GEORGIA DOT RESEARCH PROJECT 10-09

FINAL REPORT

TRAFFIC LOAD SPECTRA FOR IMPLEMENTING AND USING THE MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE IN GEORGIA

Georgia Department of Transportation

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Load Spectra – Development of Statewide Program
for Collection and Processing of Vehicle Weight Data

Final Report

TRAFFIC LOAD SPECTRA FOR IMPLEMENTING AND USING THE MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE IN GEORGIA

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16. Abstract:

The GDOT is preparing for implementation of the Mechanistic-Empirical Pavement Design Guide (MEPDG). As part of this preparation, a statewide traffic load spectra program is being developed for gathering truck axle loading data. This final report presents the results of a comprehensive research effort that culminated in recommendations for a statewide Traffic Load Spectra Program for collecting and processing truck axle loading data to support MEPDG implementation in Georgia. The recommendations include an optimal axle loading data collection plan that balances pavement design data needs, cost and number of WIM sites, and types of equipment used in obtaining the data. The report also shows how the available GDOT traffic data and other applicable data resources were used to develop traffic loading inputs and defaults to support local calibration of MEPDG models in Georgia. The available axle loading data were analyzed and the interim traffic loading defaults were developed for different groups of roads designed and maintained by GDOT, along with the recommendations for future updates of the defaults. In addition, user guidelines, decision trees, and software tools were developed to facilitate using the traffic loading defaults in MEPDG applications.

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LIST OF ABBREVIATIONS AND ACRONYMS

AADTT	Average Annual Daily Truck Traffic
AASHTO	American Association of State Highway and Transportation Officials
AVC	Automated Vehicle Classification
APC	Axle per Class (coefficient)
ATLAS	Advanced Traffic Loading Analysis System
DOT	Department of Transportation
ESAL	Equivalent Single Axle Load
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
FTE	Full-Time Equivalent
GDOT	Georgia Department of Transportation
HMA	Hot Mix Asphalt
IRI	International Roughness Index
JPCP	Jointed Plain Concrete Pavement
LTAS	LTPP Traffic Analysis Software
LTPP	Long Term Pavement Performance
MEPDG	Mechanistic-Empirical Pavement Design Guide
NALS	Normalized Axle Load Spectra
NCHRP	National Cooperative Highway Research Program
NVCD	Normalized Vehicle Class Distribution
OTD	Office of Transportation Data
PLUG	Pavement Loading User Guide
PVR	Per Vehicle Records
QA	Quality Assurance
QC	Quality Control
RPPIF	Relative Pavement Performance Impact Factor
SAWA	Steering Axle Weight Average
SEE	Standard Error of the Estimate
SPS	Specific Pavement Studies
STARS	State Traffic and Report Statistics
TMG	Traffic Monitoring Guide

TPAS	Traffic Polling and Analysis System
TPEF	Truck Payload Equivalent Factor
TPF	Transportation Pooled-Fund (study)
TTC	Truck Traffic Classification
TWRG	Truck Weight Road Group
VCD	Vehicle Class Distribution
VTRIS	Vehicle Travel Information System
VIUS	Vehicle Inventory and Use Survey
WIM	Weigh-in-Motion

EXECUTIVE SUMMARY

OVERVIEW

This report presents the results of a comprehensive research effort that culminated in recommendations for a Statewide Traffic Load Spectra Program for the Georgia Department of Transportation (GDOT). The Traffic Load Spectra Program is intended to allow GDOT to collect and process truck axle loading data to support implementation of the Mechanistic-Empirical Pavement Design Guide (MEPDG).

The primary outcomes from this study are recommendations for establishing GDOT's Traffic Load Spectra Program and the weigh-in-motion (WIM) Data Collection Plan to support pavement design using the MEPDG. The recommendations are summarized in chapter 9, and the WIM Data Collection Plan is presented in appendix A. In addition, Georgia local traffic loading defaults and site-specific traffic loading inputs were developed to support immediate steps towards MEPDG implementation. This report also includes summary descriptions of the defaults and supporting information for their derivation.

A supplemental but important outcome from this study is an interactive traffic loading database library application called GDOT Pavement Loading User Guide (GDOT PLUG) that facilitates using traffic loading data with the MEPDG methodology.

GDOT'S TRAFFIC DATA AND APPLICABILITY FOR MEPDG IMPLEMENTATION

The study included a review of literature and current practices for load spectra data collection and use for MEPDG-based pavement design. This review included the National Cooperative Highway Research Program (NCHRP) 1-37A and 1-39 studies, Federal Highway Administration (FHWA) traffic monitoring guidelines, Long Term Pavement Performance (LTPP) Traffic Pooled-Fund Study TPF 5(004), assessment of current traffic load program practices in selected States, and assessment of available traffic load data processing software. In addition, the current GDOT traffic data collection and pavement design practices were evaluated. As a result of this review, several WIM program options supporting GDOT's MEPDG implementation were identified, and recommendations on their applicability in Georgia were developed.

GDOT's available WIM data were assessed to determine their usability for developing MEPDG loading inputs and defaults. This assessment included GDOT's permanent and portable WIM sites and WIM data for LTPP study sites located in Georgia.

GDOT's permanent WIM data from two pilot sites were determined to be of acceptable quality and were used to develop MEPDG Level 1 traffic loading inputs. The distributions of heavy loads observed at Georgia permanent WIM sites were found to be more similar to the default values based on the LTPP SPS TPF 5(004) WIM sites than to default values developed under the NCHRP 1-37A project. Therefore, the MEPDG traffic loading defaults developed by the LTPP program are believed to be more applicable in Georgia than the original MEPDG defaults.

Data from GDOT's portable WIM sites were a valuable source of information on the expected loading pattern of a specific roadway. Most of these data, however, would be inadequate as a direct Level 1 input, due to the limitation of equipment accuracy and challenges with field calibration of the portable WIM system. As such, these data can aid in the selection of a default normalized axle load spectrum (NALS) that best describe the expected loading distribution but not in determining Level 1 NALS or in generating default NALS.

