are based on Witczak's predictive model using gradation and volumetric parameters of the mixture. The dynamic modulus testing results, or Level 1 inputs, for various mixture used in ODOT are not currently available. From the ODOT PMS database and design plan for each site, the type of mixture and binder grade are obtained, which can be used as Level 3 inputs. Since the actual construction gradation and volumetric indicators are not available, typical values are assumed for each mixture type according to the mixture requirements defined in the 1999 and 2009 ODOT Standard Specifications Books, as illustrated in Table 3.2.

Table 3.1 DARWin-ME Weather Stations in Oklahoma

ID	Location	Latitude	Longitude	Elevation (ft)
3932	CLINTON, OK	35.2	-99.12	1932
3981	FREDERICK, OK	34.21	-98.59	1241
13975	GAGE, OK	36.18	-99.46	2195
53913	GUTHRIE, OK	35.51	-97.25	1065
3030	GUYMON, OK	36.41	-101.31	3118
93986	HOBART, OK	35.01	-99.03	1555
3950	LAWTON, OK	34.34	-98.25	1110
93950	MC ALESTER, OK	34.54	-95.47	753
93953	MUSKOGEE, OK	35.4	-95.22	610
3954	OKLAHOMA CITY, OK	35.32	-97.39	1307
13967	OKLAHOMA CITY, OK	35.23	-97.36	1284
13969	PONCA CITY, OK	36.44	-97.06	1013
3965	STILLWATER, OK	36.1	-97.05	956
13968	TULSA, OK	36.12	-95.53	742
53908	TULSA, OK	36.02	-95.59	659

Table 3.2 Mixtures for Superpave in ODOT

Sieve Size	**Percent Passing per Surperpave Mixture Type**				
	S2	**S3**	**S4**	**S5**	**S6**
11/2 in [37.5 mm]	100	---	---	---	---
1 in [25.0 mm]	90-100	100			
¾ in [19.0 mm]	≤90	90-100	100		
½ in [12.5 mm]		≤90	90-100	100	
3/8 in [9.5 mm]			≤90	90-100	100
No. 4 [4.75 mm]	≥40			≤90	80-100
No. 8 [2.36 mm]	29-45	31-49	34-58	37-67	54-90
No. 16 [1.18 mm]					
No. 30 [0.600 mm]					
No. 50 [0.300 mm]					
No. 100 [0.150 mm]					
No. 200 [0.075 mm]	1.0-7.0 b	2.0-8.0 b	2.0-10.0 b	2.0-10.0 b	5.0-15.0
Other Mixture Requirements					
NMS c	1 in [25 mm]	¾ in [19 mm]	½ in [12.5 mm]	3/8 in [9.5 mm]	No. 4 [4.75 mm]
Asphalt Cement d, % of mix mass	≥3.7	≥4.1	≥4.6	≥5.1	≥5.6
Performance grade asphalt cement	e	e	e	e	e

a Table 708:6 reflects the sieve size boundaries for design and JMF purposes. After the design is established, the JMF will designate combined aggregate sieve requirements with tolerances in Table 708:12.

b Ensure the ratio of the percent passing the No. 200 [75 um] sieve to the percent effective asphalt cement is from 0.6 to 1.6.

c Nominal Maximum Size is defined as one size larger than the first sieve to retain more than 10 percent.

d The Department's Materials Engineer may adjust the lower limit if the effective specific gravity of the combined aggregates is greater than 2.65. The Department's Materials Engineer may allow adjustments if a theoretical lab molded specimen at the JMF asphalt content meets the VMA requirement at 4% air voids.

e The Contractor may substitute a higher grade of asphalt than that shown on the Plans at no additional cost to the Department.

Among the selected 77 sites, there are 59 sites with CABB (Coarse Aggregate Bituminous Base - base code `E), 8 sites with “unknown” base materials, 2 sites with “Stabilized Aggregate”, 1 site with “soil cement”, 1 site with “lime stab”, 4 sites with “soil asphalt”, and 2 sites with “soil asphalt on gravel”. During the data preparation for base material input, the team contacted ODOT pavement engineers for assistance on the understanding of CABB materials. It is learned that CABB has been a 20 year old technique widely used in Oklahoma and is quite different than Superpave mixtures. It is also found that the records have been added and updated in ODOT's Open-to-Traffic (OTR) and Road Inventory databases a base type code of "E" was used to describe various materials, such as "Black Base (Course [sic] Aggr.), Bituminous (Asph. Type 'A' - S3)" etc. Consequently, the base type coded as "E" probably shouldn't be interpreteded to CABB. As a matter of fact, ODOT pavement engineers conclude that ODOT didn't use CABB in this era of the selected 77 project sites. Therefore, it is advised using S3 (or AC Type "A") mixture when the database that was provided by ODOT has "CABB" base. In addition, since there are very limited number of sites are not using CABB base, these sites are excluded from the analysis. As a result, only 59 sites that have CABB are included in this project.

The characterization techniques for pavement subgrade soils can be hierarchical as well for DARWin-ME, ranging from default values for the different materials and soils to comprehensive laboratory and field testing for critical project types. Different means for subgrade or foundation characterization alternatives exist, including:

- Laboratory testing of undisturbed or reconstituted field samples recovered from the subsurface exploration process.
- Nondestructive testing of existing pavements found to have similar subgrade materials.
- Intrusive testing such as the Dynamic Cone Penetrometer (DCP)
- Reliance on an agency's experience with the subgrade type.

All of these alternatives are covered in the DARWin-ME Guide. Laboratory testing and nondestructive deflection testing (NDT) are recommended as the primary characterization methods. However, these data are not available for the selected 77 sites. In this project, subgrade type data from ODOT's Geologic Materials Classification (Red Books) are obtained and used as the subgrade inputs for DARWin-ME based design, including soil AASHTO classification, sieve analysis, soil constants, and suitability. The subgrade data are summarized in Appendix C.

3.4 Performance

The concept of pavement performance includes consideration of functional performance, structural performance, and safety. The DARWin-ME guide is primarily concerned with functional and structural performance. The structural performance of a pavement relates to its physical condition (fatigue cracking and rutting for flexible pavements). Several of these key distress types can be predicted directly using mechanistic concepts and are directly considered in the design process. Riding comfort or ride quality is the dominant characteristic of functional performance. In DARWin-ME, the chosen functional performance indicator is pavement smoothness as indicated by the International Roughness Index (IRI).

These performance data from field need to be gathered so that they can be compared with DARWin-ME predictions for local calibration. The Pavement Management Branch in ODOT contracts for a vendor to collect pavement data across Oklahoma's system of highways. The data is collected using semi-automated collection methods on a 2-year cycle. About half of the mileage is collected in the first year, and the other half of the mileage is collected in the second year. The branch has collected multiple cycles of condition data. Since the data collection is on a 2-year cycle, collection years are grouped from a pair of years together to form a combined database that covers all of our highway mileage. For example:

- **2001/2002:** collected by Roadware
- **2004/2005:** collected by Roadware
- **2006/2007:** collected by Roadware
- **2008/2009:** collected by Pathway Services
- **2010/2011:** collected by Roadware

The vendor delivers a raw condition database (Microsoft Access ".mdb" file) that is formatted with one record for every 0.01 mile of pavement. Each record includes:

- **location information:** county-control section; chainage (milepoint); GPS (latitude/longitude coordinates); "event" code (e.g., "Is it a bridge or railroad crossing?")
- **pavement type** ("PaveType")**:** code that describes the type of pavement; asphalt (AC), composite (COMP), jointed concrete pavement

(JPCP/DJCP/DMJCP), continuously reinforced concrete pavement (CRCP), brick (BRK)

- **sensor data:** roughness (IRI); rutting (for asphalt); faulting (for jointed concrete)
- **distress data:** measuring or counting of cracks, potholes, punch-outs, etc.

For this project, the following data items are provided by ODOT:

- **ElementID**: a unique identifier for each 1/2-mile site
- **location** fields
    - CtlSect: ODOT's County Control Section code (part of the way that ODOT inventories highways)
    - Direction: 5 for predominate (direction of the arrow in ODOT's Control Section book); 6 for non-predominate (the opposite direction)
    - BegChain: beginning chainage along a Control Section
    - EndChain: ending chainage along a Control Section
- **construction/maintenance history** fields
    - construction_date: date that our records indicate that the site was constructed
    - maintenance_date_1: date that our records indicate that the site had a first maintenance treatment (such as an overlay)
    - maintenance_date_2: date that our records indicate that the site had a second maintenance treatment (I don't know whether any of the sites we use would even have a second treatment.)
- **condition** fields

  - Date: Date that the data was collected by the automated collection van. (MM/DD/YYYY)
  - IRI_Avg: average of IRI for left and right wheelpaths (inch/mile)
  - Rut_Avg: average rut value of both wheel paths (inch)
  - Transv_1: number (count) of low-severity transverse cracks
  - Transv_2: number (count) of medium-severity transverse cracks
  - Transv_3: number (count) of high-severity transverse cracks
  - Transv_4: number (count) of very high severity transverse cracks
  - Allig_1: length (feet) of section with low severity fatigue cracking
  - Allig_2: length (feet) of section medium severity fatigue cracking
  - Allig_3: length (feet) of section with high severity fatigue cracking
  - Misc_1: length (feet) of section with low severity miscellaneous cracking
  - Misc_2: length (feet) of section with median severity miscellaneous cracking
  - Misc_3: length (feet) of section with high severity miscellaneous cracking
- **Layer Structural** fields
  - Ly1_Type: material type of layer 1
  - Ly1_Depth: thickness of layer 1
  - Ly1_Date: construction date of layer 1
  - the database provides data up to nine layers

It is observed that performance data at some segments are inconsistent. Figure 3.4 provides four examples at two pavement segments. Both the two sites haven't had any recorded maintenance and rehabilitation activities. The performance should be deteriorating as pavements age (the top left image). However, as shown in the Figure 3.4, the performance of site 0106-5-0100-0150 is against engineering wisdom. The IRI is deteriorating at the beginning while getting better at the end of the figure; while the number of transverse cracking keeps decreasing. During the local calibration process, data such as the transverse cracking cannot be used. This data screening process is conducted for each site to ensure good data.

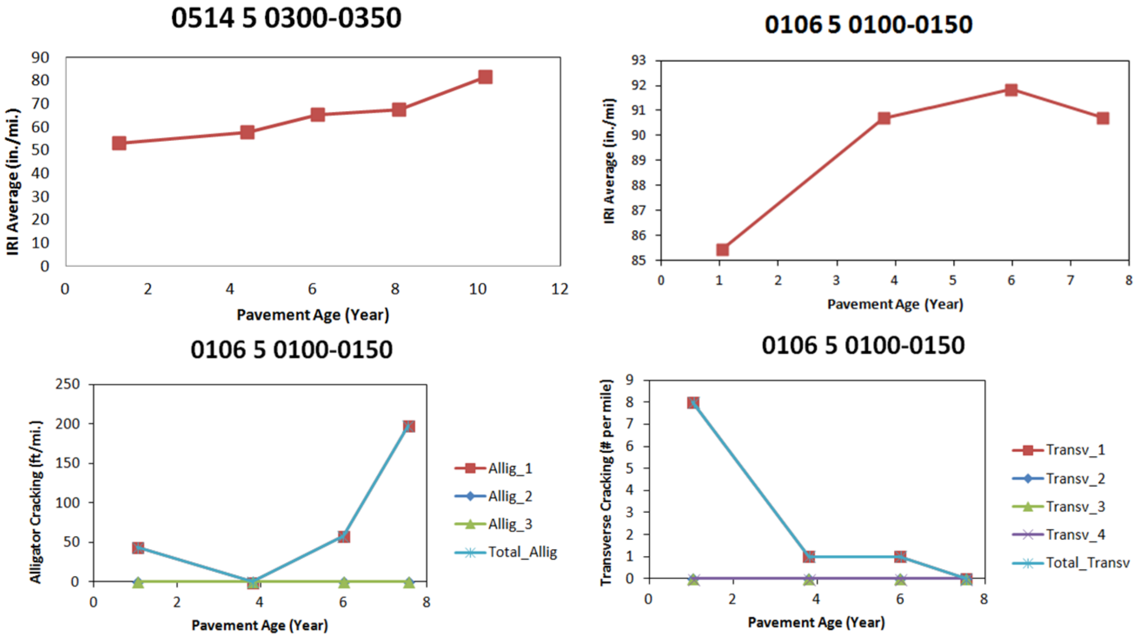


Figure 3.4 Examples of Pavement Performance Development

CHAPTER 4 TRAFFIC INPUTS USING WIM DATA

4.1 Traffic Characterization in Pavement ME Design

Traffic is one of the most important inputs in pavement design. Instead of using Equivalent Single Axle Load (ESAL) in the 1993 AASHTO Design Guide to characterize traffic throughout the pavement design life, DARWin-ME requires the full axle-load spectrum traffic inputs for estimating the magnitude, configuration and frequency of the loads to accurately determine the axle loads that will be applied on the pavement in each time increment of the damage accumulation process (ARA, 2004). As with all other inputs, MEPDG defines hierarchical traffic inputs at three levels in regard to the accuracy of axle load spectra data. The traffic design inputs at Level 1 are the most accurate inputs generated from project or segment-specific weigh-in-motion (WIM) and automatic vehicle classification (AVC) data; the traffic design inputs at Level 2 use regional WIM and AVC data and provide intermediate accuracy; traffic design inputs at Level 3 use regional or statewide default values and provide poor accuracy. The typical traffic data required for DARWin-ME are categorized as follows:

(1) The base year traffic volume. One important input in this category is annual average daily truck traffic (AADTT) of Vehicle Classes 4 through 13.

(2) The base year AADTT must be adjusted by using traffic volume adjustment factors, including monthly distribution, hourly distribution, class distribution, and traffic growth factors. These factors can be determined on the basis of classification counts obtained from WIM, AVC, or vehicle count data.

(3) Axle load distribution factors (axle load spectra). The axle load distribution factors represent the percentage of the total axle applications within each load interval for a specific axle type (single, tandem, tridem, and quad) and truck class (class 4 to class 13). The axle load distributions or spectra can be determined only from WIM data.

(4) General traffic inputs, such as number of axles per truck, axle configuration, and wheel base. These data are used in the calculation of traffic loading for determining pavement responses. The default values provided for the general traffic inputs are recommended if more accurate data are not available.

4.2 Traffic Data Collection Techniques

A statewide traffic collection plan usually consists of permanent, continuously operating data collection sites and short duration data collection efforts.

Continuous Count Programs

Continuous count programs help establish seasonal, daily and hourly traffic characteristics for a variety of design, operation and management purposes. Three types of traffic collection devices, automatic traffic recorders (ATR), automatic vehicle classifiers (AVC), and weigh-in-motion (WIM) scales are typically used.

ATRs are used to provide continuous traffic data at selected locations. Automatic traffic recorders are typically road tubes and ATR data are usually hourly traffic volumes by lane. The data are analyzed to provide statistics relative to the traffic volume for design purposes (Tran 2006): (1) Annual Average Daily Traffic at the site (AADT); (2) Annual Average Weekday Traffic at the site (AAWDT); (3) Seasonal adjustment factors; (4) Day-of-week adjustment factors; (5)

Lane/directional distribution factors; (6) Growth factors. The above factors are used to adjust short duration counts to AADT.

AVCs are used to detect and classify vehicles based on vehicle characteristics, such as the number and type of axles, vehicle length, or vehicle weight. The most common sensors in use are based on dual-inductance loops or piezoelectric cables. The continuous vehicle classification sites allow the monitoring of changes in truck traffic characteristics by classification over time (Tran 2006): (1) Annual Average Daily Truck Traffic at the site (AADTT); (2) Seasonal and day-of-week traffic patterns for trucks; (3) Direction, lane and growth factors for trucks.

Weigh-In-Motion (WIM) devices provide the most extensive traffic data, including volume, classification, and axle/weight data. WIM data in accordance with the FHWA’s Traffic Monitoring Guide (TMG) would meet the traffic characterization requirements for MEPDG. WIM devices measure transient tire forces that are utilized later to determine static axle weights using computer algorithms. Bending plates, hydraulic load cells, piezoceramic cables, piezopolymer cables, and piezoquartz sensors are typical WIM types for continuous counts. Each sensor technology has its own strengths and weaknesses. Performance of any WIM system is dependent on environment and site conditions. WIM sites cannot be selected in a purely random fashion because a WIM system only works accurately on a flat, smooth, and well condition pavement.

Short Duration Count Programs

Short count programs can provide up-to-date traffic data for a wide geographic coverage of roadways, which is normally used portable sensors or mats placed on top of the roadway surface and revised each year based on the agency design, operation, and maintenance plans. Short duration counts are most commonly collected for periods of 24 or 48 hours. Because the short count data only represent the traffic conditions in a short time period, the data should be adjusted based on the adjustment factors obtained from the continuous count program.

WIM Data in Oklahoma

In March 2013, ODOT provided the OSU research team with 5 years of 8 Gigabytes raw WIM data (from 2008 to 2012) that are following FHWA's 2001 version of Traffic Monitoring Guide (TMG) (FHWA 2001) data format, a standard data format that most state DOTs are using for WIM data collection. In total there are 23 WIM stations within the state of Oklahoma, as summarized in Table 4.1 and distributed in Figure 4.1.

The WIM traffic monitoring data following FHWA TMG guide are classified into four types (FHWA 2001): station description data, traffic volume data, vehicle classification data, and truck weight data. A Station Description file contains one record for each traffic monitoring station per year. Each type of data is recorded on monthly basis with its own individualized record format. The traffic volume data collected via the FHWA ATR format, which is known as #3 record. The Traffic Volume file contains one record for each day of traffic monitoring. The basis for the vehicle classification data record format is FHWA # 4 Card (also called C-card). This record format supplies one hour of volume information for each of the FHWA 13 category classification by lane for each record in a file. The weight data is recorded in W-Card. The Truck Weight file contains one record for each truck with its axle weights and axle spacings. Specific coding instructions and record layouts can also be found in Chapter 6 in the 2001 Traffic Monitoring Guide (FHWA 2001).