No LTPP Georgia sites had WIM data suitable as a direct MEPDG Level 1 input. Therefore, historical WIM data collected at Georgia LTPP sites are not recommended for local calibration or development of the defaults.

GDOT's vehicle classification data from automated vehicle classification (AVC) sites were also reviewed and categorized by MEPDG truck traffic classification (TTC) groups. Not all default MEPDG TTCs were observed in Georgia. Specifically, there were no sites assigned to TTC groups that have a significant presence of multi-trailer trucks (FHWA classes 11, 12, and 13). Based on this vehicle classification data assessment, GDOT should continue with the current practice of conducting site-specific vehicle classification counts and development of Level 1 MEPDG Normalized Vehicle Class Distribution (NVCD) inputs. This practice will assure that any limitations with site-specific axle weight data are minimized by using highly accurate truck volume by Class data.

COMPARISON OF LOADING CATEGORIES OBSERVED IN GEORGIA AND AVAILABLE MEPDG LOADING DEFAULTS

Several methods were used to develop an understanding of traffic loading conditions and to identify similarities in truck loading for different groupings of Georgia roads. This activity included surveys of GDOT personnel, review of freight analysis results from FHWA studies, and assessment of loading conditions from Georgia WIM data. Based on this analysis, traffic loading on most roads maintained by GDOT could be represented by the following three loading categories:

- Moderate loading category (10 to 30 percent of Class 9 trucks are heavily loaded). This loading is most likely to be observed on roads with annual average daily truck traffic (AADTT) less than 1,000 trucks in the design lane and roads with less than 50 percent of Class 9 trucks in the truck distribution. Most of these roads are likely to be urban non-interstate roads, as well as some rural principal and minor arterials. This condition is likely to be applicable to routes that primarily are used for local movements of goods (i.e., local distribution).
- Heavy 1 loading category (30 to 40 percent of Class 9 trucks are heavily loaded). This loading is observed on Georgia arterial roads with a wide range of AADTT and percentage of Class 9 trucks. It is likely that over half of urban interstates and about half of rural interstates will have this loading condition, especially roads with design lane AADTT between 1,000 and 3,000 trucks and between 50 and 80 percent of Class 9 trucks in the truck distribution. This condition could be observed on both rural and urban non-interstate principal arterials. This condition is likely to be applicable to routes that combine both local distribution and State-to-State freight movements.
- Heavy 2 loading category (40 to 50 percent of Class 9 trucks are heavily loaded). This loading is most likely to be observed on principal arterial roads with AADTT over 2,000 trucks and more than 80 percent of Class 9 trucks in the truck distribution. Most of these roads are likely to be rural interstate roads, as well as some urban interstates and rural principal arterial non-interstate roads. This condition is likely to be observed on major freight routes serving multiple States.

NALS representing different loading conditions on Georgia roads were computed based on GDOT's WIM data and compared with the available traffic loading defaults: the original NCHRP 1-37A defaults, the new LTPP SPS TPF 5(004) defaults, and Florida State defaults.

The shape of the Georgia moderate NALS distribution is similar to the Florida and LTPP moderate default distributions. The shape of the Georgia Heavy 1 distribution falls between the Florida urban interstates default and the LTPP Heavy 1 default. The shape of the Georgia Heavy 2 distribution is similar to the Florida rural interstates default and the LTPP Heavy 2 default.

Comparison of NALS from the Moderate, Heavy 1, and Heavy 2 loading categories confirmed that a statistical difference in loading exists between these three categories for both Georgia and LTPP sites. When Georgia NALS were compared to LTPP default NALS in the same loading category, statistical differences were observed. This was somewhat expected, as Georgia data were collected using less precise portable WIM equipment. Because the accuracy of the data from these two sources was different, the validity of this statistical conclusion is limited. It is very important for GDOT to install permanent WIM sites to test this conclusion and to get a reliable source of Georgia-specific WIM data for pavement design and defaults generation.

MEPDG SENSITIVITY TO AXLE LOADING DISTRIBUTIONS

A sensitivity or impact analysis was conducted to determine the importance of the NALS for predicting pavement distress and defining NALS groups representing different traffic loading conditions to use in MEPDG design. This analysis is accomplished by comparing the MEPDG results computed based on NALS representing different loading conditions observed in Georgia. The impact analysis was conducted by comparing calculated distresses, predicted design life, and pavement design thickness.

In addition to NALS representing Georgia loading conditions, NALS defaults developed under the NCHRP 1-37A project, the new national LTPP NALS defaults, and the NALS defaults developed by the Florida DOT were used in the comparative analysis of the MEPDG outcomes. MEPDG analyses were conducted using pavement designs (flexible and rigid) typical for higher volume Georgia roadways, which is the DOT's predominant use of the MEPDG.

Significant differences in pavement design life (over 50 percent) are observed when different NALS observed in Georgia are used. At the same time, however, less than a 1-inch difference in pavement thickness is expected. Because different NALS inputs could result in significantly different pavement service lives, it is recommended that multiple defaults representing different loading conditions observed on Georgia roads be used, especially during the local calibration of the transfer functions. However, this analysis did not include a comparison of predicted and measured distresses to determine which, if any, sets of NALS would result in a lower standard error of the transfer function. The impact of NALS on the standard error should be evaluated during the local calibration to determine if there is a significant difference in the standard error.

Given the limited availability of high-quality WIM data in Georgia, data from other sources are recommended to be used as a short-term solution for NALS defaults and local calibration. Because LTPP loading defaults were developed using high-quality WIM data and represent loading conditions similar to the ones observed on Georgia roads, it is recommended that GDOT consider the new LTPP NALS defaults as interim default NALS for Georgia MEPDG implementation, until sufficient high-quality WIM data are collected to develop State-specific defaults. The recommendation for future use of the NALS derived under LTPP or the GDOT study should be based on the local calibration study being conducted under another MEPDG project sponsored by GDOT.