Table 4.1 WIM Stations in Oklahoma

WIM ID	Func Class	Sensor	County FIPS	Route #	Location
1	2	P	74	75	6.3 miles south of Jt. US-60
2	1	P	50	35	3.6 miles south of Jt. SH-7
3	11	P	55	240	2.57 miles West of Jt. I-35
5	2	P	73	69	6.4 miles south Jt. US-412
6	1	P	54	40	1.0 miles west of Jt. US-75 south
7	2	P	6	270	2.7 miles west of Jt. SH-8
8	2	P	67	99	0.3 Miles North Jt. SH-59 West
9	2	P	62	3	1.1 miles East of Jt. SH-1
10	2	P	61	69	4.75 Miles North Jt. SH-113
11	6	P	26	81	2.46 Miles South Jt. US-81bus South
16	2	P	49	412	2.6 Miles West Jt. US-69
21	7	P	40	69	1.10 miles north of the Red River Bridge
22	7	P	40	112	1.2 miles East Jt. US-59
23	2	P	47	412	2.1 miles West Jt. US-58
25	2	P		287	5.6 miles north of intersect of SH-3 & US 287
27	1	P	36	35	3.5 Miles North Jt. US-60
28	1	P	9	40	Location Not set as of 10/21/02
29	1	P	68	40	0.5 Miles East Mile Marker 311
30	1	P	44	35	100 Ft. North of Mile Marker 105
32	2	P		70	4.5 miles West of Junction US-259/US-70
104	1	P	42	35	0.5 miles North of Jt. Waterloo Rd
114	1	P	75	40	0.1 Miles West of Mile Marker 43
118	2	P	16	62	1.3 Miles West Jt. SH-115

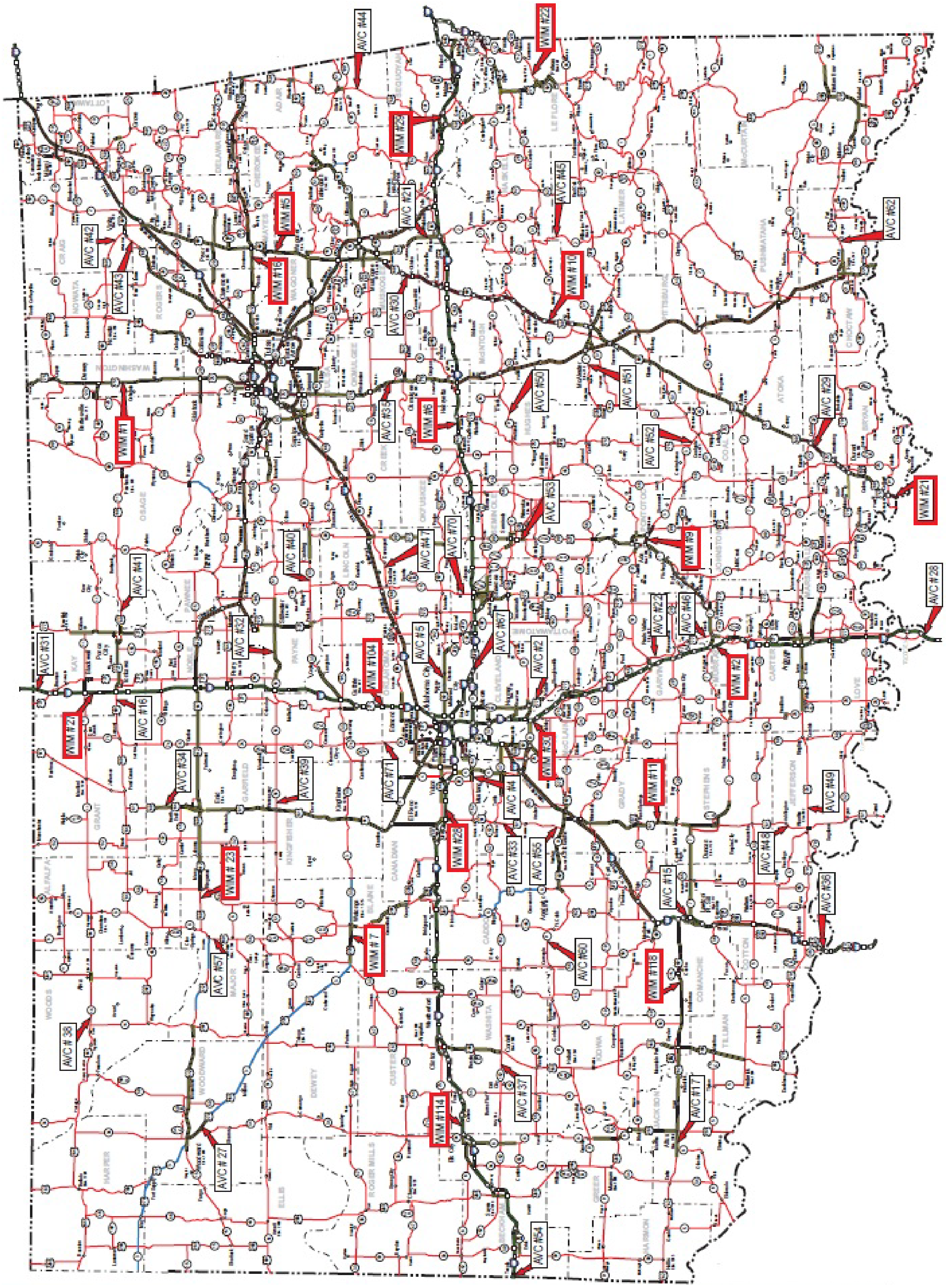


Figure 4.1 ODOT WIM Site Map

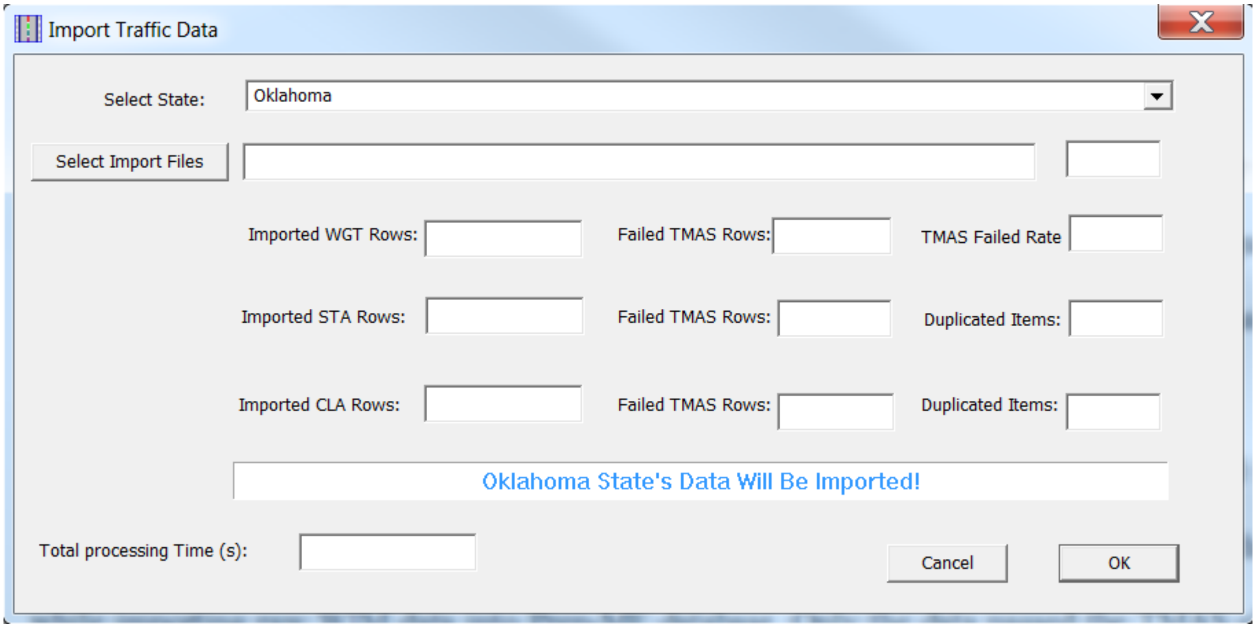
4.3 WIM Data Processing for Pavement ME Design

Several publications have reported that the traffic data collected from the automated traffic collection sites often have errors, especially the data collected from the WIM sites which use temperature-dependent piezoelectric sensors (Tran 2006, 2007). Therefore, it is of great importance to conduct quality check on the WIM traffic data before the WIM data can be utilized for Pavement ME Design.

FHWA TMAS Data Check and WIM Data Import

TMAS stands for Travel Monitoring Analysis System. TMAS provides online data submitting capabilities to State traffic offices to submit data to FHWA. TMAS runs quality control checks on all data received and only data passing the checks are used for further analysis in FHWA. The TMAS 2.0 Data Checks (FHWA 2012) are defined in the 2012 version of TMG (FHWA 2012) and attached in Appendix D.

The Prep-ME software, a product of pooled-fund study TPF-5(242) *Traffic and Data Preparation for AASHTO M-E PDG Analysis and Design* (Wang et al 2013), integrates all the TMAS data checks while importing raw WIM data into Prep-ME database. Only the WIM data which passed the TMAS check are imported. A screenshot of Prep-ME importing interface is shown in Figure 4.2. The total number of records of the raw WIM data, and the number are failed records are reported during the data importation process.



Select State: Oklahoma

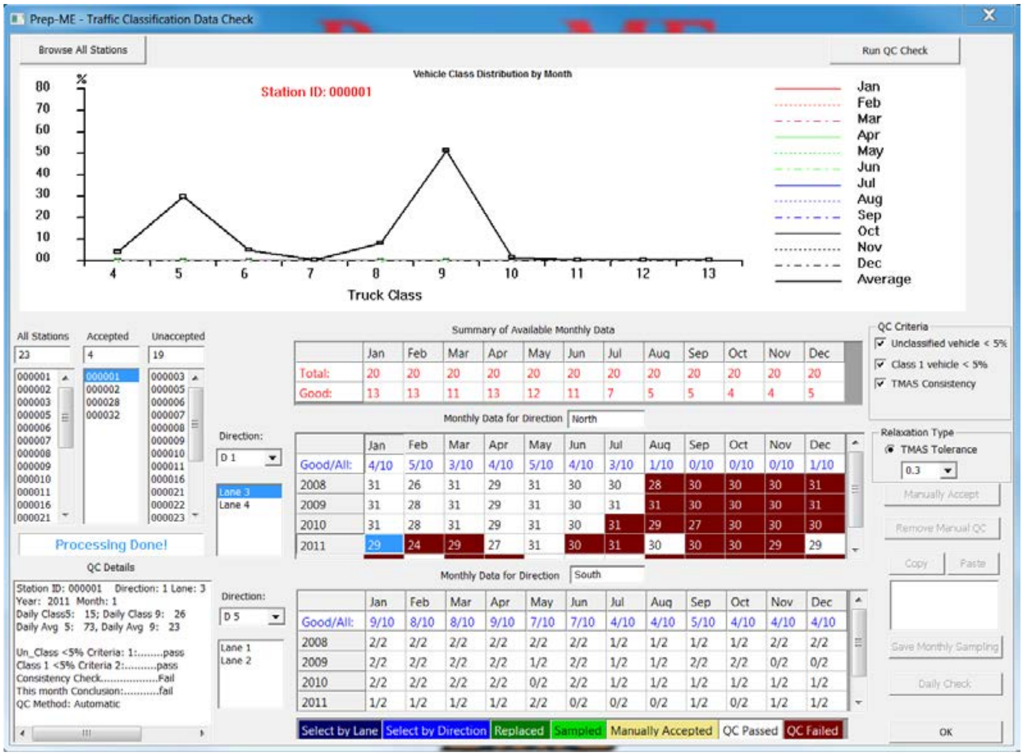
Oklahoma State's Data Will Be Imported!

Figure 4.2 Prep-ME WIM Data Import

Truck Classification Data Quality Check

After the preliminary check on data completeness, four-step data check procedure included in the FHWA 2001 TMG guide (FHWA 2001) is adopted to evaluate the vehicle classification data. The first step is to compare the manual classification counts and the WIM data. The absolute difference between the manual counts and the WIM data should be less than five percent for each of the primary vehicle categories that significantly influence traffic loading, including vehicle Classes 5, 9, and 13 (FHWA 2001, Tran 2006). The second step is to check the number of Class 1 (motorcycles). If a significant number of motorcycles are reported, the equipment may mistakenly record trailers separated from tractors, and the last tandem is recorded as a motorcycle because of its short spacing. The evaluation procedure recommended that the number of Class 1 should be less than five percent unless their presence is noted. The third step is to check the reported number of unclassified vehicles. The number of unclassified vehicles should be less than five percent of the vehicles recorded. If more than five percent of recorded vehicles are unclassified, the equipment may have axle sensing malfunctions that prevent the equipment from measuring all of the appropriate axle pulses. Finally, the current truck percentages by class are compared with the corresponding historical percentages to determine if significant changes in vehicle mix have occurred. One important thing to look for is the unexpected changes of similar vehicle classes, such as vehicle Classes 5 and 9.

The classification data check algorithms have been programmed in the Prep-ME software, as shown in Figure 4.3. It is observed that many of the WIM stations cannot pass the classification check. Further investigation reveals that those stations are mainly due to the failure of **TMAS Consistency** check. TMAS requires that monthly average daily traffic (MADT) should fall within 30% from same month in previous years. However, the WIM classification data demonstrate extensive variance. It is found that some data items in the raw WIM data are inconsistently reported. For example, in 2008 lane 1 is believed to be the outer driving lane and lane 2 is the passing lane since lane 1 carried much more truck traffic, while in 2009 lane 1 carried much more truck traffic than lane 2 did. If the **TMAS Consistency** check is not applied, significant more WIM stations can pass the classification check, as illustrated in Figure 4.4.



All Stations	Accepted	Unaccepted
23	4	19
000001 000002 000003 000005 000006 000007 000008 000009 000010 000011 000016 000021	000001 000002 000028 000032	000003 000005 000006 000007 000008 000009 000010 000011 000016 000021 000022 000023

Station ID: 000001 Direction: 1 Lane: 3
Year: 2011 Month: 1
Daily Class5: 15; Daily Class 9: 26
Daily Avg 5: 73, Daily Avg 9: 23

Un_Class <5% Criteria: 1:........pass
Class 1 <5% Criteria 2:..........pass
Consistency Check.................Fail
This month Conclusion:...........fail
QC Method: Automatic

Summary of Available Monthly Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total:	20	20	20	20	20	20	20	20	20	20	20	20
Good:	13	13	11	13	12	11	7	5	5	4	4	5

Direction: D 1
Lane 3
Lane 4

Monthly Data for Direction North

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good/All:	4/10	5/10	3/10	4/10	5/10	4/10	3/10	1/10	0/10	0/10	0/10	1/10
2008	31	26	31	29	31	30	30	28	30	30	30	31
2009	31	28	31	29	31	30	31	31	30	30	30	31
2010	31	28	31	29	31	30	31	29	27	30	30	30
2011	29	24	29	27	31	30	31	30	30	30	29	29

Direction: D 5
Lane 1
Lane 2

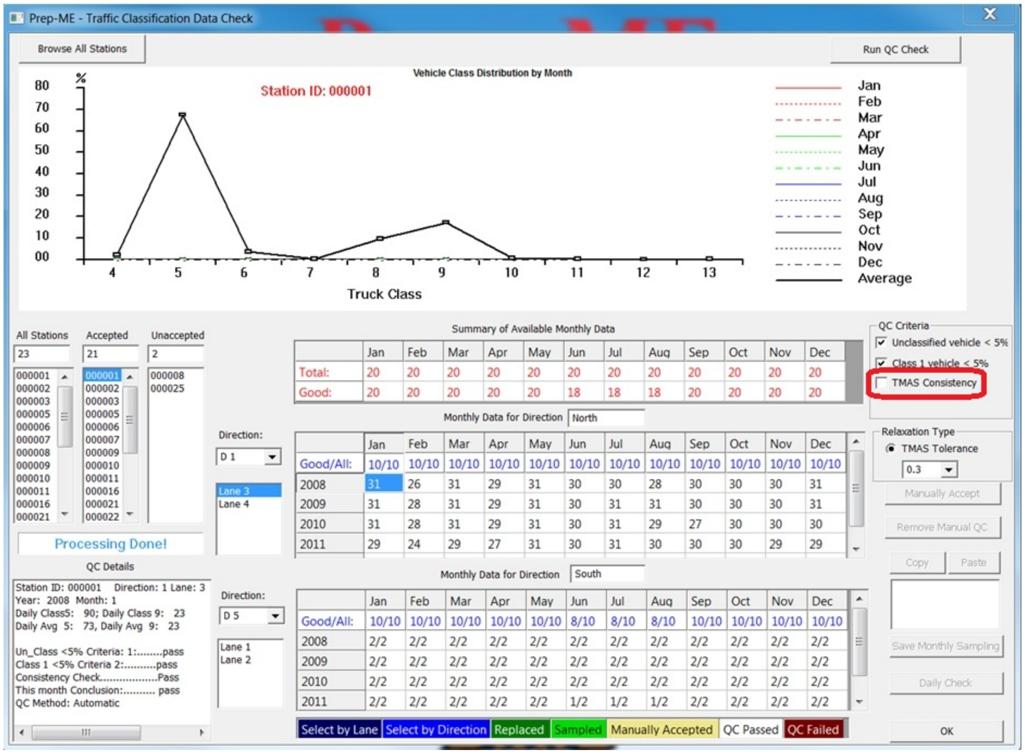
Monthly Data for Direction South

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good/All:	9/10	8/10	8/10	9/10	7/10	7/10	4/10	4/10	5/10	4/10	4/10	4/10
2008	2/2	2/2	2/2	2/2	2/2	2/2	1/2	1/2	1/2	1/2	2/2	2/2
2009	2/2	2/2	2/2	2/2	1/2	2/2	1/2	1/2	2/2	2/2	0/2	0/2
2010	2/2	2/2	2/2	2/2	0/2	2/2	1/2	1/2	1/2	1/2	1/2	1/2
2011	1/2	1/2	1/2	1/2	2/2	0/2	0/2	0/2	1/2	0/2	1/2	1/2

QC Criteria
☑ Unclassified vehicle < 5%
☑ Class 1 vehicle < 5%
☑ TMAS Consistency

Relaxation Type
● TMAS Tolerance
0.3

Figure 4.3 Classification Data with TMAS Consistency Checks in Prep-ME



All Stations	Accepted	Unaccepted
23	21	2
000001 000002 000003 000005 000006 000007 000008 000009 000010 000011 000016 000021	000001 000002 000003 000005 000006 000007 000009 000010 000011 000016 000021 000022	000008 000025

Station ID: 000001 Direction: 1 Lane: 3
Year: 2008 Month: 1
Daily Class5: 90; Daily Class 9: 23
Daily Avg 5: 73, Daily Avg 9: 23

Un_Class <5% Criteria: 1:........pass
Class 1 <5% Criteria 2:..........pass
Consistency Check.................Pass
This month Conclusion:.......... pass
QC Method: Automatic

Summary of Available Monthly Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total:	20	20	20	20	20	20	20	20	20	20	20	20
Good:	20	20	20	20	20	18	18	18	20	20	20	20

Direction: D 1
Lane 3
Lane 4

Monthly Data for Direction North

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good/All:	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
2008	31	26	31	29	31	30	30	28	30	30	30	31
2009	31	28	31	29	31	30	31	31	30	30	30	31
2010	31	28	31	29	31	30	31	29	27	30	30	30
2011	29	24	29	27	31	30	31	30	30	30	29	29

Direction: D 5
Lane 1
Lane 2

Monthly Data for Direction South

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good/All:	10/10	10/10	10/10	10/10	10/10	8/10	8/10	8/10	10/10	10/10	10/10	10/10
2008	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
2009	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
2010	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2
2011	2/2	2/2	2/2	2/2	2/2	1/2	1/2	1/2	2/2	2/2	2/2	2/2

QC Criteria
☑ Unclassified vehicle < 5%
☑ Class 1 vehicle < 5%
☐ TMAS Consistency

Relaxation Type
● TMAS Tolerance
0.3

Figure 4.4 Classification Data without TMAS Consistency Checks in Prep-ME

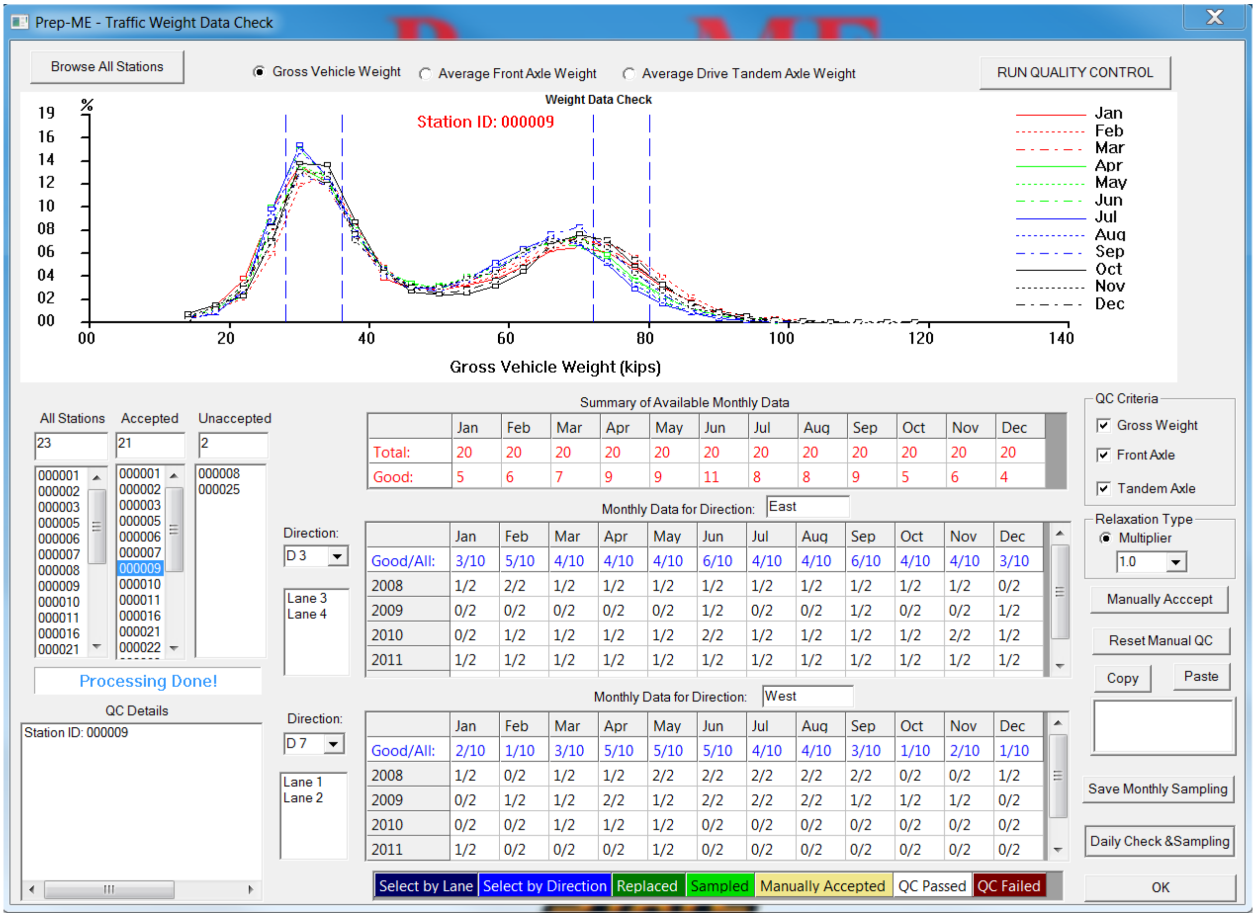
Truck Weight Data Check

The FHWA TMG guide recommends two basic steps to perform the quality control checks for vehicle weight data (FHWA 2001, Tran 2006). All the data check processes are based on vehicle Class 9 because vehicle class 9 accounts for the majority of the truck traffic stream. First, the front axle and drive tandem axle weights of Class 9 trucks are checked. Although the front axle is heavier when a truck is loaded, the front axle weight should be between 8,000 and 12,000 lb. The drive tandems of a fully loaded Class 9 truck (generally more than 72,000lb.) should be between 30,000 and 36,000 lb.

The next step is to check the gross vehicle weights of Class 9 trucks (FHWA 2001, Tran 2006). This step requires a histogram plot of the gross vehicle weights of Class 9 trucks using a 4,000-lb. increment. The histogram plot should have two peaks for most sites. Based on the LTPP data, for most sites the height of these peaks may be seasonally changed, but the location of the two peaks is fairly constant over time (FHWA 2001, Tran 2006). One represents unloaded Class 9 trucks and should be between 28,000 and 36,000 lb. The second peak represents the most common loaded vehicle condition, whose weigh should be between 72,000 and 80,000 lb. If both peaks shifted in the same direction from their locations based on historical data, the scale is most likely out of calibration. If the loaded peak shifted and the other peak correctly located, the site should be reviewed using additional information, including the types of commodities carried by Class 9 trucks and the load distribution right after the site was last calibrated.

Another statistical parameter should be reviewed is the number of vehicles over the legal weight limit (for the state of Arkansas, the legal weight limit is 80,000 lb.), especially the number of Class 9 vehicles over 100,000 lb. If the percentage of overweight vehicles is high, the scale calibration should be checked.

The weight data check algorithms have been programmed in the Prep-ME software, as shown in Figure 4.5.



All Stations: 23

Accepted: 21

Unaccepted: 2

All Stations list: 000001, 000002, 000003, 000005, 000006, 000007, 000008, 000009, 000010, 000011, 000016, 000021

Accepted list: 000001, 000002, 000003, 000005, 000006, 000007, 000009, 000010, 000011, 000016, 000021, 000022

Unaccepted list: 000008, 000025

Processing Done!

QC Details

Station ID: 000009

Relaxation Type: Multiplier 1.0

Summary of Available Monthly Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total:	20	20	20	20	20	20	20	20	20	20	20	20
Good:	5	6	7	9	9	11	8	8	9	5	6	4

Direction: D 3

Lane 3
Lane 4

Monthly Data for Direction: East

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good/All:	3/10	5/10	4/10	4/10	4/10	6/10	4/10	4/10	6/10	4/10	4/10	3/10
2008	1/2	2/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	0/2
2009	0/2	0/2	0/2	0/2	0/2	1/2	0/2	0/2	1/2	0/2	0/2	1/2
2010	0/2	1/2	1/2	1/2	1/2	2/2	1/2	1/2	1/2	1/2	2/2	1/2
2011	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2

Direction: D 7

Lane 1
Lane 2

Monthly Data for Direction: West

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good/All:	2/10	1/10	3/10	5/10	5/10	5/10	4/10	4/10	3/10	1/10	2/10	1/10
2008	1/2	0/2	1/2	1/2	2/2	2/2	2/2	2/2	2/2	0/2	0/2	1/2
2009	0/2	1/2	1/2	2/2	1/2	2/2	2/2	2/2	1/2	1/2	1/2	0/2
2010	0/2	0/2	1/2	1/2	1/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
2011	1/2	0/2	0/2	0/2	1/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2

Figure 4.5 ODOT WIM Weight Data Check with Prep-ME

Clustering Analysis for Pavement ME Design Traffic Inputs

Pavement ME Design accepts hierarchical traffic data which provide the designer with flexibility in obtaining the design inputs based on the criticality of the project and the available resources (ARA, 2004). Ideally, Level 1 traffic inputs are obtained from a Weigh-In-Motion (WIM) system operating continuously at the design site over extended periods of time. In practice, however, when new pavements are designed, no prior Level 1 traffic WIM data are available. In such cases, Levels 2 regional average traffic inputs are considered by combining existing site-specific data from WIM systems located on sites that exhibit similar traffic characteristics and developing loading clusters. Alternatively, if no data are available, Level 3 Pavement ME Design default values are used.

Most state agencies have various amounts of WIM data using different data collection techniques. Therefore, how to qualify traffic characteristic similarities and develop loading clusters for Level 2 Pavement ME Design inputs is a recent interest in the U.S. Various State Departments of Transportation (DOTs) deployed clustering algorithms to develop traffic inputs in different regions to support the new design (Prozzi and Hong, 2005; Lu and Harvey, 2006; Wang et al., 2007; Lu et al., 2008; Sayyady et al., 2010; Wang et al., 2011). This research is intended to simplify the understanding and applicability of traffic patterns and ultimately ease the preparation of traffic load spectra inputs based on WIM data for the DARWin-ME procedure. However, these approaches are computationally extensive and require pre-design site-specific truck data to determine the corresponding clusters.

DARWin-ME has proposed a relatively straightforward Truck Traffic Classification (TTC) grouping approach to describe the commonly encountered distribution spectra of trucks travelling on roadways (ARA 2004). During pavement design, engineers identify the TTC group for the design location so that the traffic data inputs required in DARWin-ME can be generated from historical databases. However, it should be noted that the differences of truck distributions among some of the 17 DARWin-ME TTC groups are insignificant. Pre-design truck distribution data are needed to determine the TTC group for a design location.

In this research, no site-specific traffic information or truck distribution data is available for the selected 77 ODOT sites. As a result, neither a sophisticated clustering approach nor the DARWin-ME TTC approach can be applied easily for routine pavement design. Li etc. (2013) developed a simplified TTC truck clusters based on the relative proportion of Class 4, Class5, and Class 9 trucks. This simplified approach is slightly modified in this project based on the percentage of bus, single unit trucks, and combination trucks because the percentage of single unit and combination data are available in the Highway Performance Monitoring System (HPMS) data sets and can be used for this study. The HPMS is a national transportation data system providing detailed data on highway inventory, condition, performance, and operations. The criteria used for differentiating these four TTC clusters are presented in Table 4.2.

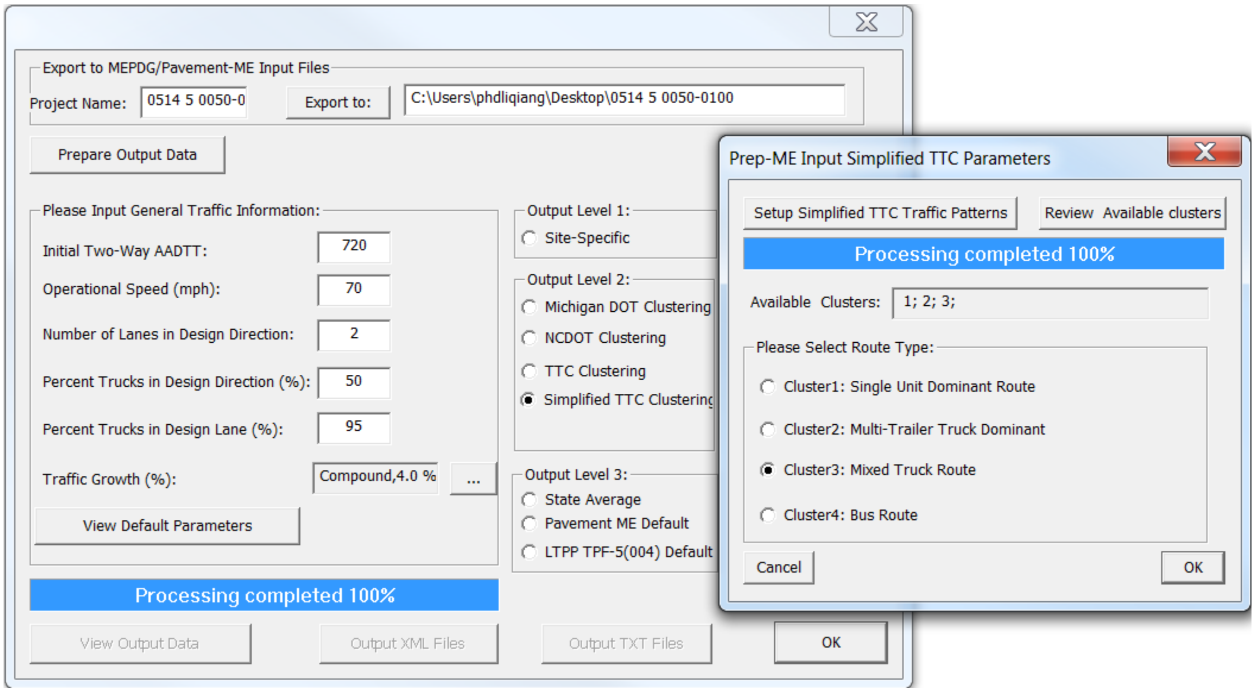
Table 4.2 Simplified Truck Traffic Classification Cluster Criteria

Cluster	Cluster Description	Percent of AADTT

#		**VC4**	**% Single Unit**	**% Combination Truck**
1	Single-Unit Dominant Route	-	>65	-
2	Multi-Trailer Dominant Route	-	-	>65
3	Mixed Truck Route	-	<65	<65
4	Bus Dominant Route	>35	-	-

The simplified clustering approach has been programmed in the Prep-ME software, as shown in Figure 4.6. The base year truck traffic volumes - AADTTs for the 77 sites are obtained from the 2010 HPMS data. For this project, the AADT, percentage of single-unit trucks, percentages of multiple-unit trucks from the HPMS data sets are used to calculate the AADTT. Based on the composition data of single truck and combination vehicles from HPMS data sets, the simplified clusters for the ODOT 77 sites are determined. Meanwhile, based on the WIM vehicle classification data, the clusters for the 23 ODOT WIM sites could also be determined. As a result, traffic inputs required by Pavement ME Design for each of the 77 sites can be generated. In addition, posted speed and the number of lanes of each site are also obtained from HPMS. The data for the 77 sites are tabulated in Appendix E.

Subsequently, the traffic inputs for each site can be generated using Prep-ME software, and imported in Pavement ME Design software for pavement performance simulation.



Export to MEPDG/Pavement-ME Input Files

Project Name: 0514 5 0050-0

Export to: C:\Users\phdliqiang\Desktop\0514 5 0050-0100

Please Input General Traffic Information:

Initial Two-Way AADTT: 720

Operational Speed (mph): 70

Number of Lanes in Design Direction: 2

Percent Trucks in Design Direction (%): 50

Percent Trucks in Design Lane (%): 95

Traffic Growth (%): Compound,4.0 %

Output Level 1:

○ Site-Specific

Output Level 2:

○ Michigan DOT Clustering

○ NCDOT Clustering

○ TTC Clustering

● Simplified TTC Clustering

Output Level 3:

○ State Average

○ Pavement ME Default

○ LTPP TPF-5(004) Default

Processing completed 100%

Prep-ME Input Simplified TTC Parameters

Processing completed 100%

Available Clusters: 1; 2; 3;

Please Select Route Type:

○ Cluster1: Single Unit Dominant Route

○ Cluster2: Multi-Trailer Truck Dominant

● Cluster3: Mixed Truck Route

○ Cluster4: Bus Route

Figure 4.6 Prep-ME Simplified Traffic Clustering Approach

CHAPTER 5 LTPP SITES

5.1 Introduction

The LTPP database was critical to the development of the MEPDG, as it is the only source of comprehensive pavement data representing a wide range of loading, climate, and subgrade conditions with varying structural compositions across the country. In fact, the MEPDG could not have been completed without the type and national extent of data provided by the LTPP studies (ARA 2004). All of the traffic loading defaults provided in the MEPDG, for example, was derived from the LTPP traffic database using WIM sites across the United States and Canada, and all of the distress and smoothness models in the MEPDG were calibrated using LTPP data. In addition, LTPP data is invaluable to local validation and calibration process as many agencies do not otherwise have the data necessary to complete this endeavor. In addition, local performance evaluation may be inconsistent between MEPDG and state practices. All performance parameters such as alligator cracking, transverse cracking, rutting and IRI are based on LTPP’s guidelines and specifications. However, state highway agencies may have used different taxonomy and specification on pavement performance. Therefore, parameters in PMS have to be converted to the parameters and units used in MEPDG before the data can be used for local calibration (Quintus 2007, 2009). The differences between state PMS and LTPP have been widely observed.

The LTPP program is divided into two fundamental classes of pavement studies, General Pavement Studies (GPS) and Specific Pavement Studies (SPS). The fundamental difference between these two classifications is that at the start of the LTPP program, the GPS test sections are existing pavements and the SPS projects are sites where multiple test sections of differing experimental treatment factors are constructed. The GPS test sections are located on pavement structures constructed up to 15 years prior to the start of the LTPP program. Detailed research-level measurements on these pavements during the early years of their lives are generally not available. The SPS program is a study of specially constructed, maintained, or rehabilitated pavement sections incorporating a controlled set of experiment design and construction features. Essentially, the SPS program involves monitoring newly constructed sections or existing pavement sections subjected to maintenance or rehabilitation treatments. Each SPS experiment requires construction of multiple test sections at each site. The number of test sections may range from two for SPS-8 to twelve for SPS-1 and -2. In addition, a highway agency may construct supplemental test sections on an SPS site to investigate other factors of interest to the agency.

In this project, data from SPS 1 study - *Strategic Study of Structural Factors for Flexible Pavements* are used to compliment the data provided by ODOT. The selected 77 flexible sites were all constructed after 2000. As a result, the maximum observed distress values are significantly lower than the agency’s design criteria for that distress, and the accuracy and bias of the transfer function may not be well defined at the values that trigger major rehabilitation. As recommended in the AASHTO Local Calibration Guide (AASHTO, 2010), the average maximum distress values from the sampling template should exceed 50 percent of the design criteria. Therefore, it is anticipated that the inclusion of LTPP sites in the analysis will generate more data points that are approaching the maximum design thresholds, and thus improve the robustness of the local calibration analysis.

5.2 LTPP Data Preparation for Pavement ME Design

The LTPP SPS1 sites in Oklahoma and Kansas are investigated. SPS 0100 section with 19 500-ft segments located on US 54 East Bound at milepost of 114.94 east of Greensburg, Kansas, and SPS 0100 section with 14 500-ft segments located on US 62 approximately 0.5 miles west of State Highway 115 and 7 miles east of State Highway 54 are selected. The locations of the two sections are shown in Figure 5.1.

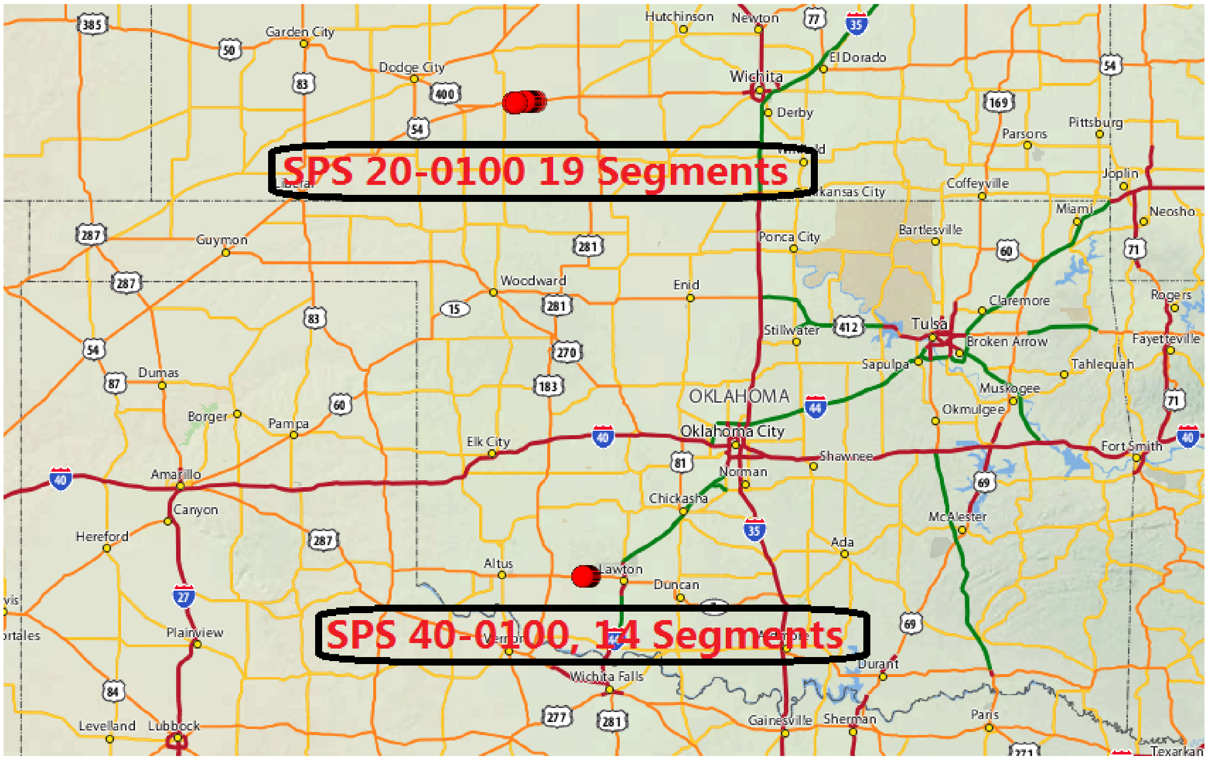


Figure 5.1 Locations of the Selected Two LTPP SPS Sections

In order to prepare the data for Pavement ME Design, the data from the following LTPP tables are utilized:

- **SPS1_LAYER:** This table contains the pavement materials layer structure, layer thicknesses, etc.
- **SPS1_PMA_AC_PROPERTIES:** This table contains the properties of the asphalt cement that was used in the PMA-bound layers of the SPS section. These properties were typically obtained from the asphalt supplier or from tests conducted by the State highway agency.
- **SPS1_PMA_AGGREGATE_PROP:** This table contains the properties of the aggregate that was used in the PMA-bound layers of the SPS section. These properties were typically obtained from the asphalt supplier or from tests conducted by the State highway agency.
- **SPS1_PMA_MIXTURE_PROP:** This table contains mixture properties for each PMA-bound layer.
- **SPS1_UNBOUND_AGG_BASE:** This table contains placement information associated with unbound aggregate base layers, including compaction equipment and lift thicknesses.
- **SPS#_PMA_DENSITY_PROFILE:** This table contains PMA-bound layer nuclear density measurements and profilograph data. The densities of ATB, binder, surface, and friction are courses that are included.