INTERMEDIATE MEPDG LOADING DEFAULTS FOR GEORGIA

Due to the limited availability of site-specific truck loading weight data in Georgia, default NALS will be used for the majority of MEPDG-based designs in Georgia. Use of multiple loading defaults is recommended to best represent the expected loading condition at the design location. The selection of loading defaults should be focused on NALS for Class 9 trucks because these trucks carry the majority of heavy loads on Georgia roads. The following loading categories were identified and defaults recommendations developed:

- The Moderate loading condition is most likely to be observed on Georgia roads with AADTT less than 1,000 trucks and less than 50 percent Class 9 trucks for the design lane. In Georgia, most of these roads are likely to be urban non-interstates, as well as some rural principal and minor arterials. This condition is likely to be applicable to routes that primarily are used for local movements of goods (local distribution), away from major industrial and multi-modal transportation facilities and warehouses. For these roads, use the LTPP Moderate default for Class 9 vehicles and "typical" default for all other vehicle classes. This default should not be used for the routes designated as Georgia State freight routes.
- The Heavy 1 loading condition is observed on Georgia roads with a wide range of AADTT and percentages of Class 9 trucks for the design lane. It is likely that over half of Georgia urban interstates and about half of rural interstates will have this loading condition, especially roads with design lane AADTT from 1,000 to 3,000 trucks and 50 to 80 percent Class 9 trucks. This condition could also be observed on both rural and urban non-interstate principal arterials in Georgia. This condition is likely to be applicable to routes that combine local distribution and state-to-state freight movements. For these routes, use the LTPP Heavy 1 default for Class 9 vehicles and "typical" default for all other vehicle classes. Use this default distribution for all non-interstate roads designated as Georgia State freight routes and for urban interstates designated as Georgia State freight routes.
- The Heavy 2 loading condition is most likely to be observed on Georgia roads with AADTT over 2,000 trucks and more than 80 percent Class 9 trucks for the design lane. Most of these roads are likely to be Georgia rural interstate roads, as well as some urban interstates and rural principal arterial non-interstate roads. This condition is likely to be applicable to major freight routes serving multiple States. For these routes, use the LTPP Heavy 2 default for Class 9 vehicles and "typical" default for all other vehicle classes. Use this default distribution for interstates designated as freight routes located in rural areas. This distribution may also be applicable for routes serving major industrial and multi-modal transportation facilities and warehouses.

In addition to the analysis of NALS for Class 9 vehicles, it is recommended that GDOT select load-specific LTPP defaults for vehicles in any other classes carrying over 20 percent of the total pavement load (not total volume). Defaults should be selected based on the expected loading category for these dominant classes. In the interim, the LTPP "typical" default is recommended for all other vehicle classes. These defaults are included in the GDOT PLUG software application.

NALS developed from the Georgia axle weight data should be used whenever applicable. If site-specific WIM data quality is questionable, use site-specific NALS at least to establish the loading category and select the appropriate default NALS.

GDOT PAVEMENT LOADING USER GUIDE (PLUG) – A TOOL FOR SELECTING MEPDG TRAFFIC LOADING INPUTS AND DEFAULTS

The LTPP Pavement Loading User Guide database software application was customized to better serve GDOT pavement engineers in the selection of NALS for MEPDG pavement design and generation of axle load distribution files. Under this study, a customized version of the LTPP PLUG software was developed specifically for GDOT. GDOT PLUG contains a library of NALS, including site-specific load distributions for GDOT WIM sites, interim GDOT NALS defaults, and a full library of LTPP NALS defaults.

The GDOT PLUG could be used for developing MEPDG site-specific, site-related, or default (statewide or for specific types of roads) axle load distribution input files. It is especially beneficial for selecting loading inputs for projects that have site-specific vehicle classification and/or truck volume data but no axle load information, or if the accuracy of the loading information is questionable due to limited data availability or traffic monitoring equipment type. GDOT PLUG could also be used to develop and update MEPDG NALS defaults for Georgia. The GDOT PLUG user's manual contains detailed instructions for selecting pavement loading inputs and/or defaults from the PLUG database library and for developing user-defined NALS and default NALS.

In addition to GDOT PLUG, a set of guidelines and decision trees were developed to help GDOT pavement engineers in selecting traffic loading inputs for MEPDG designs. These guidelines were developed for designs involving both new alignments and existing roadways.

RECOMMENDATIONS FOR WIM DATA COLLECTION PROGRAM TO SUPPORT MEPDG IMPLEMENTATION AND USE

Detailed recommendations were developed for WIM data collection to support the implementation of the MEPDG pavement design method and for calibrating the MEPDG transfer functions. These recommendations should be considered in the overall program that will serve multiple GDOT WIM data users, including the selection of WIM technology; installation, operation, and calibration of WIM sites; data collection, quality control/quality assurance, processing, and summarization; and distribution of axle load spectra data to MEPDG users.

The recommended emphasis of GDOT's WIM program to support MEPDG implementation is on developing permanent and portable WIM program components that would support the development of default MEPDG traffic loading inputs (statewide and/or for specific types of roads).

To develop traffic loading inputs for pavement designs, pavement design engineers need to have knowledge of the following:

- The expected loading category for the road being designed, overall or by vehicle Class and axle type. In the interim, the loading categories developed for LTPP defaults are recommended. This information could be obtained from the portable WIM data.
- Default axle load distribution for each identified loading category for each truck Class (FHWA classes 4-13) and axle type (single, tandem, tridem, and quad). These default distributions should be constructed based on the data from the permanent WIM sites installed on different types of Georgia roads.

The WIM Data Collection Plan (presented in appendix A) addresses in detail the number, location, and type of WIM sites necessary to support MEPDG implementation in Georgia, including a phased implementation plan.

CHAPTER 1 – INTRODUCTION

1.1 BACKGROUND

The Georgia Department of Transportation (GDOT) is preparing for implementation of the Mechanistic-Empirical Pavement Design Guide (MEPDG). The MEPDG methodology was developed under National Cooperative Highway Research Program (NCHRP) Project 1-37A*(1)* and recently approved by the American Association of State Highway and Transportation Officials (AASHTO).[1] The MEPDG design methodology directly considers truck traffic loading and volume data for predicting pavement distress. As a result, an important input towards Georgia's MEPDG implementation is the availability and continuous supply of good quality truck loading data to determine the impact of truck traffic.