The pavement structures of the total 33 segments are shown in Appendix F.

The WIM data are extracted from the following LTPP database tables:

- **TRF_MEPDG_AADTT_LTPP_LN:** This table contains estimates of the annual average daily truck traffic (AADT) in the LTPP test section lane computed by three alternate computation methods based on a combination of classification or weight data, only classification, or only weight data.

- **TRF_MEPDG_AX_DIST:** This table contains normalized axle distributions by month, truck class and axle group. Records in this table are generated from sites that contain at least 210 days of WIM data in that calendar year. The monthly distribution bin counts are based on day of the week averages. The 4,000-lb weight bins for quad axles in the LTPP traffic database are reduced to the MEPDG 3,000-lb weight bins using an assumption that the 4,000-lb bins have a uniform distribution between adjacent bins.
- **TRF_MEPDG_AX_PER_TRUCK:** This table contains the annual average number of number of axles by vehicle class and axle type by year.
- **TRF_MEPDG_HOURLY_DIST**: This table contains annual average hourly distribution of trucks by hour in the LTPP lane based on classification data. Only years with at least 210 days of classification data are included.
- **TRF_MEPDG_MONTH_ADJ_FACTR**: This table contains adjustment factors for ADTT for each truck class by month based on either classification or weight monitoring data.
- **TRF_MEPDG_VEH_CLASS_DIST:** This table contains the percentage of trucks by vehicle class within the truck population (FHWA Classes 4-13) in the LTPP lane based classification, weight or a combination of on classification and weight data.

CHAPTER 6 VALIDATION OF FLEXIBLE PAVEMENT DISTRESS MODELS

6.1 Distresses in DARWin-ME

This subsection provides the definition of each distress and performance indicator predicted in DARWin-ME for asphalt concrete pavements.

Alligator Cracking

A form of fatigue or load related cracking and is defined as a series of interconnected cracks (characteristically with a “chicken wire/alligator” pattern) that initiate at the bottom of the HMA layers. Alligator cracks initially show up as multiple short, longitudinal or transverse cracks in the wheel path that become interconnected laterally with continued truck loadings. Alligator cracking is calculated as a percent of total lane area in the MEPDG. The MEPDG does not predict the severity of alligator cracking. In other words, fatigue cracking predicted in MEPDG includes fatigue cracks at all the three severity levels (low, medium, and high).

Longitudinal Cracking

A form of fatigue or load related cracking that occurs within the wheel path and is defined as cracks parallel to the pavement centerline. Longitudinal cracks initiate at the surface of the HMA pavement and initially show up as short longitudinal cracks that become connected longitudinally with continued truck loadings. Raveling or crack deterioration can occur along the edges of these cracks but they do not form an alligator cracking pattern defined above. The unit of longitudinal cracking calculated by the MEPDG is feet per mile (meters per kilometer). The MEPDG does not predict severity of the longitudinal cracks.

Unless an agency cuts cores or trenches through the HMA surface to confirm where the cracks initiated, it is recommended that the local calibration refinement be confined to total cracking that combines alligator and longitudinal cracks. To combine percent total lane area fatigue cracks with linear or longitudinal fatigue cracks, the total length of longitudinal cracks should be multiplied by 1-foot and that area divided by the total lane area. When an agency decides to combine alligator and longitudinal cracks, the alligator transfer function should be the one used in the local calibration process for determining the local calibration values. If an agency recovers cores or cuts trenches, but cannot determine where the cracks initiated, it is recommended that the agency assume all cracks initiated at the bottom of the HMA layer.

Reflective Cracking

Fatigue cracks in HMA overlays of flexible pavements and of semi-rigid and composite pavements, plus transverse cracks that occur over transverse cracks and joints and cracks in jointed PCC pavements. The unit of reflective cracking calculated by the MEPDG is feet per mile (meters per kilometer). The MEPDG does not predict the severity of reflective cracks. Unless an agency cuts cores or trenches through the HMA overlay of flexible pavements to confirm reflective cracks, it is recommended that the local calibration refinement be confined to total cracking of HMA overlays. In this case, all surface cracks in the wheel path (reflective, alligator, and longitudinal cracks) should be combined, using the recommendation for longitudinal cracking listed above. If all cracks are combined, the alligator and reflection cracking transfer functions can be used in the local calibration process.

Rutting or Rut Depth

Rutting is a longitudinal surface depression in the wheel path resulting from plastic or permanent deformation in each pavement layer. The rut depth is representative of the maximum vertical difference in elevation between the transverse profile of the HMA surface and a wire-line across the lane width. The unit of rutting calculated by the MEPDG is inches (millimeters). The MEPDG also computes the rut depths within the HMA, unbound aggregate layers, and foundation. Unless an agency cuts trenches through pavement sections, however, it is recommended that the calibration refinement be confined to the total rut depth predicted with the MEPDG.

Transverse Cracking

Non-wheel load related cracking that is predominately perpendicular to the pavement centerline and caused by low temperatures or thermal cycling. The unit of transverse cracking calculated by the MEPDG is feet per mile (meters per kilometer) or spacing of transverse cracks in feet. The MEPDG does not predict the severity of transverse cracks.

6.2 Distresses in ODOT

The Oklahoma Department of Transportation (ODOT) has contracted for the collection of pavement management condition data since 1994. The data collection contractor records images of the pavement and then views those images to measure and record the pavement distresses according to ODOT protocols (ODOT 2005). The purpose of this manual is to provide thorough and clear descriptions of ODOT's definitions of pavement distresses and guidelines for rating and recording of distress data. The objective is to achieve consistent, accurate, and repeatable distress ratings for use in the pavement management system. The format of this manual is modeled after the Virginia Department of Transportation's "Guide to Evaluating Pavement Distress Through the Use of Video Images."

ODOT's current distress rating protocols were developed in 2001 as a renewed pavement management effort was begun within the agency. These protocols were modified from the Federal Highway Administration (FHWA) provisional standards for measuring pavement cracking.

For asphaltic concrete pavement, the following distresses are collected and rated:

Transverse Cracking

Defined as a crack longer than two meters (6 ft), excluding saw cuts, that projects within 45 degrees of perpendicular to the pavement centerline. Four severity levels are defined:

- Level 1 - A crack with a mean width less than 6 mm (0.25 in); or sealed cracks in good condition whose width cannot be determined;
- Level 2 - A crack with a mean width greater than or equal to 6 mm (0.25 in) and less than 12 mm (0.5 in);
- Level 3 - A crack with a mean width greater than or equal to 12 mm (0.5 in) and less than 25 mm (1 in) or a spalling or deteriorating crack with interconnected pieces less than 50 mm (2 in) wide;

- Level 4 - A crack with a mean width greater than 25 mm (1 in) or a spalling or deteriorating crack with interconnected pieces greater than 50 mm (2 in) wide;

Record the number of transverse cracks at each severity level within the 0.01-mile section. Cracks must be at least two meters (6 ft) long to be recorded and severity level should be based on average crack width. Sealed cracks whose width can be determined should be rated according to width, otherwise rate at Level 1.

Fatigue Cracking

Defined as cracks occurring in the 0.75 meter (2.5 ft) wide wheelpaths (nominally centered in each wheelpath) not already identified as transverse cracks. They may be observed as: 1) longitudinal cracks in the wheelpath with few or no intersecting cracks, or 2) a series of interconnected transverse and longitudinal cracks located in the wheelpath forming a series of polygons. If fatigue cracking occurs simultaneously in both wheelpaths, the most severe level of cracking occurring in either wheelpath is recorded for that extent. All fatigue cracking present, even if it is sealed, were rated. There are three levels of severity:

- Level 1 - Either of the following two cases: a) Longitudinal cracks in the wheelpath with few or no intersecting cracks, or b) Intersecting longitudinal and transverse cracking that form large polygons (greater than 0.1 square meters or 1 sq ft) which occur primarily in the wheelpaths.
- Level 2 - Interconnected longitudinal, diagonal, and short transverse cracks in the wheelpath whose crack width ranges from hairline to 6mm (0.25 in). These cracks form a network of polygons, often referred to as

alligator or chicken-wire cracks. Some spalling may be observed; however, there will be no loose pieces of asphalt concrete nor will there be any indications of “potholes.”

- Level 3 - Interconnected longitudinal, diagonal, and short transverse cracks in the wheelpath whose crack width is generally greater than 6mm. These cracks form a network of polygons, often referred to as alligator or chicken-wire cracks. These cracks are generally spalled and some potholes may bepresent. The average size of the pieces formed by the cracks will be less than 0.1 square meters (1 sq ft). it should be noted that AC Patching in the wheelpath should be rated as Level 3 Fatigue Cracking with 5-ft minimum length recorded.

Record the length in feet at each severity level of the 0.01-mile section affected. The sum of lengths recorded for all severity levels cannot exceed the length of the section. If different severity levels exist within a given length, rate the length at the highest severity present in either wheelpath. If potholes are present, rate a minimum of 5 ft of length at Fatigue Cracking Level 3 for that section.

Miscellaneous Cracking

Defined as any crack in the non-wheelpath areas and not already identified as transverse. Miscellaneous cracking includes longitudinal cracks, and interconnected longitudinal and transverse cracks forming a series of polygons (block cracking). Do not rate centerline or shoulder seams unless they are deteriorated and only if they fall inside the lane stripes. Rate sealed miscellaneous cracking as Level 1 if the width of the cracks cannot be determined. there are three severity levels:

- Level 1 - non-wheelpath longitudinal cracks with mean width less than 6 mm (0.25 in) wide and without the presence of interconnected cracking
- Level 2 - either non-wheelpath longitudinal cracks with mean width greater than or equal to 6 mm (0.25 in) wide or interconnected longitudinal and transverse cracks with mean width less than 6 mm (0.25 in) wide that form polygons
- Level 3 - interconnected longitudinal and transverse cracks with mean width greater than or equal to 6 mm (0.25 in) wide that form polygons

If block cracking is present, rate it as Miscellaneous Level 2 or 3 and do not rate the individual longitudinal and transverse cracks that form the polygons. Do rate transverse cracks separately if they are not part of a block pattern. Record the length in feet of the 0.01-mile section affected. The sum of lengths recorded for all severity levels cannot exceed the length of the section. If different severity levels exist within a given length, rate the length at the highest severity present within that length.

Raveling

Defined as the wearing away of the pavement surface caused by the dislodging of aggregate particles. The surface texture is typically rough and pitted.

Record the length in feet where raveling exists in either one or both wheelpaths in the 0.01-mile section. Note: The total length recorded cannot exceed the length of the section. If raveling occurs in both wheelpaths simultaneously the length of one wheelpath should be recorded.

AC Patching

AC patching is defined as asphalt patching on asphaltic or concrete pavement surface. AC Patching at bridges and/or approach slabs should not be recorded. This distress category should be used to record large areas of blade or "skin" patching where the underlying distress is not discernible. Smaller areas of AC patching should be recorded as Fatigue Cracking Level 3 or other appropriate distress. As a general guideline, AC Patching should be 100 sf minimum and 1500 sf maximum. Patches larger than 1500 sf should not be recorded as AC Patching but should have all other AC distresses recorded if present. Record the area in square feet of patching within the 0.01 mile section.

6.3 Comparisons of DARWin-ME and ODOT Monitored Distresses

In order to generate comparable cracking between DARWin-ME predictions and ODOT field monitoring performance, the following assumptions are made to validate DARWin-ME distress models:

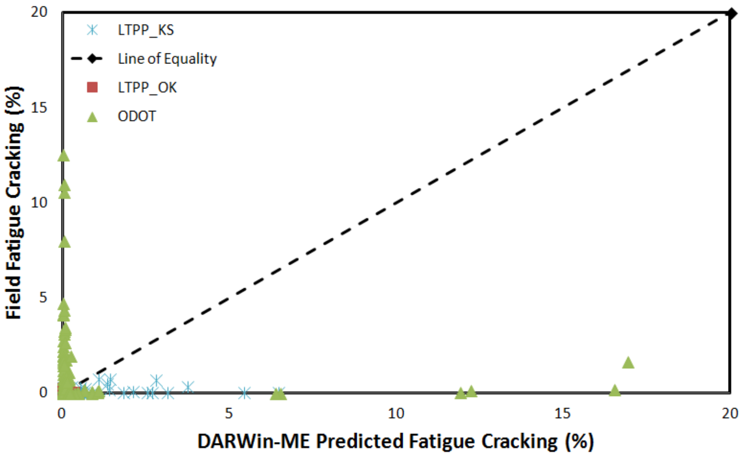
- Since ODOT data do not differentiate where the cracks initiated, it is recommended that alligator and longitudinal cracks in the wheel-path be combined as total fatigue cracking. As recommended in the AASHTO Local Calibration Guide (AASHTO 2012), the total length of linear or longitudinal cracks predicted in DARWin-ME should be multiplied by 1-foot and then divided by the total lane area to obtain percent total lane area fatigue cracks. For ODOT fatigue cracking, it assumes that the length of Level 1 low severity cracks should be multiplied by 1.0ft, length of Level 2 cracks by 1.5ft, while the Level 3 cracks by 2.5 ft (which is the width of wheelpath), and then divided the total lane area.

- Since either flexible or granular bases were constructed on new or rehabilitated ODOT sites, it is assumed that those sites under study don't experience much reflective cracking. Therefore, the ODOT transverse cracking is assumed to be thermal cracking only and compared with DARWin-ME predicted values. To transfer ODOT transverse cracking from the unit of number of cracks to ft per mile, it is assumed that the average lengths of transverse crack are 6ft, 8ft, 10ft, 12ft for the four cracking levels.
- Because ODOT only collects total rut depth on pavement surface, the validation is only confined to the total rut depth.
- IRI data from ODOT database can be directly used to compare with those predicted from Pavement ME Design.

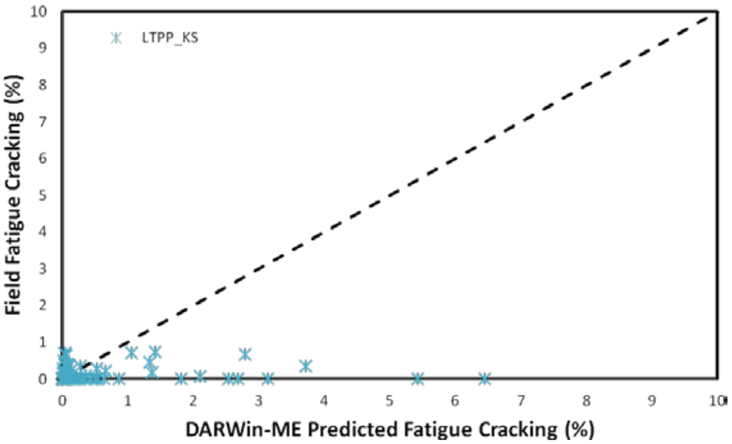
DARWin-ME analysis for each site is performed. The DARWin-ME predicted values and field monitoring results are compared, as shown in Figure 6.1 for total fatigue cracking, Figure 6.2 for transverse cracking, Figure 6.3 for IRI, and Figure 6.4 for total rutting. The comparisons are observed as follows:

- Significant variations are observed between field monitoring fatigue and transverse cracking and DARWin-ME predictions, and thus local calibration of the distress models should be conducted to improve model prediction performance for Oklahoma's implementation of DARWin-ME.

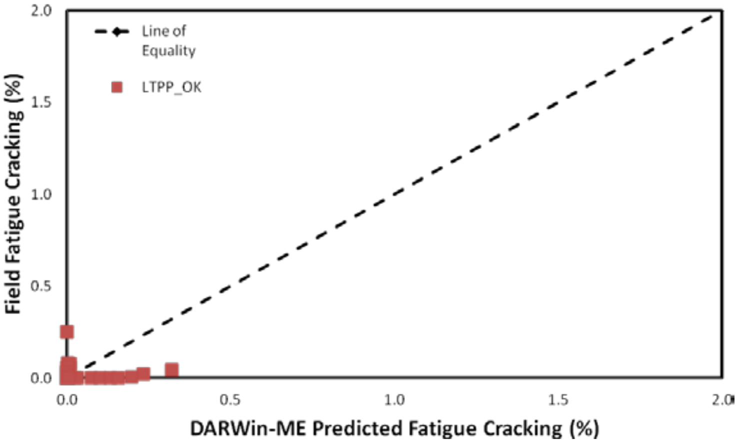
- Comparing to the DARWin-ME predictions, either much more fatigue cracking or zero fatigue cracking is observed on ODOT sites. LTPP sites reports consistently less fatigue than DARWin-ME predicts.
- DARWin-ME does not predict any thermal cracking for all the selected sites. As long as the right binder grade or a more conservative binder is used, no thermal cracking is predicted in DARWin-ME. However, transverse cracks are observed in the field. Therefore, the thermal cracking model in DARWin-ME needs further improvement.
- Compared to distress predictions, rutting predictions and IRI predictions from DARWin-ME demonstrated much better correlations with field monitoring values.