Traffic loading data for pavement design typically are collected using weigh-in-motion (WIM) devices permanently installed in a pavement structure (permanent WIM). Currently, GDOT has only two permanent WIM sites (one is one-directional and the other is two-directional). In addition, GDOT collects portable WIM data at about 90 locations. These data provide valuable information about traffic loading conditions, but due to the limitations associated with portable WIM technology and the short periods of data collection, these data have limited application as a direct source of traffic loading inputs for pavement design. As part of this study, a statewide GDOT Traffic Load Spectra Program for gathering truck axle loading data is being developed to increase the reliability of the truck weight data for pavement design purposes.

1.2 PROJECT OBJECTIVE

The objectives of this project are twofold:

- Develop recommendations for a statewide Traffic Load Spectra Program for collecting and processing truck axle loading data to support MEPDG implementation in Georgia. The recommendations must take into account pavement design data needs, cost and number of WIM sites, and types of equipment used in obtaining the data.

  To facilitate a phased approach for Traffic Load Spectra Program implementation, the data collection plan considers the existing data collection system and includes recommendations with specific steps for expansion into a future statewide data collection program that is optimized for use with the MEPDG design method. The plan goals and milestones are specific to address current pavement design needs, as well as in the short-term (within 2 years), mid-term (within 5 years), and long-term (over 5 years).

- Use the available GDOT traffic data and other applicable data resources to develop traffic loading inputs and defaults to support local calibration of MEPDG models in Georgia.

  The available axle loading data were analyzed and interim traffic loading defaults for different groups of roads designed and maintained by GDOT were developed, along with recommendations for future updates of the defaults and for the number of future data collection sites. In addition, user guidelines, decision trees, and software tools were

[1] The MEPDG Manual of Practice, Interim Edition, was adopted and published by AASHTO in 2008.

developed to facilitate the use of traffic loading defaults in support of using the MEPDG for pavement design applications. This includes new pavement design, rehabilitation design, and forensic investigations.

1.3 STUDY SCOPE

The following tasks were conducted to achieve the project objectives:

a. Conduct a literature search and provide recommendations for the approach to develop Load Spectra Program to support MEPDG implementation.
b. Develop a data collection plan (preliminary and final).
c. Develop Level 1 MEPDG traffic inputs using available site-specific WIM data.
d. Conduct an MEPDG sensitivity analysis of the data and evaluate local and global default values.
e. Evaluate additional default load spectra from alternative sources to fill any gaps in GDOT’s data.
f. Develop GDOT initial local default normalized axle load distributions (identify local conditions or traffic generators that are common to each default load group) – Level 2 MEPDG traffic loading inputs.
g. Design a decision tree for determining the local default values for individual projects.
h. Develop an MEPDG traffic library database to facilitate the use of Georgia traffic loading defaults with MEPDG design.
i. Develop a final report that includes recommendations for implementation of GDOT's Traffic Load Spectra Program.

1.4 STUDY RESULTS

The primary outcome from this study is the recommendations for establishing GDOT's Traffic Load Spectra Program and the WIM Data Collection Plan to support MEPDG implementation in Georgia. This recommendation is summarized in chapter 9 of this report. In addition, initial Georgia local traffic loading defaults and site-specific traffic loading inputs were developed to support immediate steps towards MEPDG implementation.

A supplemental but important outcome is an interactive traffic loading database library application called GDOT Pavement Loading User Guide (GDOT PLUG) that facilitates using traffic loading data for MEPDG applications. In addition, five interim reports were prepared over the course of the project. This comprehensive final report incorporates the information included in these five reports. This report also includes a summary description of the defaults and supporting information for their derivation.

1.5 FINAL REPORT ORGANIZATION

The information presented in this report is organized in the following chapters:

- Chapter 1: Introduction
- Chapter 2: Review of Literature and Current Practices for WIM Data Collection and Use for Pavement Design
- Chapter 3: Overview of GDOT’S Practices Related to Traffic Data Collection and Use for Pavement Design
- Chapter 4: Review and Analysis of GDOT’s Historical Traffic Data and its Applicability for MEPDG Implementation

- Chapter 5: Analysis of Traffic Loading Categories Observed on Georgia Roads
- Chapter 6: Comparison of Loading Categories Observed in Georgia with the Available MEPDG Loading Defaults
- Chapter 7: Analysis of MEPDG Sensitivity to Axle Loading Distributions
- Chapter 8: Guidelines for Selecting MEPDG Traffic Loading Inputs and Defaults
- Chapter 9: Recommendations for WIM Data Collection Program to Support MEPDG Implementation and Use
- Appendix A: WIM Data Collection Plan to Support GDOT's MEPDG Implementation

CHAPTER 2 – REVIEW OF LITERATURE AND CURRENT PRACTICES FOR LOAD SPECTRA DATA COLLECTION AND USE FOR PAVEMENT DESIGN

2.1 OVERVIEW OF MEPDG REQUIREMENTS FOR TRAFFIC DATA

This section summarizes the traffic data inputs for the MEPDG and how these inputs are obtained using the methodology included in the MEPDG.

2.1.1 Hierarchical Approach for MEPDG Inputs

All inputs to the MEPDG are structured in a hierarchical manner reflective of road importance. The following defines the three hierarchical levels for the truck traffic loading data to determine each input:

- For Level 1, project-specific data are used in the design process. For traffic data, this means collecting truck volume and axle loadings by vehicle classification for segment-specific data. The traffic data can be collected from locations along the same segment of roadway, but outside the project limits, assuming there are no features or truck traffic generators between the project site and data collection station that could alter truck traffic significantly.
- For Level 2, other parameters are used to estimate the inputs. For truck traffic inputs, data from multiple sites with similar loading patterns or local conditions are collected and averaged to determine the "best-estimate" for the input parameters. In other words, Level 2 inputs are estimated by applying regional (i.e., used for a region or a group of roads within a State) axle loading defaults to regional classification data identified as a close match for the truck traffic along the project location.
- For Level 3 inputs, typical average values are used. For truck traffic, the statewide defaults can be developed to substitute for the global (national) defaults. The global default values currently included in the MEPDG software were determined within NCHRP project 1-37A[1] using LTPP sites that satisfied minimum criteria established during development of the MEPDG. In addition, in 2012 the FHWA LTPP Program developed an updated set of traffic loading defaults using research-quality data from a limited number of WIM sites constructed under transportation pooled fund study TPF5(004).

The MEPDG Manual of Practice[6] recommends to use the best available data for individual input parameters. The three hierarchical input levels are applicable to all truck traffic inputs except those that are related to geometric-design (number of lanes, lane and direction distribution factors, operational speed, etc.).

2.1.2 MEPDG Traffic Input Parameters

Table 1 provides a summary of the MEPDG traffic input parameters, the source for the data used to develop those parameters, the assumption within the design period considered by the MEPDG, and an overall summary of what has been found from previous implementation-verification studies regarding use of these parameters. Only parameters that have WIM identified as a source of data are considered in this study.

TABLE 1
Truck traffic input parameters and defaults considered by the MEPDG

MEPDG Input Parameter	Description of Defaults	Assumptions Included in the MEPDG	Comments Related to Input Parameter	Summary of Previous Local Verification Studies	Source for Input
Normalized Axle Load Spectra (NALS); sum for all load intervals for a specific axle type within a specific truck Class = 100.	DEFAULT: 1 set of global NALS that are independent of season, but dependent on axle type and truck class.	Values are dependent on season but independent with time (the values do not change over the analysis period; year-to-year).	Many sites located on the Interstate and primary roadways have axle load spectra that are not likely to be dependent on season. Most of the sites used in NCHRP 1-37A were located on rural interstates and primary arterials.	Local calibration studies have found that the NALS are reasonable, with the exception of secondary and local routes or routes that have high percentage of vehicles transporting special commodities (coal, timber, etc.).	WIM
Normalized Truck Class Distribution; sum for all truck classes = 100.	DEFAULT: 17 default Truck Traffic Classification (TTC) distributions were developed and tied to functional roadway class.	Federal Highway Administration (FHWA) truck Class definitions were included in the MEPDG software.	Sites located in many different areas with different traffic generators and traffic volumes.	Local calibration studies have concluded that the selected TTC groups provide a reasonable estimate of the volume distribution. Functional Class was tied to the TTC groups at the request of the NCHRP 1-37A panel.	WIM & Automatic vehicle classification (AVC)
Monthly Adjustment Factors; the sum for all months for one truck Class = 12.	DEFAULT: Global default values =1.0 for all trucks and months.	Values dependent on truck class, local industries, and climatic regions.	Most sites used were along the Interstate or primary roadways for which seasonal differences are minimal. Observed monthly changes were site-specific rather than global.	Local calibration studies have found secondary and local routes are significantly different than 1.0.	WIM & AVC
Hourly Distribution Factors; sum for all hours = 1.0.	DEFAULT: 1 set of global hourly factors.	Values are the same for all truck classes and only apply to volume.	Input parameter only applies to portland cement concrete (PCC) pavements.	Local calibration studies confirmed the global values for interstate and primary arterials, but identified them as truck Class dependent for secondary and local routes.	WIM & AVC

MEPDG Input Parameter	Description of Defaults	Assumptions Included in the MEPDG	Comments Related to Input Parameter	Summary of Previous Local Verification Studies	Source for Input
Number of Axles per truck class.	DEFAULT: 1 set of number of axles per truck Class were determined.	WIM equipment has been properly calibrated.	Four axle types are included: single, tandem, tridem, and quads.	Local values can be different from default, especially for unique truck Class definitions not included in the MEPDG software. However, most studies have found the values to be reasonable for the standard truck Class definitions.	WIM
Axle Spacing	DEFAULT: 1 set of axle spacing defaults.	WIM equipment has been properly calibrated, are constant between truck classes, and do not change over time.	Default axle spacing limited to three axle types: tandem, tridem and quads.	Similar to the global default values, but few studies have checked this value. Defaults for this input parameter can vary State-by-state and depend on the truck Class definitions.	W-card WIM
Average Annual Daily Truck Volume (AADTT)	DEFAULT: None.	For vehicle classes 4-13.	No default values are included in the software.	Site specific input value.	WIM & AVC
Average Annual Daily Volume (AADT) and % trucks	DEFAULT: None.		No default values are included in the software. These two parameters were only included in software for agencies that did not want to do calculation external to program.	Site specific input values.	Automatic traffic recorder (ATR) and estimate of % trucks
Average Axle Width	DEFAULT: 1 parameter or value.	Constant between all truck classes.	Obtained from truck manufacturers and only needed for rigid pavement designs.	Has not been checked since default values determined from NCHRP 1-37A.	Manufacturer's specification
Mean Wheel Location	DEFAULT: 1 parameter or value.	Constant between all truck classes.	Defined from other historical studies and only needed for rigid pavement designs.	Has not been checked since default values determined from NCHRP 1-37A.	Site Surveys
Dual Tire Spacing	DEFAULT: 1 parameter or value.	Constant between all truck classes and all axles have dual tires.	Obtained from truck & tire manufacturers.	Has not been checked since default values determined from NCHRP 1-37A.	Manufacturer's specification

MEPDG Input Parameter	Description of Defaults	Assumptions Included in the MEPDG	Comments Related to Input Parameter	Summary of Previous Local Verification Studies	Source for Input
Tire Pressure	DEFAULT: 1 parameter or value.	Tire pressure is constant between all truck classes and does not change over with time.	Obtained from tire manufacturers based on predominate truck tire sold in the US & represents hot tire inflation pressure.	Reasonableness of default value was based on a limited number of tire pressure studies conducted by different agencies.	Obtained from tire manufacturers.
Truck Growth	DEFAULT: None, but 4% linear growth included as a placeholder for all truck classes.	The value and function does not change over time for individual truck classes.	Site specific; values & growth function can change between truck class.	Site specific input values.	Historical AVC or truck count data.
Truck Wander	DEFAULT: 1 parameter or value.	Value is constant for all truck classes and does not change over time.	Based on limited data collected at AASHO Road Test and from a few limited studies.	Has been checked in one or two cases.	Site surveys.
Truck Speed	DEFAULT: None.	Value is independent of truck class.	Value defined as posted speed limit or the average speed of the heavier trucks through the project limits.	Site specific input value.	Geometric conditions & site surveys.