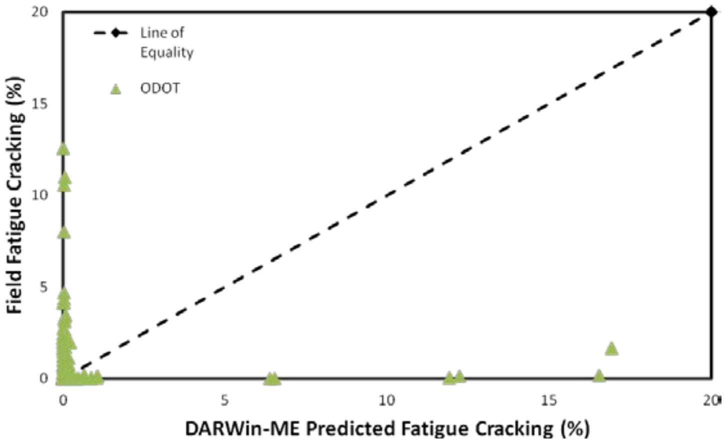
(a) Fatigue cracking comparisons of all sites



(b) Fatigue cracking comparisons of LTPP Kansas Sites



(c) Fatigue cracking comparisons of LTPP Oklahoma Sites



(d) Fatigue cracking comparisons of ODOT Sites

Figure 6.1 Comparisons of Total Fatigue Cracking (%)

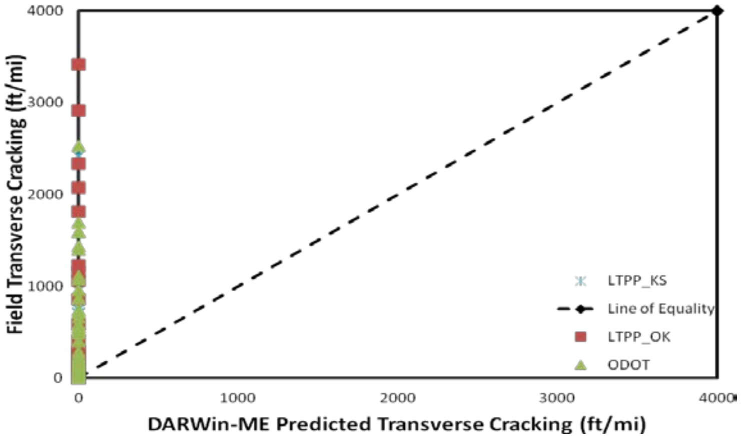
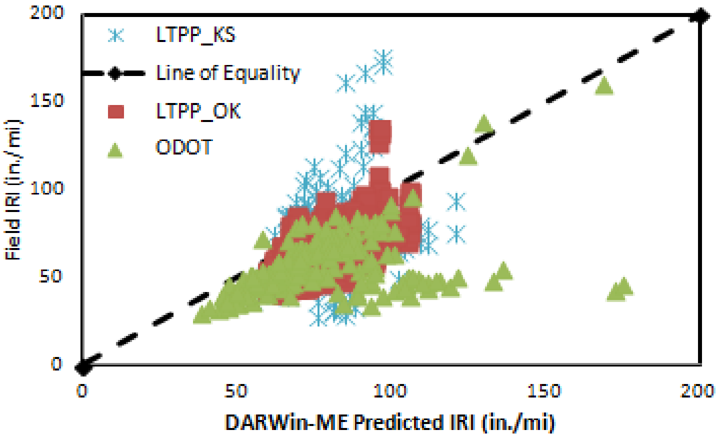
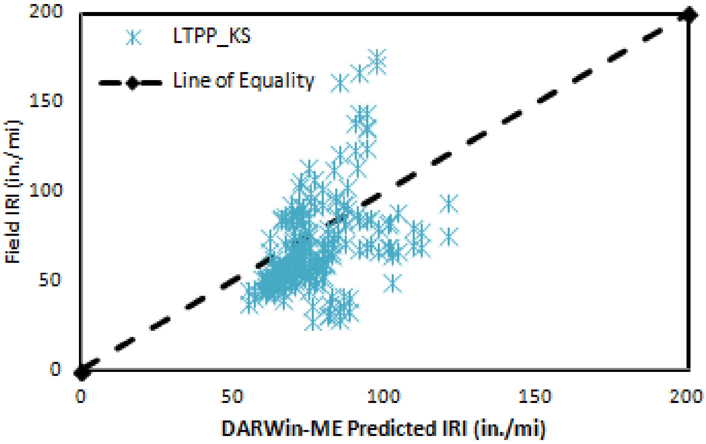


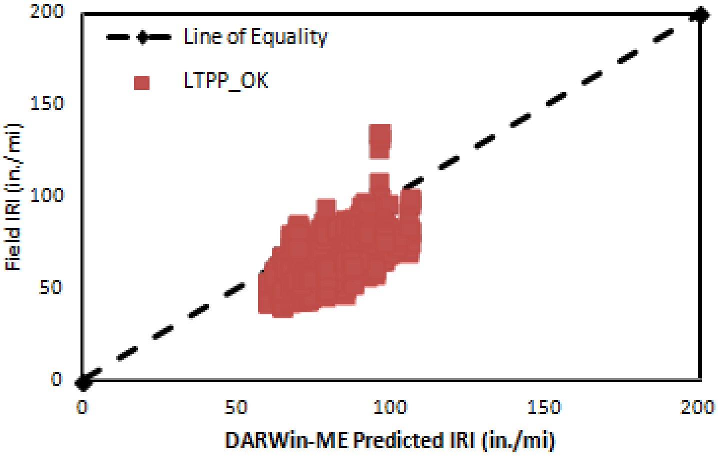
Figure 6.2 Comparisons of Transverse Cracking (ft/mi)



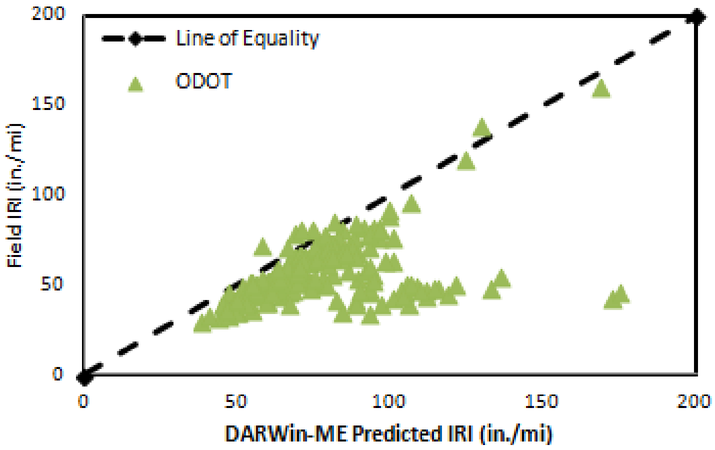
(a) IRI comparisons of all sites



(b) IRI comparisons of LTPP Kansas Sites

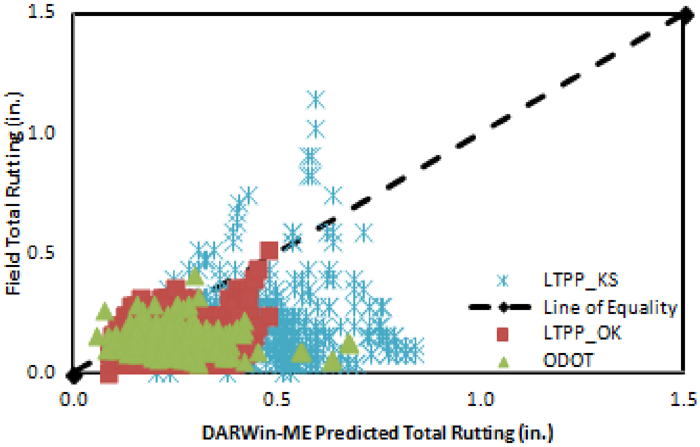


(c) IRI comparisons of LTPP Oklahoma Sites

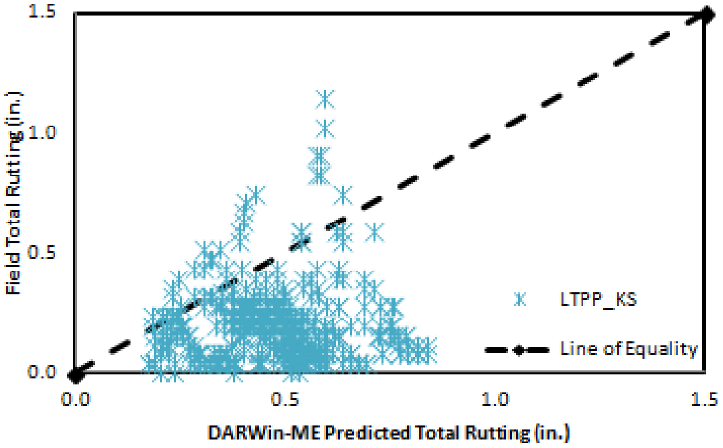


(d) IRI comparisons of ODOT Sites

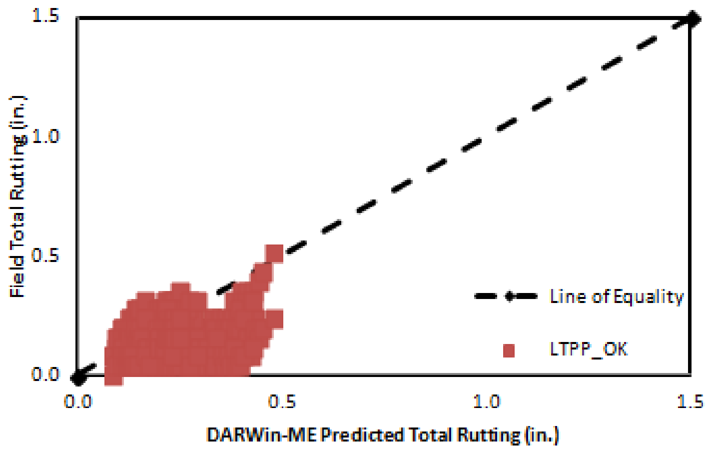
Figure 6.3 Comparisons of IRI (in./mi)



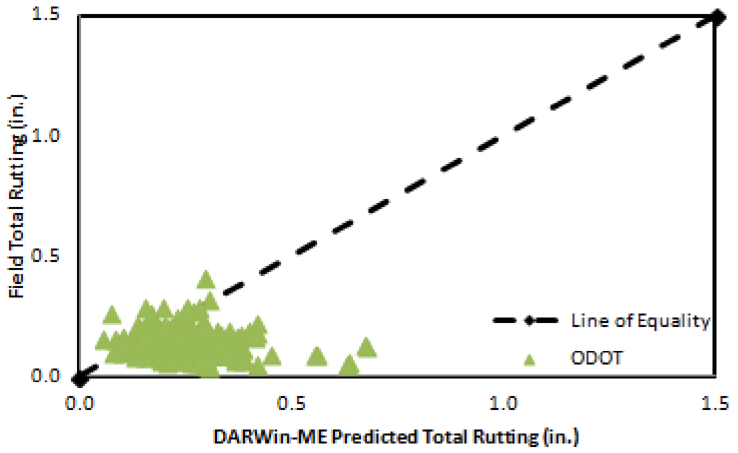
(a) Rutting comparisons of all sites



(b) Rutting comparisons of LTPP Kansas Sites



(c) Rutting comparisons of LTPP Oklahoma Sites



(d) Rutting comparisons of ODOT Sites

Figure 6.4 Comparisons of Total Rut Depth (in.)

To better understand the data comparisons, statistical summary is provided in Table 6.1. Bias is defined as average over or under prediction. P-value helps determine whether the comparisons are significantly different. A small p-value (typically ≤ 0.05) indicates strong evidence to reject the null hypothesis (assumes no significant difference), which indicates that bias should be eliminated through local calibration. The standard error of the estimate (SEE) is a measure of the accuracy of predictions. The AASHTO Local Calibration Guide (AASHTO 2010) recommended reasonable values for the standard error for each distress transfer function, which is used to determine whether standard error should be eliminated through local calibration process. It is observed that:

- There are significant differences between DARWin-ME predictions and field monitoring values for transverse cracking, IRI and rutting. As a result, bias needs to be eliminated first for these performance models and followed by the validation of standard error.
- It should be noted that bias is observed only between DARWin-ME predictions and field monitoring values from LTPP Kansas sites for fatigue cracking. This observation seems to be contradictory to the data comparisons shown in Figure 4, which demonstrates significant variations. Further investigation found that over 98.5% of the DARWin-ME predictions and field observations of fatigue cracking are for pavements with less than 5% cracking. Such small percentage of cracking cannot define the bias and precision of the transfer function well. It is recommended in the AASHTO Local Calibration Guide (AASHTO 2010) that the average maximum values from the sampling sites should exceed at a minimum of 50% of the design criteria. Therefore, new sites with more extensive fatigue cracking that can meet this requirement should be included to reevaluate the fatigue cracking model.
- Therefore, all the four DARWin-ME global prediction models should be local calibrated using Oklahoma data sets.

- Among the three data sources: LTPP Kansas sites, LTPP Oklahoma sites, and ODOT sites, the field monitoring performance at LTPP Oklahoma sites always approaches the DARWin-ME predictions the most.

Table 6.1 Statistical Summary of Data Comparisons

Performance	Data	Bias	P-value	SSE	Eliminate bias?	Eliminate error?
Fatigue Cracking (%)	LTPP_KS vs. ME	-0.37	0.00	0.19	Y	Y
	LTPP_OK vs. ME	0.00	0.97	0.03	N	N
	ODOT vs. ME	0.22	0.24	1.67	N	N
	All data sets	0.02	0.83	1.20	N	N
Transverse Cracking (ft/mi)	LTPP_KS vs. ME	109.06	0.00	315.75	Y	Y
	LTPP_OK vs. ME	160.37	0.00	534.10	Y	Y
	ODOT vs. ME	127.19	0.00	342.07	Y	Y
	All data sets	133.21	0.00	402.55	Y	Y
IRI (in/mi)	LTPP_KS vs. ME	-7.16	0.00	23.17	Y	Y
	LTPP_OK vs. ME	-13.91	0.00	9.35	Y	Y
	ODOT vs. ME	-18.13	0.00	15.14	Y	Y
	All data sets	-13.57	0.00	13.08	Y	Y
Rut (in)	LTPP_KS vs. ME	-0.27	0.00	0.16	Y	Y
	LTPP_OK vs. ME	-0.08	0.00	0.08	Y	Y
	ODOT vs. ME	-0.11	0.00	0.06	Y	Y
	All data sets	-0.17	0.00	0.12	Y	Y

CHAPTER 7 WORKFOLOW FOR ODOT DARWIN-ME IMPLEMENTATION

7.1 Calibration

The primary objective of model calibration is to reduce bias (AASHTO 2010). A biased model will consistently produce either over-designed or under-designed pavements, both of which have important cost consequences. The secondary objective of calibration is to increase precision of the model predictions. A model that lacks precision is undesirable because it leads to inconsistency in design effectiveness, including some premature failures. As part of the calibration process, predicted distress is compared against measured distress and appropriate calibration adjustment factors are applied to eliminate significant bias and maximize precision in the model predictions.

Two different calibration approaches may be required depending upon the nature of the distress being predicted through the transfer function. One approach was used for those models that directly calculate the magnitude of the surface distress, while the other approach was used for those models that calculate the incremental damage index rather than the actual distress magnitude.

Two calibration factors are used in the MEPDG – global and local. These calibration factors are adjustments applied to the coefficients and/or exponents of the transfer function to eliminate bias between the predicted and measured pavement distresses and IRI. The combination of calibration factors (coefficients and exponents for the different distress prediction equations) can also be used to minimize the standard error of the prediction equation. The standard error of the estimate (SEE) measures the amount of dispersion of the data points around the line of equality between the observed and predicted values.

7.2 Validation

The objective of model validation is to demonstrate whether the calibrated model can produce robust and accurate predictions of pavement distress for cases other than those used for model calibration (AASHTO 2010). Validation typically requires an additional and independent set of in-service pavement performance data. Successful model validation requires that the bias and precision statistics of the model when applied to the validation data set are similar to those obtained from model calibration.

The split sample approach is typically used in the calibration and validation of statistical and simulation models. A typical split of a sample is 80/20 with 80 percent of the data used in calibration and 20 percent used for verification, which should be chosen randomly.

7.3 Step-by-Step Workflow

The AASHTO *Local Calibration Guideline* (AASHTO 2010) defines eleven steps for calibrating the DARWin-ME to local conditions, policies, and materials. The flow chart of the 11-step is shown in Figure 7.1 and the steps are summarized in the following for ODOT's local calibration of Pavement ME Design:

Step 1 – Select Hierarchical Input Level for Each Input Parameter

This step is a policy decision, influenced by the ODOT's current field and laboratory testing capabilities, material and construction specifications, and traffic data availability and quality. In addition, a comprehensive sensitivity analysis is anticipated to identify the most critical design inputs in Oklahoma and assist the policy decision making. This step is currently missing in Oklahoma.

Step 2 – Develop Local Experimental Plan and Sampling Template

The selected ODOT sites presented in this study are primarily based on data availability in ODOT's PMS database, while a comprehensive experimental design to cover Oklahoma's local conditions, traffic, and materials is not well considered. The primary tier parameters should be distress dependent, including pavement type, surface layer type and thickness, and subgrade soil type. The secondary tier parameters should include climate (temperature), traffic, and other design features that are pavement type dependent.

Step 3 – Estimate Sample Size for Specific Distress Prediction Models

At minimum, the sampling size recommended in the AASHTO Local Calibration Guide (AASHTO 2010) should be met to achieve sound statistical conclusions. A level of significance of 90 percent is suggested as a practical level in determining the sample size to be used in the experiment. The following provides guidance for the minimum number of total test sections for each distress.

- Distortion (Total Rutting or Faulting)—20 roadway segments
- Load-Related Cracking—30 roadway segments

- Non-Load-Related Cracking—26 roadway segments
- Reflection Cracking (H MA surfaces only)—26 roadway segment.

Step 4 – Select Roadway Segments

Long-term, full-scale roadway segments or test sections should be used to fully validate and calibrate the distress prediction models and confirm the superposition of the environmental, aging, and wheel-load effects on the predictions of distress. PMS segments and those that are research-grade roadway segments should be investigated. The bottom-line for the selection is that the input data required for DARWin-ME and monitoring performance data for local calibration should be available with reasonable good quality. A listing of some factors that should be considered in selecting roadway segments for use in the local validation-calibration refinement plan has been discussed in Chapter 3.

Step 5 – Extract and Evaluate Distress and Project Data

This step is to collect all data and identify any missing data elements that are needed to execute DARWin-ME. In this paper, many of the inputs are based on Level 3 default values. A comprehensive research is needed to identify the missing data, which may include (1) the investigation and integration of available data sources at ODOT along with national studies for Pavement ME Design calibration and implementation; (2) laboratory material testing to obtain typical dynamic modulus values for Oklahoma HMA mixtures; (3) new field distress data collection that is consistent and accurate based on the LTPP distress protocol; (4) selection of more sites that the average maximum distress values exceed 50 percent of the design criteria; (5) field investigations such as FWD deflection basin and other field tests may need to confirm layer thickness and estimate the in-place modulus values for each structural layer.

Step 6 – Conduct Field and Forensic Investigations

ODOT needs to decide whether forensic investigations are required to confirm the assumptions embedded in DARWin-ME. As an example, the portion of total rutting measured at the surface that can be assigned to each pavement layer and the location of where cracks initiated (top-down versus bottom-up cracking). If ODOT elects to accept the DARWin-ME assumptions, no forensic investigations are required. As a result, ODOT should restrict the local calibration to total rut depth and total load related cracking—combining longitudinal and alligator cracks within the wheel path. If ODOT rejects the assumptions, trenches and cores will be needed to measure the rut depths within each pavement layer and estimate the direction of crack propagation.

Step 7 – Assess Bias: Validation of Global Calibration Values

Run the DARWin-ME software using the global model coefficients. The accuracy of the prediction models is evaluated using bias and standard error. If there is a significant bias and residual error, calibrate the models to local conditions is needed. If bias is identified, proceed to Step 8. If no bias is observed but high standard error, proceed to Step 9.

Step 8 – Eliminate Local Bias of Distress and IRI Prediction Models

AASHTO Local Calibration Guide (AASHTO 2012) list the local calibration parameters of the DARWin-ME transfer functions or distress and IRI prediction models that should be considered for revising the predictions to eliminate bias, as shown in Table 7.1. These tables are provided for guidance only in eliminating any local bias in the predictions.

After the bias has been eliminated, compute the standard error of the estimate using the local calibration values to validate the local calibration efforts.

Step 9 – Assess the Standard Error of the Estimate

In this step, it is desired to compare the standard error determined from the sampling template to the standard error derived from the global data set. Reasonable values for the standard error for each distress transfer function (Table 7.2) are recommended in the AASHTO Local Calibration Guide (AASHTO 2012). If the local calibration has a lower standard error term, proceed to Step 11. Otherwise, the distress model should be recalibrated to lower the standard error as described in Step 10.

Table 7.1 Transfer Function Calibration (AASHTO 2010)

Distress		Eliminate Bias	Reduce Standard Error
Total Rutting	Unbound Materials & HMA Layers	$k_{r1}, \beta_{s1}, or\ \beta_{r1}$	$k_{r2}, k_{r3}, and\ \beta_{r2}, \beta_{r3}$
Load Related Cracking	Alligator Cracking	$C_2\ or\ k_{f1}$	$k_{f2}, k_{f3}, and\ C_1$
	Longitudinal Cracking	$C_2\ or\ k_{f1}$	$k_{f2}, k_{f3}, and\ C_1$
	Semi-Rigid Pavements	$C_2\ or\ \beta_{c1}$	C_1, C_2, C_4
Non-Load Related Cracking	Transverse Cracking	β_{t3}	β_{t3}
IRI		C_4	C_1, C_2, C_3

Table 7.2 Reasonable Values of the Standard Error (AASHTO 2010)

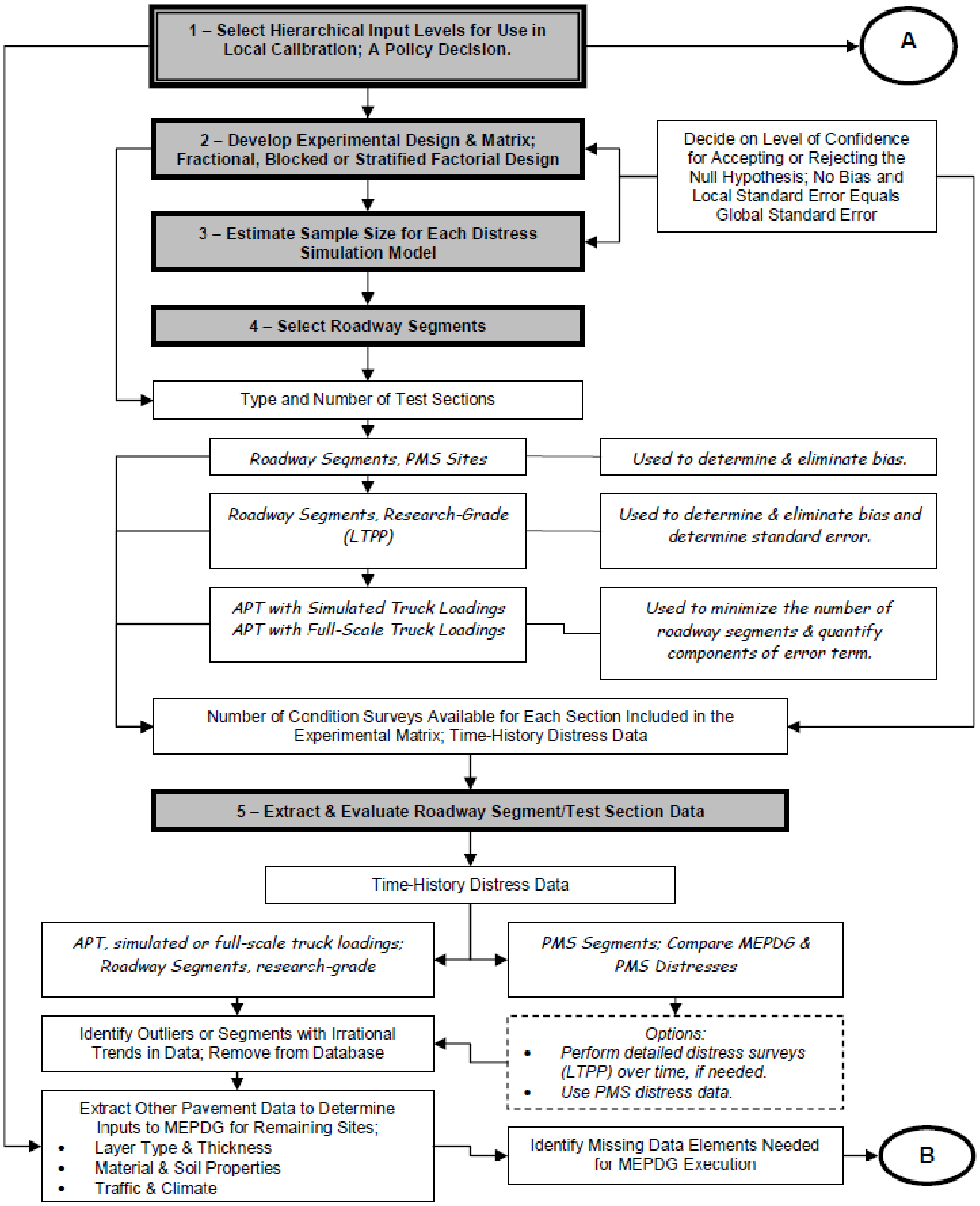
Indicator	**Reasonable standard error**
alligator or bottom-up cracking	7%
longitudinal or top-down cracking	600 ft/mi
Reflective Cracking	N/A
Rutting or Rut Depth	0.10 in.
Transverse Cracking	600 ft/mi
IRI	17 in/mi

- Step 10 – Reduce Standard Error of the Estimate

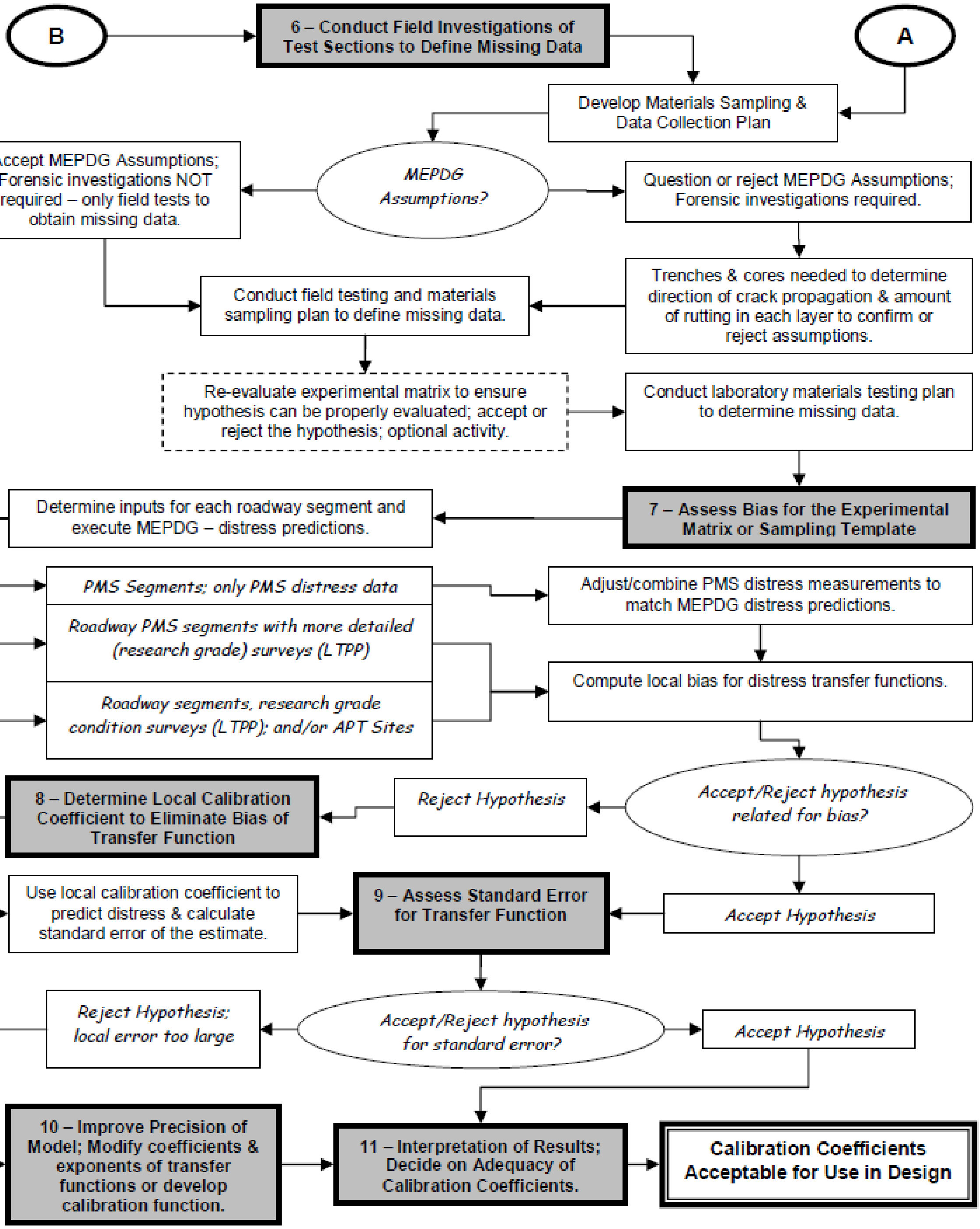
Compute the standard error within each block of the sampling template to determine whether the local standard error term is dependent on any primary or secondary tier parameter of the matrix. Results from the analysis of local standard errors within each block can be used to make revisions to specific local calibration parameters as recommended in the AASHTO Local Calibration Guide. A fitting process of the model constants is evaluated using of either the analytical linear models or non-linear numerical optimization models. These local calibration values that result in the lowest standard error should be used for pavement design.

- Step 11 – Interpretation of Results

The local calibrated model coefficients and new SEE can now be entered into DARWin-ME for use in new and rehabilitation designs. The local standard error of the estimate for each distress and IRI prediction models should be evaluated to determine the impact on the resulting designs at different reliability levels. The sampling template should be used to determine the design life of typical ODOT sites and pavement structures for different reliability levels.


1 – Select Hierarchical Input Levels for Use in Local Calibration; A Policy Decision.
A
2 – Develop Experimental Design & Matrix; Fractional, Blocked or Stratified Factorial Design
Decide on Level of Confidence for Accepting or Rejecting the Null Hypothesis; No Bias and Local Standard Error Equals Global Standard Error
3 – Estimate Sample Size for Each Distress Simulation Model
4 – Select Roadway Segments
Type and Number of Test Sections
Roadway Segments, PMS Sites
Used to determine & eliminate bias.
Roadway Segments, Research-Grade (LTPP)
Used to determine & eliminate bias and determine standard error.
APT with Simulated Truck Loadings
APT with Full-Scale Truck Loadings
Used to minimize the number of roadway segments & quantify components of error term.
Number of Condition Surveys Available for Each Section Included in the Experimental Matrix; Time-History Distress Data
5 – Extract & Evaluate Roadway Segment/Test Section Data
Time-History Distress Data
APT, simulated or full-scale truck loadings; Roadway Segments, research-grade
PMS Segments; Compare MEPDG & PMS Distresses
Identify Outliers or Segments with Irrational Trends in Data; Remove from Database
Options:
• Perform detailed distress surveys (LTPP) over time, if needed.
• Use PMS distress data.
Extract Other Pavement Data to Determine Inputs to MEPDG for Remaining Sites;
• Layer Type & Thickness
• Material & Soil Properties
• Traffic & Climate
Identify Missing Data Elements Needed for MEPDG Execution
B

(a) Part I



(B) Part II

Figure 7.1. Procedure and Steps for Local Calibration (AASHTO 2012)

CHAPTER 8 CONCLUSIONS

This project investigates data needs for the validation of distress models for flexible pavements in the Pavement ME Design in Oklahoma. Large amount of data have been collected to prepare the DARWin-ME data inputs for 77 selected ODOT flexible pavement segments and LTPP sites in Oklahoma and Kansas. A number of DARWin-ME runs are performed. The comparisons and statistical analysis between filed monitoring performance and DARWin-ME predictions indicate that the distress models need to be local calibrated in Oklahoma with more comprehensive experimental design and more accurate data inputs such as Levels 1 or 2. Finally, a workflow for Oklahoma to local calibrate DARWin-ME distress prediction models is streamlined, which will assist ODOT in implementing DARWin-ME in the next decade as part of ODOT long-term plan in studying and deploying DARWin-ME in a production environment.

Data availability and data quality are two critical implementation hurdles for ODOT, as well as for many other DOTs in their recent efforts in studying MEPDG, DARWin-ME, and Pavement ME Design. Among them, traffic WIM data, material characterization, and distress data are generally not adequate for ME design and therefore frequently studied. Particularly for ODOT, even though large amount of WIM traffic data are analyzed, those WIM stations are not located at the selected 77 ODOT sites. In order to prepare traffic loading spectra inputs for Pavement ME Design, assumptions are made to generate simplified traffic clusters so that traffic inputs can be generated for the sites. A robust clustering approach is expected to utilize those abundant WIM traffic data for more accurate traffic inputs. Second, almost all the material data inputs for the 77 ODOT sites, including those for HMA layer, base layer, and subgrade, are not available at the current phase. As a result, Level 3 material data have to be used in the DARWin-ME analysis in this project. Laboratory or field material testing based on comprehensive experimental design is therefore needed to obtain Level 1 or Level 2 material inputs. Third, the inconsistency of the distress data trend and the low distress values observed on the majority of the selected sites hinders the comparisons of field monitoring results and DARWin-ME predictions to be statistically meaningful. From that perspective, more sites with a wide range of distress severity levels are desired. In addition, the time-series distress data are expected to have more rigorous quality control checks before they can be used for the local calibration of distress models.

Through a separate effort with a pooled-fund project supported by eight state DOTs and FHWA, the OSU research team has developed a version of the Prep-ME software that can be used to prepare and qualify traffic and other data sets for Pavement ME Design calibration and implementation. Based on the outcomes of this and several other ODOT research projects, ODOT pavement engineers have a good database of knowledge to move forward with production level calibration of Pavement ME Design. The eventual implementation of Pavement ME Design at ODOT will substantially enhance the design quality and pavement performance in the long run in Oklahoma.

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APPENDIX A HMA LOCAL CALIBRATION SECTIONS FOR ODOT

Element ID	Route	Direction	Length (mile)	Latitude	Longitude	Construction Year
0514 5 0050-0100	SH 6	5	0.5	35.298536	-99.399531	2001
0514 5 0300-0350	SH 6	5	0.5	35.334822	-99.399579	2001
0604 5 1180-1230	US 270	5	0.5	35.690448	-98.351886	2003
0624 5 0025-0075	SH 51A	5	0.5	35.897452	-98.422372	2002
0624 5 0125-0175	SH 51A	5	0.5	35.898756	-98.439754	2002
0814 5 0025-0075	US 281	5	0.5	35.312419	-98.341683	2001
0814 5 0100-0150	US 281	5	0.5	35.321493	-98.347362	2001
0814 5 0250-0300	US 281	5	0.5	35.339432	-98.359329	2001
0814 5 0375-0425	US 281	5	0.5	35.356277	-98.365913	2001
0912 6 0350-0400	US 81	6	0.5	35.582566	-97.959413	2003
0922 5 0302-0352	SH 3	5	0.5	35.690921	-97.951158	2000
0922 5 0677-0727	SH 3	5	0.5	35.665706	-97.892037	2000
1037 5 0124-0174	US 70	5	0.5	34.139182	-97.134417	2001
1037 5 0374-0424	US 70	5	0.5	34.132576	-97.091517	2001
1134 5 0200-0250	SH 51	5	0.5	35.945658	-94.988088	2002
1134 6 0025-0075	SH 51	6	0.5	35.923777	-95.00231	2002
1134 6 0100-0150	SH 51	6	0.5	35.93406	-94.998669	2002
1134 6 0250-0300	SH 51	6	0.5	35.950528	-94.98158	2002
1606 5 0089-0139	US 62	5	0.5	34.795222	-98.387562	2002
1642 5 0563-0613	SH 49	5	0.5	34.721708	-98.420418	2004
1802 5 0150-0200	US 59	5	0.5	36.874084	-95.026102	2000
1918 5 1972-2022	SH 33	5	0.5	35.988543	-96.27843	2004

Element ID	Route	Direction	Length (mile)	Latitude	Longitude	Construction Year
1918 5 2097-2147	SH 33	5	0.5	35.988512	-96.25609	2004
2508 5 0434-0484	SH 19	5	0.5	34.83624	-97.594303	2001
2508 5 0664-0714	SH 19	5	0.5	34.826886	-97.555684	2000
2508 5 0814-0864	SH 19	5	0.5	34.823352	-97.529594	2000
2508 5 1139-1189	SH 19	5	0.5	34.819182	-97.472864	2000
2508 5 1259-1309	SH 19	5	0.5	34.819178	-97.451706	2000
2602 5 0239-0289	US 62	5	0.5	35.086746	-98.051577	2004
2602 5 0439-0489	US 62	5	0.5	35.078544	-98.01792	2004
2602 5 0539-0589	US 62	5	0.5	35.073819	-98.001233	2004
2602 6 0214-0264	US 62	6	0.5	35.086977	-98.05535	2004
2602 6 0464-0514	US 62	6	0.5	35.07744	-98.013141	2004
2604 5 0450-0500	US 62	5	0.5	35.076	-97.752374	2002
2604 5 0525-0575	US 62	5	0.5	35.08487	-97.744708	2002
2604 5 0775-0825	US 62	5	0.5	35.111784	-97.715213	2002
2604 5 0925-0975	US 62	5	0.5	35.124175	-97.694573	2002
2806 5 0075-0125	SH 6	5	0.5	34.867376	-99.378388	2003
3324 5 0616-0666	SH 34	5	0.5	34.6012	-99.561509	2004
3324 5 0716-0766	SH 34	5	0.5	34.615698	-99.561527	2004
3324 5 0791-0841	SH 34	5	0.5	34.626576	-99.561548	2004
3624 5 0100-0150	US 177	5	0.5	36.608297	-97.075725	2002
3624 6 0075-0125	US 177	6	0.5	36.604095	-97.076008	2004
3712 5 0181-0231	SH 51	5	0.5	36.115626	-98.177768	2004
3806 5 2451-2501	US 183	5	0.5	34.958991	-99.060955	2000
3806 5 2601-	US 183	5	0.5	34.98079	-99.060969	2000