2.2 OVERVIEW OF TRAFFIC MONITORING GUIDELINES TO SUPPORT MEPDG PAVEMENT DESIGN

This chapter summarizes the results of four national research studies related to loading data use with the MEPDG design procedure:

1. NCHRP 1-37A Truck Traffic Data Collection Recommendations [(1)]
2. Federal Traffic Monitoring Guidelines [(2)]
3. NCHRP 1-39 Guidelines [(3)]
4. LTPP Study to Develop New MEPDG Loading Defaults [(4)]

Many other State agencies, however, have completed studies to determine the truck traffic weight and volume defaults to be used with the MEPDG. Some of these agencies include Arizona, Colorado, Florida, Idaho, Mississippi, Missouri, Montana, North Carolina, Utah, Wisconsin, and Wyoming. Most studies have found that the axle load spectra deviate from the global default values currently included in the MEPDG software, especially for local and secondary routes. Thus, the axle load spectra or distributions can depend on the roadway use and/or geographical locale. Details of selected agency WIM programs are presented and compared in a later section of this chapter.

2.2.1 NCHRP 1-37A Truck Traffic Data Collection Recommendations

Truck traffic data collection guidelines for both axle weights and truck volumes were provided in the NCHRP 1-37A final report [(1)] based on the allowable error and permissible bias for each data element in establishing the normalized truck volume distribution and NALS. As noted previously, this project is focused on truck weighs or establishing a truck weight program for GDOT. However, both volume and weights are discussed in this section for completeness in terms of data quantity and quality.

2.2.1.1 MEPDG Truck Traffic Classification Groups

To aid in generating traffic inputs for MEPDG pavement design, TTC groups were developed as a part of NCHRP 1-37A project [(1)] based on the analysis of national WIM and AVC data collected through the LTPP program (refer to table 1). These TTC groups are used to characterize truck volume by vehicle Class rather than by vehicle weight. Each TTC group represents a traffic stream with unique truck traffic characteristics (see table 2). For example, TTC 1 describes a traffic stream heavily populated with single-trailer trucks, while TTC 17 is populated with buses. A standardized set of TTC groups that best describes the traffic stream for the different road functional classes is presented in table 3. The NCHRP 1-37A panel requested that these groups be tied back to roadway functional class. The frequency of data collection recommended from NCHRP 1-37A[(1)] for determining if the normalized truck volume distribution is similar to one of the TTC groups is provided in table 4.

TABLE 2

NCHRP 1-37A Truck traffic classification (TTC) groups (1)

TTC Group	TTC Description	Vehicle/Truck Class Distribution (percent)									
		4	5	6	7	8	9	10	11	12	13
1	Major single-trailer truck route (Type I)	1.3	8.5	2.8	0.3	7.6	74.0	1.2	3.4	0.6	0.3
2	Major single-trailer truck route (Type II)	2.4	14.1	4.5	0.7	7.9	66.3	1.4	2.2	0.3	0.2
3	Major single- and multi- trailer truck route (Type I)	0.9	11.6	3.6	0.2	6.7	62.0	4.8	2.6	1.4	6.2
4	Major single-trailer truck route (Type III)	2.4	22.7	5.7	1.4	8.1	55.5	1.7	2.2	0.2	0.4
5	Major single- and multi- trailer truck route (Type II)	0.9	14.2	3.5	0.6	6.9	54.0	5.0	2.7	1.2	11.0
6	Intermediate light and single-trailer truck route (I)	2.8	31.0	7.3	0.8	9.3	44.8	2.3	1.0	0.4	0.3
7	Major mixed truck route (Type I)	1.0	23.8	4.2	0.5	10.2	42.2	5.8	2.6	1.3	8.4
8	Major multi-trailer truck route (Type I)	1.7	19.3	4.6	0.9	6.7	44.8	6.0	2.6	1.6	11.8
9	Intermediate light and single-trailer truck route (II)	3.3	34.0	11.7	1.6	9.9	36.2	1.0	1.8	0.2	0.3
10	Major mixed truck route (Type II)	0.8	30.8	6.9	0.1	7.8	37.5	3.7	1.2	4.5	6.7
11	Major multi-trailer truck route (Type II)	1.8	24.6	7.6	0.5	5.0	31.3	9.8	0.8	3.3	15.3
12	Intermediate light and single-trailer truck route (III)	3.9	40.8	11.7	1.5	12.2	25.0	2.7	0.6	0.3	1.3
13	Major mixed truck route (Type III)	0.8	33.6	6.2	0.1	7.9	26.0	10.5	1.4	3.2	10.3
14	Major light truck route (Type I)	2.9	56.9	10.4	3.7	9.2	15.3	0.6	0.3	0.4	0.3
15	Major light truck route (Type II)	1.8	56.5	8.5	1.8	6.2	14.1	5.4	0.0	0.0	5.7
16	Major light and multi-trailer truck route	1.3	48.4	10.8	1.9	6.7	13.4	4.3	0.5	0.1	12.6
17	Major bus route	36.2	14.6	13.4	0.5	14.6	17.8	0.5	0.8	0.1	1.5

TABLE 3

NCHRP 1-37A guide for selecting appropriate TTC groups (1)

Highway Functional Classification Descriptions	Applicable Truck Traffic Classification (TTC) Group Number
Principal Arterials – Interstate and Defense Routes	1,2,3,4,5,8,11,13
Principal Arterials – Intrastate Routes, including Freeways and Expressways	1,2,3,4,6,7,8,9,10,11,12,14,16
Minor Arterials	4,6,8,9,10,11,12,15,16,17
Major Collectors	6,9,.12,14,15,17
Minor Collectors	9,12,14,17
Local Routes and Streets	9,12,14,17

TABLE 4
Minimum sample size (number of continuous days per season) to estimate the normalized truck traffic distribution – AVC data[2]

Expected Error	Level of Confidence or Significance, percent				
(± percent)	**80**	**90**	**95**	**97.5**	**99**
20	1	1	1	2	2
10	1	2	3	5	6
5	3	8	12	17	24
2	20	45	74	105	148
1	78	180	295	—	—

***Continuous sampling is required for these conditions.

Note: If the difference between weekday and weekend truck volumes is required, the number of days per season must be measured on both the weekdays and weekends.