Element ID	Route	Direction	Length (mile)	Latitude	Longitude	Construction Year
2651						
3806 5 2676-2726	US 183	5	0.5	34.991697	-99.060931	2000
4008 6 1060-1110	US 59	6	0.5	35.330851	-94.761275	2003
4128 5 1150-1200	SH 99	5	0.5	35.647842	-96.662352	2003
4128 6 0975-1025	SH 99	6	0.5	35.620539	-96.66251	2003
4718 5 0350-0400	SH 8	5	0.5	36.215724	-98.317417	2001
4726 5 2368-2418	US 412	5	0.5	36.362227	-98.485478	2004
4908 5 0284-0334	SH 20	5	0.5	36.29998	-95.270149	2000
4908 5 0387-0437	SH 20	5	0.5	36.29998	-95.251668	2000
4908 5 0487-0537	SH 20	5	0.5	36.3	-95.233721	2000
4908 5 0717-0767	SH 20	5	0.5	36.298495	-95.192594	2000
5408 5 0050-0100	SH 27	5	0.5	35.296893	-96.282071	2001
6020 5 0405-0455	SH 51	5	0.5	36.116317	-96.978985	2003
6212 5 1745-1795	SH 3W	5	0.5	34.79366	-96.733242	2003
6354 5 0059-0109	SH 102	5	0.5	35.392112	-97.089482	2002
6802 5 0061-0111	US 59	5	0.5	35.357362	-94.775695	2003
7002 5 1047-1097	US 54	5	0.5	36.588204	-101.636105	2001
7004 6 1110-1160	US 54	6	0.5	36.778547	-101.329477	2002
7004 6 1310-1360	US 54	6	0.5	36.797331	-101.301945	2002
7110 5 1135-1185	US 183	5	0.5	34.551523	-98.970813	2002
7110 6 0985-1035	US 183	6	0.5	34.529493	-98.97789	2002
7506 5 0666-0716	US 183	5	0.5	35.384222	-98.97605	2000
7506 5 0766-0816	US 183	5	0.5	35.398579	-98.976209	2000
7506 5 0891-0941	US 183	5	0.5	35.416758	-98.976001	2000

Element ID	Route	Direction	Length (mile)	Latitude	Longitude	Construction Year
7506 5 1003-1053	US 183	5	0.5	35.433042	-98.975773	2001
7506 6 0691-0741	US 183	6	0.5	35.387237	-98.976876	2000
7506 6 0841-0891	US 183	6	0.5	35.408887	-98.976366	2000
7608 5 0250-0300	US 64	5	0.5	36.797389	-98.603065	2004
7608 5 0400-0450	US 64	5	0.5	36.797345	-98.576044	2004
0106 5 0100-0150	US 59	5	0.5	36.002594	-94.583659	2001
0513 5 0202-0252	SH 6	5	0.5	35.248304	-99.399453	2001
0513 5 0302-0352	SH 6	5	0.5	35.26282	-99.39949	2001

APPENDIX B PAVEMENT STRUCTURAL AND MATERIALS DATA

Section ID	Layer Information			Binder Types (Design Plans)	Binder Types (LTPP)
	No.	Material Type	Thickness (in.)		
0514 5 0050-0100	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	8		
	3	Fly Ash @15%	8		
0514 5 0300-0350	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	8		
	3	Fly Ash @15%	8		
0604 5 1180-1230	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S2	5		
	4	Fly Ash @15%	8		
0624 5 0025-0075	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	8		
	3	Fly Ash @15%			
0624 5 0125-0175	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	8		
	3	Fly Ash @15%	8		
0814 5 0025-0075	1	S4	2	PG 64-22 PG 74-22	PG 70-22
	2	S3	7		
	3	Fly Ash @15%	8		
0814 5 0100-0150	1	S4	2	PG 64-22 PG 74-22	PG 70-22
	2	S3	7		
	3	Fly Ash @15%	8		
0814 5 0250-0300	1	S4	2	PG 64-22 PG 74-22	PG 70-22
	2	S3	7		
	3	Fly Ash @15%	8		
0814 5 0375-0425	1	S4	2	PG 64-22 PG 74-22	PG 70-22
	2	S3	7		
	3	Fly Ash @15%	8		
0912 6 0350-0400	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S2	5		
	4	Fly Ash @15%	8		
0922 5 0302-0352	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	8		
	3	Fly Ash @18%	8		
0922 5 0677-0727	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	8		
	3	Fly Ash @15%	8		
1037 5 0124-0174	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	3		

Section ID	Layer Information			Binder Types (Design Plans)	Binder Types (LTPP)
	No.	Material Type	Thickness (in.)		
	4	Aggregate Base	6		
	4	lime treated	8		
1037 5 0374-0424	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	3		
	4	Aggregate Base	6		
	5	lime treated	8		
1134 5 0200-0250	1	S4	2	PG 70-28 PG 70-28	PG 70-22
	2	S3	7		
	3	Aggregate Base	6		
	4	Fly Ash @15%	8		
1134 6 0025-0075	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	4		
	4	chert base	12		
1134 6 0100-0150	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	4		
	4	chert base	12		
1134 6 0250-0300	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	4		
	4	chert base	12		
1606 5 0089-0139	1	S4	2	PG 70-28 PG 70-22 PG 70-22	PG 70-22
	2	S3	4		
	3	S3	7		
	4	fine grade	24		
1642 5 0563-0613	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S2	4		
	4	aggregate base	8		
	5	lime stabilized(8%)	8		
1802 5 0150-0200	1	S4	2	PG 64-28 PG 64-22	PG 70-22
	2	S3	6		
	3	aggregate base	6		
1918 5 1972-2022	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S2	4		
	4	aggregate base	6		
	5	lime treated	8		
1918 5 2097-2147	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S2	4		
	4	aggregate base	6		

Section ID	Layer Information			Binder Types (Design Plans)	Binder Types (LTPP)
	No.	Material Type	Thickness (in.)		
	5	lime treated	8		
2508 5 0434-0484	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	PG 64-22	
	3	aggregate base type E	6		
2508 5 0664-0714	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	Fly Ash (15%)	8		
2508 5 0814-0864	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	Fly Ash (15%)	8		
2508 5 1139-1189	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S3	10	PG 64-22	
	4	Fly Ash (15%)	8		
2508 5 1259-1309	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S3	10	PG 64-22	
	4	Fly Ash (15%)	8		
2602 5 0239-0289	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S2	6	PG 64-22	
	4	Fly Ash (8%)	8		
2602 5 0439-0489	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S2	6	PG 64-22	
	4	lime treated (8%)	8		
2602 5 0539-0589	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S2	6	PG 64-22	
	4	lime treated (8%)	8		
2602 6 0214-0264	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S2	6	PG 64-22	
	4	lime treated (8%)	8		
2602 6 0464-0514	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S2	6	PG 64-22	
	4	lime treated (8%)	8		
2604 5 0450-0500	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	aggregate base	6		
	4	lime treated	8		

Section ID	Layer Information			Binder Types (Design Plans)	Binder Types (LTPP)
	No.	Material Type	Thickness (in.)		
2604 5 0525-0575	1	S4	2	PG 70-28 PG 70-28	PG 70-22
	2	S3	3		
	3	aggregate base	6		
	4	lime treated	8		
2604 5 0775-0825	1	S4	2	PG 70-28 PG 70-28	PG 70-22
	2	S3	3		
	3	aggregate base	6		
	4	lime treated	8		
2604 5 0925-0975	1	S4	2	PG 70-28 PG 70-28	PG 70-22
	2	S3	3		
	3	aggregate base	6		
	4	lime treated	8		
3624 5 0100-0150	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	3		
	4	aggregate base	6		
	5	lime treated	6		
3624 6 0075-0125	1	S4	2	PG 70-28 PG 70-28	PG 70-22
	2	S3	6		
	3	aggregate base	6		
	4	lime treated	6		
3712 5 0181-0231	1	S4	2	PG 64-22 PG 64-22 PG 64-22	PG 70-22
	2	S3	3		
	3	S2	5		
	4	Fly Ash @15%	8		
3806 5 2451-2501	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	4		
	3	lime Treated	8		
3806 5 2601-2651	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	4		
	3	lime Treated	8		
3806 5 2676-2726	1	S4	2	PG 70-28 PG 64-22	PG 70-22
	2	S3	4		
	3	lime Treated	8		
3324 5 0791-0841	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	3		
	3	S3	7		
	4	Fly Ash @15%	8		
4128 5 1150-1200	1	S4	2	PG 70-28 PG 70-28 PG 64-22	PG 70-22
	2	S3	4		
	3	S3	4		
	4	aggregate base	6		
	5	Fly Ash @16%	6		
4128 6 0975-	1	S4	2	PG 70-28	PG 70-22

Section ID	Layer Information			Binder Types (Design Plans)	Binder Types (LTPP)
	No.	Material Type	Thickness (in.)		
1025	2	S3	4	PG 70-28	
	3	S3	4	PG 64-22	
	4	aggregate base	6		
	5	Fly Ash @16%	6		
4726 5 2368-2418	1	S4	5	PG 76-28	PG 70-22
	2	S3	9	PG 64-22	
	3	aggregate base	6		
	4	Fly Ash @15%	8		
4908 5 0284-0334	1	S4	2	PG 70-28	PG 70-22
	2	S3	6	PG 70-22	
	3	aggregate base	6		
	4	lime treated	6		
4908 5 0387-0437	1	S4	5	PG 76-28	PG 70-22
	2	S3	9	PG 64-22	
	3	aggregate base	6		
	4	Fly Ash @15%	8		
4908 5 0487-0537	1	S4	5	PG 76-28	PG 70-22
	2	S3	9	PG 64-22	
	3	aggregate base	6		
	4	Fly Ash @15%	8		
4908 5 0717-0767	1	S4	5	PG 76-28	PG 70-22
	2	S3	9	PG 64-22	
	3	aggregate base	6		
	4	Fly Ash @15%	8		
5408 5 0050-0100	1	S4	1.5	PG 64-28	PG 70-22
	2	S3	2.5	PG 64-22	
	3	Fly Ash	8		
6020 5 0405-0455	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S2	6	PG 64-22	
6212 5 1745-1795	1	S4	1.5	PG 70-28	PG 70-22
	2	S3	2.5	PG 70-28	
	3	S3	5	PG 70-28	
	4	lime treated 5%	8		
6354 5 0059-0109	1	S4	1.5	PG 64-22	PG 70-22
	2	S3	5.5	PG 64-22	
	3	S3	2.5	PG 64-22	
	4	Fly Ash @18%	6		
6802 5 0061-0111	1	S4	2	PG 70-28	PG 70-22
	2	S3	3	PG 70-28	
	3	S3	7	PG 64-22	
	4	Fly Ash @15%	8		
7002 5 1047-1097	1	S4	2	PG 76-28	PG 70-22
	2	S3	4	PG 76-28	

Section ID	Layer Information			Binder Types (Design Plans)	Binder Types (LTPP)
	No.	Material Type	Thickness (in.)		
	3	S3	6	PG 64-22	
	4	Fly Ash @15%	8		
7004 6 1110-1160	1	S4	2	PG 76-28	PG 70-22
	2	S3	3	PG 76-28	
	3	type S3 aggregate base	8		
7004 6 1310-1360	1	S4	2	PG 76-28	PG 70-22
	2	S3	3	PG 76-28	
	3	type S3 aggregate base	8		
7110 5 1135-1185	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7110 6 0985-1035	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7506 5 0666-0716	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7506 5 0766-0816	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7506 5 0891-0941	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7506 5 1003-1053	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7506 6 0691-0741	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28	
	3	lime treated	8	4’’ PG 64-22	
7506 6 0841-0891	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-28 4’’ PG 64-22	
	3	lime treated	8		
7608 5 0250-0300	1	S4	2	PG 70-28	PG 70-22
	2	S3	7	PG 70-28	
	3	fly ash	8		
7608 5 0400-0450	1	S4	2	PG 70-28	PG 70-22
	2	S3	7	PG 70-28	
	3	fly ash	8		
0106 5 0100-0150	1	S4	2	PG 76-28	PG 70-22
	2	S3	8	PG 70-28	
	3	fly ash	8		
0513 5 0202-	1	S4	2	PG 70-28	PG 70-22

Section ID	**Layer Information**			**Binder Types (Design Plans)**	**Binder Types (LTPP)**
	No.	**Material Type**	**Thickness (in.)**		
0252	2	S3	8	4’’ PG 70-22	
	3	fly ash	8	4’’ PG 64-22	
0513 5 0302-0352	1	S4	2	PG 70-28	PG 70-22
	2	S3	8	4’’ PG 70-22	
	3	fly ash	8	4’’ PG 64-22	

APPENDIX C SUBGRADE DATA FOR THE SELECTED SITES

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
0514 5 0050-0100	Doxey	A-4 (5)	100	100	99	82				28	7							X	
	Bechman																		
0514 5 0300-0350	Doxey	A-4 (5)	100	100	99	82				28	7							X	
	Bechman																		
0604 5 1180-1230	Dog Creek	11	A-6 (11)	100	99	99	93				32	12							X
	Blaine																		
0624 5 0025-0075	Terrace	11	A-6 (11)	100	99	99	93				32	12							X
	Blaine (use dog creek close by)																		
0624 5 0125-0175	Terrace	11 A-6 (11)	100	99	99	93				32	12							X	
	Blaine (use dog creek close by)																		
0814 5 0025-0075	Marlow	10	100	100	99	94				33	9	32	17	1.86	27			X	
	Caddo (use Marlow in Grady)	A-4 (9)																	
0814 5 0100-0150	Marlow	10	100	100	99	94				33	9	32	17	1.86	27			X	
	Caddo (use Marlow in Grady)	A-4 (9)																	
0814 5 0250-0300	Marlow	10	100	100	99	94				33	9	32	17	1.86	27			X	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Caddo (use Marlow in Grady)	A-4 (9)																	
0814 5 0375-0425	Rush Springs	10	100	100	100	73											X		
	Caddo (use Rush Spring in Grady)	A-4 (9)																	
0912 6 0350-0400	Terrace Deposits (use chicksha)	15	100	99	97	93				41	17	32	13	1.93	37			X	
	Canadian	A-7-6 (11)																	
0922 5 0302-0352	Chickasha Subunit	A-7-6 (11)	100	99	97	93				41	17							X	
	Canadian																		
0922 5 0677-0727	Terrace Deposits (use Duncan)	7	100	100	99	96				26	5							X	
	Canadian	A-4 (8)																	
1037 5 0124-0174	Deese Unit	A-7-5 (35)	100	99	99	97				60	30								X
	Carter																		
1037 5 0374-0424	Oscar	A-7-6 (34)	100	99	98	96				55	31								X
	Carter																		
1134 5 0200-0250	Boone	10	100	98	93	80				31	9	30	15	1.87	28			X	
	Cherokee (use in Adair)	A-4 (8)																	
1134 6 0025-0075	Chester-Meramec	1	A-2-4 (0)	100	52	41	24				33	6						X	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Cherokee																		
1134 6 0100-0150	Chester-Meramec	1	A-2-4 (0)	100	52	41	24				33	6						X	
	Cherokee																		
1134 6 0250-0300	Boone	10	100	98	93	80				31	9	30	15	1.87	28			X	
	Cherokee (use in Adair)	A-4 (8)																	
1606 5 0089-0139	Hennessey	A-6 (20)	100	100	100	96				40	20							X	
	Comanche																		
1642 5 0563-0613	Hennessey	A-6 (20)	100	100	100	96				40	20							X	
	Comanche																		
1802 5 0150-0200	Savanna	A-4 (6)	100	86	81	66				33	4							X	
	Craig																		
1918 5 1972-2022	Chanute	12	100	99	99	97				36	13	33	14	1.92	36			X	
	Creek (use Wann Unit in Tulsa)	A-6 (9)																	
1918 5 2097-2147	Chanute	12	100	99	99	97				36	13	33	14	1.92	36			X	
	Creek (use Wann Unit in Tulsa)	A-6 (9)																	
2508 5 0434-0484	Garber wellinton	19	100	100	98	95				50	23							X	
	Garvin	A-7-6 (25)																	
2508 5 0664-0714	Garber wellinton	19	100	100	98	95				50	23							X	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Garvin	A-7-6 (25)																	
2508 5 0814-0864	Garber wellinton	19	100	100	98	95				50	23							X	
	Garvin	A-7-6 (25)																	
2508 5 1139-1189	Garber wellinton	19	100	100	98	95				50	23							X	
	Garvin	A-7-6 (25)																	
2508 5 1259-1309	Hennessey	A-6 (13)	100	99	99	97				35	12							X	
	Garvin																		
2602 5 0239-0289	Terrace	12	100	100	100	100				35	12	30	14	1.98	31			X	
	Grady (use Dog Creek)	A-6 (13)																	
2602 5 0439-0489	Terrace	12	100	100	100	100				35	12	30	14	1.98	31			X	
	Grady (use Dog Creek)	A-6 (13)																	
2602 5 0539-0589	Terrace	12	100	100	100	100				35	12	30	14	1.98	31			X	
	Grady (use Dog Creek)	A-6 (13)																	
2602 6 0214-0264	Terrace	12	100	100	100	100				35	12	30	14	1.98	31			X	
	Grady (use Dog Creek)	A-6 (13)																	
2602 6 0464-0514	Terrace	12	100	100	100	100				35	12	30	14	1.98	31			X	
	Grady (use Dog Creek)	A-6 (13)																	
2604 5 0450-0500	EL Reno	12	100	98	96	90				35	13	34	14	1.9	38			X	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Grady (use in Stephens)	A-6 (12)																	
2604 5 0525-0575	EL Reno	12	100	98	96	90				35	13	34	14	1.9	38			X	
	Grady (use in Stephens)	A-6 (12)																	
2604 5 0775-0825	EL Reno	12	100	98	96	90				35	13	34	14	1.9	38			X	
	Grady (use in Stephens)	A-6 (12)																	
2604 5 0925-0975	EL Reno	12	100	98	96	90				35	13	34	14	1.9	38			X	
	Grady (use in Stephens)	A-6 (12)																	
2806 5 0075-0125	Hennessey	A-4 (1)	100	86	71	53				32	6						X		
	Greer																		
3324 5 0616-0666	Van Vacter Subunit	A-4 (12)	100	99	98	97				37	10							X	
	Jackson																		
3324 5 0716-0766	Van Vacter Subunit	A-4 (12)	100	99	98	97				37	10							X	
	Jackson																		
3324 5 0791-0841	Van Vacter Subunit	A-4 (12)	100	99	98	97				37	10							X	
	Jackson																		
3624 5 0100-0150	Terrace Deposits	16	100	98	97	91				42	18	34	14	1.87	38			X	
	Kay (Use Wellington Unit)	A-7-6 (12)																	
3624 6 0075-0125	Terrace Deposits	16	100	98	97	91				42	18	34	14	1.87	38			X	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Kay (Use Wellington Unit)	A-7-6 (12)																	
3712 5 0181-0231	Alluvium	A-7-6																	
	Kingfisher																		
3806 5 2451-2501	Hennessey	A-6 (10)	100	99	98	92				28	13							X	
	Kiowa																		
3806 5 2601-2651	Hennessey	A-6 (10)	100	99	98	92				28	13							X	
	Kiowa																		
3806 5 2676-2726	Hennessey	A-6 (10)	100	99	98	92				28	13							X	
	Kiowa																		
4008 6 1060-1110	Savanna	A-7-6 (10)	100	95	92	86				41	13							X	
	Le Flore																		
4128 5 1150-1200	Vanoss-ADA	A-6 (9)	100	100	100	91				31	13							X	
	Lincoln																		
4128 6 0975-1025	Vanoss-ADA	A-6 (9)	100	100	100	91				31	13							X	
	Lincoln																		
4718 5 0350-0400	Flowerpot	A-4 (12)	100	100	100	97				39	10							X	
	Major																		
4726 5 2368-2418	Flowerpot	A-4 (12)	100	100	100	97				39	10							X	
	Major																		
4908 5 0284-0334	Chester-Meramec	A-4 (8)	100	99	96	84				35	10							X	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Mayes																		
4908 5 0387-0437	Chester-Meramec	A-4 (8)	100	99	96	84				35	10							X	
	Mayes																		
4908 5 0487-0537	Chester-Meramec	A-4 (8)	100	99	96	84				35	10							X	
	Mayes																		
4908 5 0717-0767	Terrace Deposits	A-7-6																	
	Mayes																		
5408 5 0050-0100	Wewoka	A-6 (16)	99	98	97	96				39	15							X	
	Okfuskee																		
6020 5 0405-0455	Wellington	18	A-7-6 (14)	100	99	99	97				48	22							
	Payne																		
6212 5 1745-1795	Gerty Sand	18	100	99	97	76				53	19	50	15	1.88	66			X	
	Pontotoc (use Vanoss Unit instead)	A-7-5 (16)																	
6354 5 0059-0109	Wellington-Admire	A-7-6 (28)	100	99	96	89				52	29								X
	Pottawatomie																		
6802 5 0061-0111	Alluvium	17	100	96	95	86				47	20	36	16	1.84	23				X
	Sequoyah (Use McAlester Unit)	A-7-6 (13)																	
7002 5 1047-1097	Ogallala	A-7-5																	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
	Texas																		
7004 6 1110-1160	Ogallala	A-7-5																	
	Texas																		
7004 6 1310-1360	Ogallala	A-7-5																	
	Texas																		
7110 5 1135-1185	Addington	17	A-7-6 (24)	100	99	99	99				42	22							
	Tillman																		
7110 6 0985-1035	Addington	17	A-7-6 (24)	100	99	99	99				42	22							
	Tillman																		
7506 5 0666-0716	Cloud Chief	29	100	100	99	97				65	39	50	15	1.88	66				X
	Washita (use in Roger Mills)	A-7-6 (44)																	
7506 5 0766-0816	Cloud Chief	29	100	100	99	97				65	39	50	15	1.88	66				X
	Washita (use in Roger Mills)	A-7-6 (44)																	
7506 5 0891-0941	Cloud Chief	29	100	100	99	97				65	39	50	15	1.88	66				X
	Washita (use in Roger Mills)	A-7-6 (44)																	
7506 5 1003-1053	Cloud Chief	29	100	100	99	97				65	39	50	15	1.88	66				X
	Washita (use in Roger Mills)	A-7-6 (44)																	