2.2.1.2 MEPDG NALS Defaults

The initial plan was to develop NALS for each TTC group and combine the TTC groups with indifferent NALS related to the predicted pavement distress. During the project, however, the NCHRP 1-37A panel requested that the TTC groups and NALS be tied back to roadway functional class. Table 3 showed the tie between the TTC groups and roadway functional class. None of the NALS for the different roadway functional classes, however, were found to be significantly different in terms of the predicted distress, so only one set of NALS for each truck Class was determined and included in the software. One reason that a statistical difference was not found is that most of the WIM sites were located along rural interstates and/or primary arterials where the NALS is less influenced or impacted by local truck traffic. Table 5 provides the frequency of truck weight data collection recommended from NCHRP 1-37A[(1)] for establishing the NALS.

TABLE 5
Minimum sample size (number of continuous days per year) to estimate the normalized axle load distribution – WIM data[3]

Expected Error	Level of Confidence or Significance, percent				
(± percent)	**80**	**90**	**95**	**97.5**	**99**
20	1	1	1	1	1
10	1	1	2	2	3
5	2	3	5	7	10
2	8	19	30	43	61
1	32	74	122	172	242

2.2.1.3 Low Volume Roads

Based on NCHRP 1-37A report[(1)] , it is not necessary to extend traffic loading data collection for roads with AADTT of 70 heavy vehicles (FHWA Class scheme 4-13) or less. Because the MEPDG

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[2] Table 4 was extracted from the NCHRP 1-37A draft final report submitted to NCHRP in 2004. The values included in Table 4 were based on the truck volume data collected and reported for the LTPP sites used in preparing the normalized truck volume distribution default values included in the software.
[3] Table 5 was extracted from the NCHRP 1-37A draft final report submitted to NCHRP in 2004. The values included in Table 5 were based on the truck axle weight data collected and reported for the LTPP sites used in preparing the normalized axle load spectra default values included in the software.

design models were not developed or calibrated for low volume roads. Pavement thickness for low volume roads is based not as much on traffic loads as on the minimum thickness required by construction practices or to account for environmental impacts on pavement performance. As a result, the benefits of using loading data for pavement design for low volume roads will not justify the cost of loading data.

2.2.2 Federal Traffic Monitoring Guidelines

The 2013 FHWA Traffic Monitoring Guide (TMG) [(3)] provides recommendations and best practices for highway traffic monitoring, including monitoring of traffic loading. The TMG recommends a relatively small truck weight program, primarily due to the cost of weight data collection and the limitations in available equipment. The TMG recommends:

- Collecting representative sample of traffic loading data using truck weight roadway groups (TWRG).
- TWRG should have similar vehicle types and similar truck axle weight distributions for all roads within that group. At least six WIM sites is recommended for each road group to account for variability in truck weights.
- Weight data should be collected using permanently installed WIM sites or at least permanently installed in-pavement WIM sensors to achieve accurate data.
- Proper and systematic calibration of the WIM equipment is critical to WIM data collection.
- Data collection should account for the day-of-week and seasonal changes in vehicle weights that occur within each group.

2.2.2.1 Truck Weight Roadway Groups

The TMG States that truck traffic may vary significantly within the State depending on road use. To account for variability in truck weights and truck types, the TMG recommends that each State divides its roadway system into TWRG, so that each road within a group experiences truck loading patterns (in terms of weight per vehicle or load factors) similar to those of other roads within that group. TWRG should be defined in such a way that they can provide simple, logical means for discriminating between roads that are likely to have very high load factors and roads that have lower load factors.

To establish TWRG, the TMG recommends using the characteristics of the freight moved on the roads, including the type of commodities carried, the vehicles used, and the freight movement function performed by each road. In addition, vehicle classification counts are helpful in the development of the truck weight groups. These groups may be defined based on different methods, such as statistical analysis, professional judgment based on local knowledge of loading characteristics, or as combination of both. One of the examples provided in the TMG gives is shown in the table below.

TABLE 6
Example Truck Loading Groups [2]

Rural	Urban
Interstate and arterial major through-truck routes	Interstate and arterial major truck routes
Other roads (e.g., regional agricultural with little through-trucks)	Interstate and other freeways serving primarily local truck traffic
Other non-restricted truck routes	Other non-restricted truck routes
Other rural roads (mining areas)	Other roads (non-truck routes)
Special cases (e.g., recreational, ports)	

The TMG recommends that initially defined TWRG should be periodically reviewed, assuming that more information about traffic loading variation within the State becomes available over time.

2.2.2.2 Number of WIM Sites

The TMG States that the size of any State's weight data collection program is a function of the variability of the truck weights and the accuracy and precision desired to monitor and report those weights. As a result, a different number of WIM sites may be needed to support each TWRG or other default loading group. The more count locations measured within a TWRG, the better the highway agency will understand the weights present on that group of roads. The TMG recommends at least six WIM sites with permanently installed WIM sensors per truck weight group.

2.2.3 NCHRP 1-39 Guidelines

The NCHRP 1-39 report [3] contains guidelines for collecting traffic data to be used in mechanistic-empirical pavement design. It discusses three alternative data collection programs (or levels) to derive axle-load distribution (or "load spectra") data needed for use with the MEPDG:

- Site-specific
- TWRG
- Statewide averages

These alternatives, including pros and cons, are summarized in the following subsections.

2.2.3.1 Site-Specific Load Distribution Data

Site-specific data collection means that the State can weigh trucks accurately on or near the roadway segment where the new pavement will be constructed (or existing pavement rehabilitated). To use the site-specific data, the State needs to ensure that the WIM system is calibrated properly and QC checks are implemented.