ID	Geologic unit & county	AASHTO Classification	Sieve Analysis				Particle Sizes			Soil Constants							Suitability - Subgrade		
			#10	#40	#60	#200	%sand	%silt	%clay	LL	PI	Field moisture	Shrinkage Limit	Shrinkage ratio	Volumetric change	Potential vertical rise	Good	Fair	Poor
7506 6 0691-0741	Cloud Chief	29	100	100	99	97				65	39	50	15	1.88	66				X
	Washita (use in Roger Mills)	A-7-6 (44)																	
7506 6 0841-0891	Cloud Chief	29	100	100	99	97				65	39	50	15	1.88	66				X
	Washita (use in Roger Mills)	A-7-6 (44)																	
7608 5 0250-0300	Cloud Chief	12	100	97	93	83				34	14	29	16	1.78	24			X	
	Woods (use in woodward)	A-6 (11)																	
7608 5 0400-0450	Cloud Chief	12	100	97	93	83				34	14	29	16	1.78	24			X	
	Woods (use in woodward)	A-6 (11)																	
0106 5 0100-0150	Boone	10	A-4 (8)	100	98	93	80				31	9							X
	Adair																		
0513 5 0202-0252	Cloud Chief	A-6 (14)	100	100	99	95				37	14							X	
	Beckham																		
0513 5 0302-0352	Cloud Chief	A-6 (14)	100	100	99	95				37	14							X	
	Beckham																		

APPENDIX D TMAS QUALITY CONTROL CHECK

Station data (S-card) –Yearly or more often

Duplicates within the batch
Duplicates against the National Database
- Fatal errors
  - no S or 1 in the 1st digit of the record
  - record length less than 167 characters
  - no station ID in the record (columns 4-9)

Critical errors occur if:
- blank or invalid lane
- blank or invalid direction
- blank or invalid functional classification
- blank or invalid state code
- improper vehicle classification designated (column 24-25)
  - (all critical errors are correctable in TMAS)

Caution flags – any other fields left blank or invalid characters in their perspective fields
(all caution errors are correctable in TMAS)

Volume Data (TMG 3-card) - Monthly

- Duplicates within the batch
- Fatal error occurs if:
  - no 3 in the 1st digit of the record
  - record length less than 141 characters
  - no station ID in the record (columns 6-11)
  - no corresponding station in National Database
- Critical error occurs if:
  - record includes 7 or more consecutive zero hours
  - every DOW check
  - record includes zero hour volume with one or more boundary with over 50 vehicles
  - 24 hours of data not in a given record
  - any hourly volume exceeds the max per hour per lane value
  - splits check show unbalanced directional volumes greater than 5% variance from 50%
  - MADT from same month previous year not within 30%
  - State marks data as restricted in column 141

Classification (TMG C-card) - Monthly

- Duplicates within the batch
- Fatal error occurs if:
  - no C in the 1st digit of the record
  - record length less than # of characters based on station data field 15

        - no station ID in the record (columns 4-9)
        - no corresponding station in National Database
    - Critical errors occur if:
        - Volume checks
            - record includes 7 or more consecutive zero hours
            - record includes zero hour volume with one or more boundaries with over 50 vehicles
            - 24 hours of data not in a given record
            - any hourly volume exceeds the max per hour per lane value
            - splits check show unbalanced directional volumes greater than 5% variance from 50%
            - MADT from same month previous year not within 30%
    - Caution flags occur if:
        - Classification checks
            - % class by day maximum check
            - % class by day based on historical value

Weight (TMG W-card) - Monthly

- Duplicates within the batch
- Fatal error occurs if:
    - no W in the 1st digit of the record
    - record length less than 39 characters
    - no station ID in the record (columns 4-9)
    - any record with more than 25 axles
- Critical error occurs if:
    - none
- Caution flags
    - total weight = sum of axle weights
    - every axle weight within acceptable range (1 kip to 50 kip)
    - any inter-axle spacing within acceptable range (1' to 50')
    - sum of axle spacings by class within acceptable range
    - minimum number of axles by vehicle class
    - SAWA by day by lane check against historical average
    - ATS - average tandem spacing check by day by lane for classes 8-13
- Warning errors
    - any record with more than 13 axles and 25 or fewer axles will not be processed and will be placed in a special database.

List of Abbreviations:

ATS – average tandem axle spacing
DOW – day of week
ID – identification
kip – unit of measure 1,000 pounds
MADT – monthly average daily traffic
SAWA – steering axle weight average
TMAS – travel monitoring analysis system

APPENDIX E TRAFFIC DATA FOR CALIBRATION SITES

Section ID	AADT	%SU	%MU	AADTT	Speed (mph)	# lanes	Cluster #
0514 5 0050-0100	1800	7	13	360	70	2	3
0514 5 0300-0350	2600	7	13	520	70	2	3
0604 5 1180-1230	3000	6	19	750	60	2	2
0624 5 0025-0075	1200	4	5	108	70	2	3
0624 5 0125-0175	1200	4	5	108	70	2	3
0814 5 0025-0075	2600	4	12	416	60	2	2
0814 5 0100-0150	1900	4	12	304	60	2	2
0814 5 0250-0300	1900	4	12	304	60	2	2
0814 5 0375-0425	1900	4	12	304	60	2	2
0912 6 0350-0400	5400	12	7	1026	60	2	3
0922 5 0302-0352	4800	9	4	624	70	2	1
0922 5 0677-0727	4800	9	4	624	70	2	1
1037 5 0124-0174	6000	7	11	1080	60	2	3
1037 5 0374-0424	5600	7	11	1080	60	2	3
1134 5 0200-0250	7900	6	6	948	70	2	3
1134 6 0025-0075	7900	6	6	948	70	2	3
1134 6 0100-0150	7900	6	6	948	70	2	3
1134 6 0250-0300	7900	6	6	948	70	2	3
1606 5 0089-0139	3900	2	2	156	60	2	3
1642 5 0563-0613	5600	5	6	616	70	2	3
1802 5 0150-0200	1700	5	6	187	60	2	3
1918 5 1972-2022	3300	6	6	396	70	2	3

Section ID	AADT	%SU	%MU	AADTT	Speed (mph)	# lanes	Cluster #
1918 5 2097-2147	4100	6	6	492	70	2	3
2508 5 0434-0484	1600	7	5	192	70	2	3
2508 5 0664-0714	1600	7	5	192	70	2	3
2508 5 0814-0864	1600	7	5	192	70	2	3
2508 5 1139-1189	1600	7	5	192	70	2	3
2508 5 1259-1309	1600	7	5	192	70	2	3
2602 5 0239-0289	7000	3	9	840	60	2	2
2602 5 0439-0489	7000	3	9	840	60	2	2
2602 5 0539-0589	7000	3	9	840	60	2	2
2602 6 0214-0264	7000	3	9	840	60	2	2
2602 6 0464-0514	7000	3	9	840	60	2	2
2604 5 0450-0500	3300	3	9	396	60	2	2
2604 5 0525-0575	3300	3	9	396	60	2	2
2604 5 0775-0825	3300	3	9	396	60	2	2
2604 5 0925-0975	3500	3	9	420	60	2	2
2806 5 0075-0125	1400	4	6	140	60	2	3
3324 5 0616-0666	2900	6	7	377	70	2	3
3324 5 0716-0766	2900	6	7	377	70	2	3
3324 5 0791-0841	2900	6	7	377	70	2	3
3624 5 0100-0150	6100	4	14	1098	70	2	2
3624 6 0075-0125	6100	4	14	1098	60	2	2
3712 5 0181-0231	7800	5	3	624	60	2	3
3806 5 2451-2501	1500	7	18	375	70	2	2
3806 5 2601-	1500	7	18	375	60	2	2

Section ID	**AADT**	**%SU**	**%MU**	**AADTT**	**Speed (mph)**	**# lanes**	**Cluster #**
2651							
3806 5 2676-2726	1500	7	18	375	60	2	2
4008 6 1060-1110	4000	7	8	600	60	2	3
4128 5 1150-1200	2500	1	3	100	60	2	2
4128 6 0975-1025	2400	1	3	96	70	2	2
4718 5 0350-0400	1700	4	7	187	70	2	3
4726 5 2368-2418	1700	4	26	510	70	2	2
4908 5 0284-0334	5500	5	8	715	60	2	3
4908 5 0387-0437	5500	5	8	715	70	2	3
4908 5 0487-0537	5500	5	8	715	70	2	3
4908 5 0717-0767	6500	5	8	845	70	2	3
5408 5 0050-0100	2100	9	13	462	70	2	3
6020 5 0405-0455	10200	5	3	816	70	2	3
6212 5 1745-1795	7500	10	8	1350	70	2	3
6354 5 0059-0109	4900	6	15	1029	70	2	2
6802 5 0061-0111	3700	6	12	666	70	2	2
7002 5 1047-1097	6200	5	27	1984	60	2	2
7004 6 1110-1160	6000	5	27	1920	60	2	2
7004 6 1310-1360	5900	5	27	1888	60	2	2
7110 5 1135-1185	1800	6	18	432	60	2	2
7110 6 0985-1035	1800	6	18	432	60	2	2
7506 5 0666-0716	4400	6	19	1100	60	2	2
7506 5 0766-0816	4400	6	19	1100	60	2	2
7506 5 0891-0941	5300	6	19	1325	60	2	2

Section ID	**AADT**	**%SU**	**%MU**	**AADTT**	**Speed (mph)**	**# lanes**	**Cluster #**
7506 5 1003-1053	5300	6	19	1325	60	2	2
7506 6 0691-0741	4400	6	19	1100	60	2	2
7506 6 0841-0891	5300	6	19	1325	60	2	2
7608 5 0250-0300	1700	10	11	357	60	2	3
7608 5 0400-0450	1700	10	11	357	60	2	3
0106 5 0100-0150	6500	4	7	715	60	2	3
0513 5 0202-0252	1800	7	13	360	70	2	3
0513 5 0302-0352	1800	7	13	360	70	2	3

APPENDIX F PAVEMENT STRUCTURES OF THE LTPP SEGMENTS

State	SHRP ID	Layer Information				Binder Type
		No.	Material Name	Thickness (in.)	Modulus (psi)	
20	101	1	AC	7.2		PG 64-22
		2	Crushed Gravel	8.3	27896	
		3	Crushed Gravel	6	20537	
		4	Permeable Aggregate	18	19212	
		5	A-4		13000	
20	102	1	AC	4.3		PG 64-22
		2	Crushed Gravel	12.3	27986	
		3	Crushed Gravel	6	20537	
		4	River-run Gravel	17	19213	
		5	A-4		13000	
20	103	1	AC	3.6		PG 64-22
		2	Crushed Gravel	7.1	20537	
		3	River-run Gravel	6	19213	
		4	A-4		12821	
20	104	1	AC	6.6		PG 64-22
		2	Crushed Gravel	12.1	20537	
		3	River-run Gravel	6	16408	
		4	A-4		12436	
20	105	1	AC	4.2		PG 64-22
		2	Crushed Stone	3.8	27896	
		3	Crushed Gravel	4	24217	
		4	River-run Gravel	6	17071	
		5	River-run Gravel	24	13605	
		6	A-4		12050	
20	106	1	AC	7.2		PG 64-22
		2	Crushed Stone	7.4	26228	
		3	Crushed Gravel	3.9	20537	
		4	River-run Gravel	6	12710	
		5	A-4		11664	
20	107	1	AC	4.1		PG 64-22
		2	Crushed Stone	3.7	24560	
		3	Crushed Gravel	3.9	20537	
		4	River-run Gravel	6	11816	
		5	A-4		11596	
20	108	1	AC	7.5		PG 64-22
		2	Crushed Stone	3.6	22892	
		3	Crushed Gravel	7.6	20537	
		4	River-run Gravel	6	11603	
		5	A-4		11528	
20	109	1	AC	8.1		PG 64-22

State	SHRP ID	Layer Information				Binder Type
		No.	Material Name	Thickness (in.)	Modulus (psi)	
		2	Crushed Stone	3.3	21224	
		3	Crushed Gravel	12	20537	
		4	River-run Gravel	6	10027	
		5	River-run Gravel	18	9718	
		6	A-6		9427	
20	110	1	AC	6.7		PG 64-22
		2	Crushed Gravel	4.5	21224	
		3	Crushed Gravel	3.7	21537	
		4	Crushed Gravel	6	20537	
		5	River-run Gravel	18	15359	
		6	A-6		11390	
20	111	1	AC	4.2		PG 64-22
		2	Crushed Stone	8.3	23206	
		3	Crushed Gravel	3.6	22862	
		4	River-run Gravel	6	18861	
		5	A-6		12948	
20	112	1	AC	4.7		PG 64-22
		2	Crushed Stone	12.1	27896	
		3	Crushed Gravel	3.8	25186	
		4	Crushed Gravel	6	22476	
		5	A-6		14504	
20	159	1	AC	1.2		PG 64-22
		2	AC	1.3		PG 64-22
		3	AC	2.8		PG 64-22
		4	AC	6		PG 64-22
		5	Crushed Gravel	6	26034	
		6	A-7-6		16061	
20	160	1	AC	1.6		PG 64-22
		2	AC	4		PG 64-22
		3	Crushed Gravel	7	27896	
		4	River-run Gravel	6	26034	
		5	A-6		16383	
20	161	1	AC	1.6		PG 64-22
		2	AC	4.2		PG 64-22
		3	Crushed Stone	11	26965	
		4	Crushed Gravel	6	26034	
		5	A-6		16705	
20	162	1	AC	1.6		PG 64-22
		2	AC	9.9		
		3	Crushed Stone	6	26034	
		4	A-4		17027	
20	163	1	AC	1.7		PG 64-22
		2	AC	3.1		PG 64-22
		3	Crushed Stone	8	26965	

State	SHRP ID	Layer Information				Binder Type
		No.	Material Name	Thickness (in.)	Modulus (psi)	
		4	Crushed Stone	6	26034	
		5	A-6		16705	
20	164	1	AC	1.7		PG 64-22
		2	AC	2.5		PG 64-22
		3	AC	8.1		PG 64-22
		4	Crushed Gravel	6	26034	
		5	A-6		17027	
40	113	1	AC	1.5		PG 64-22
		2	AC	3		PG 64-22
		3	Crushed Stone	6.9	24000	
		4	A-2-7	8	16000	
		5	A-6	12	14000	
		6	A-6		14000	
40	114	1	AC	2		PG 64-22
		2	AC	6.1		PG 64-22
		3	Crushed Stone	9.8	24000	
		4	A-2-7	9	24000	
		5	A-6	12	16000	
		6	A-6		16000	
40	115	1	AC	2		PG 64-22
		2	AC	5.6		PG 64-22
		3	AC	9		
		4	A-2-7	8	16000	
		5	A-7-6	12	13500	
		6	A-7-6		13500	
40	116	1	AC	1.8		PG 64-22
		2	AC	2.3		PG 64-22
		3	AC	11.7		PG 64-22
		4	A-2-7	8	16000	
		5	A-7-6	12	10000	
		6	A-7-6			
40	117	1	AC	1.9		PG 64-22
		2	AC	5.9		PG 64-22
		3	AC	4.1		PG 64-22
		4	Crushed Stone	4	24000	
		5	A-2-7	8	24000	
		6	A-6	12		
40	118	1	AC	1.8		PG 64-22
		2	AC	2.7		PG 64-22
		3	AC	8.4		PG 64-22
		4	Crushed Stone	3.6	24000	
		5	A-2-7	8	16000	
		6	A-6	12	14500	
		7	A-6		14500	

State	SHRP ID	Layer Information				Binder Type
		No.	Material Name	Thickness (in.)	Modulus (psi)	
40	119	1	AC	1.5		PG 64-22
		2	AC	5.8		PG 64-22
		3	Soil Cement	4	50000	
		4	Crushed Stone	4.3	24000	
		5	A-2-7	8	16000	
		6	A-6	12	14500	
		7	A-6		14500	
40	120	1	AC	1.6		PG 64-22
		2	AC	3.1		PG 64-22
		3	Soil Cement	4.8	50000	
		4	Crushed Stone	7.9	24000	
		5	A-2-7	9	16000	
		6	A-6		9000	
40	121	1	AC	1.5		PG 64-22
		2	AC	2.5		PG 64-22
		3	Soil Cement	4.4	55000	
		4	Crushed Stone	11	24000	
		5	A-2-6	8	16000	
		6	A-6		9000	
40	122	1	AC	1.8		PG 64-22
		2	AC	2.6		PG 64-22
		3	AC	3.9		PG 64-22
		4	Soil Cement	4.8	50000	
		5	A-2-6	8	16000	
		6	A-6		16000	
40	123	1	AC	1.6		PG 64-22
		2	AC	5.5		PG 64-22
		3	AC	8.6		PG 64-22
		4	Soil Cement	4.4	2000000	
		5	A-2-7	8	16000	
		6	A-6		14500	
40	124	1	AC	1.6		PG 64-22
		2	AC	5.5		PG 64-22
		3	AC	8.6		PG 64-22
		4	Soil Cement	4.4	2000000	
		5	A-2-7	8	16000	
		6	A-6		14500	
40	160	1	AC	1.5		PG 64-22
		2	AC	6.5		PG 64-22
		3	AC	4		PG 64-22
		4	Soil Cement	5.4	24000	
		5	A-2-7	8	16000	
		6	A-6	12	14000	
		7	A-6		14000	PG 64-22