If the data is collected using a device that is not calibrated or incapable of producing data satisfying ASTM[5] requirements (such as short-term portable WIM data collection with a sensor temporarily mounted on the top of the pavement), the site-specific data should be used only to identify which TWRG data set is most appropriate for that pavement project, and Level 2 design inputs should be used to characterize traffic for design.

The major sources of error in the axle distributions at site-specific locations usually are from two sources: (1) equipment and calibration error and (2) errors caused by sampling of the traffic stream.

2.2.3.2 Truck Weight Road Group Data

TWRG axle-loading tables (i.e. a set of defaults) are needed because most States do not have sufficient site-specific WIM data for the majority of pavements they design each year. The TWRGs are likely to be State-specific, but multiple States can create "regional" load distribution tables if these States have similar truck weight laws and enforcement programs.

TWRG axle-load distributions are summary load distributions that represent axle loads found on roads with similar truck weight characteristics. The intent is to group roads by their trucking characteristics so that the load spectra on all the roads in a group are similar.

The challenge is to determine which roads (and directions of travel, in some cases) are typified by which basic loading conditions (such as light, moderate, and heavy loading conditions). This grouping process requires analysis of a State's available weight data and trucking patterns, possibly for different truck classes, and it results in the creation of appropriate TWRGs.

Road characteristics or features that can be used to define road groups include the region of the State, particularly where the economic activity in a State differs from region to region (e.g., agricultural areas versus mining areas); the nature of the commodities being carried (e.g., roads leading to a port versus roads in other parts of an urban area); and sometimes the functional Class and location of the facility (e.g., urban freeway versus suburban arterial).

Roadways with similar truck classes may carry different loads. For example, for the same road, one direction may have loaded trucks and the other direction may have unloaded trucks, resulting in two TWRGs needed to characterize axle load distributions for that road.

2.2.3.3 Statewide Load Distribution Data

Statewide axle-load distribution should be used only when a highway agency has little knowledge of the loads that trucks will carry on the roadway being designed. This means that the agency has little confidence in its ability to predict the TWRG for the pavement section.

Statewide load distributions are obtained (for each vehicle class) by combining the data collected from all WIM sites in a State. These distributions then serve to represent "average conditions" that can be used whenever something better is unavailable.

2.2.4 WIM Data and Defaults from LTPP Traffic Pooled-Fund Study Sites

2.2.4.1 Background

LTPP undertook Transportation Pooled-Fund (TPF) Study TPF-5(004) that focused on the installation of highly reliable permanent WIM systems and the collection of axle loading data using a uniform vehicle classification scheme and rigorous quality control procedures to produce high-quality traffic data (classification and weight). This study has generated high-quality traffic loading information for 26 LTPP Special Pavement Study (SPS) sites located in 23 different States and representing moderate and high volume rural principal arterial interstate and non-interstate highways.

2.2.4.2 WIM Equipment

Table 7 describes the location, road type, and WIM technology for each LTPP SPS TPF site. Typically, one of two types of weighing sensors was used at these sites: bending plate or quartz piezo electric. Both types of sensors have a proven history of reliable performance. As noted, the two Ohio sites are using load cell technology.

TABLE 7
SPS WIM site locations

State	SPS Site	Route and Site Location	WIM Sensor	Road Functional Class
1. Arizona	040100	US-93 North at MP 52.62	Bending Plate	Rural Principal Arterial - Other
2. Arizona	040200	I-10 East at MP 108.6	Quartz Piezo	Rural Principal Arterial - Interstate
3. Arkansas	050200	I-30 North of SR74 Overpass	Bending Plate	Rural Principal Arterial - Interstate
4. California	060200	SR-99 at MP 32.5	Bending Plate	Rural Principal Arterial - Other
5. Colorado	080200	I-76 East at MP 39.7	Bending Plate	Rural Principal Arterial - Interstate
6. Delaware	100100	US-113 Southbound North of SR 579	Quartz Piezo	Rural Principal Arterial - Other
7. Florida	120100	US-27 at MP 12.03	Quartz Piezo	Rural Principal Arterial - Other
8. Florida	120500	US-1	Quartz Piezo	Rural Principal Arterial - Other
9. Illinois	170600	I-57 at MP 225.6	Bending Plate	Rural Principal Arterial - Interstate
10. Indiana	180600	US-31 North at MP 216.9	Bending Plate	Rural Principal Arterial - Other
11. Kansas	200200	I-70 West at MP 287.48	Bending Plate	Rural Principal Arterial - Interstate
12. Louisiana	220100	US-171 at MP 8.4	Quartz Piezo	Rural Principal Arterial - Other
13. Maine	230500	I-95 at MP 200.1	Quartz Piezo	Rural Principal Arterial - Interstate
14. Maryland	240500	US-15 North at MP 4.62	Bending Plate	Rural Principal Arterial - Other
15. Michigan	260100	US-27 South	Quartz Piezo	Rural Principal Arterial - Other
16. Minnesota	270500	US-2 at MP 91.8	Quartz Piezo	Rural Principal Arterial - Other
17. New Mexico	350100	I-25 North at MP 36.1	Quartz Piezo	Rural Principal Arterial - Interstate
18. New Mexico	350500	I-10 East at MP 50.2	Quartz Piezo	Rural Principal Arterial - Interstate
19. Ohio	390100	US-23 at MP 19.7	Load Cell	Rural Principal Arterial - Other
20. Ohio	390200	US-23 at MP 19.7	Load Cell	Rural Principal Arterial - Other
21. Pennsylvania	420600	I -80 at MP 158.2	Quartz Piezo	Rural Principal Arterial - Interstate
22. Tennessee	470600	I-40 West at MP 91.67	Quartz Piezo	Rural Principal Arterial - Interstate
23. Texas	480100	US-281 South	Bending Plate	Rural Principal Arterial - Other
24. Virginia	510100	US-29 bypass at MP 12.8	Bending Plate	Rural Principal Arterial - Other
25. Washington	530200	US-395 at MP 93.01	Quartz Piezo	Urban Principal Arterial - Other Freeways or Expressways
26. Wisconsin	550100	US-29 at MP 189.8	Bending Plate	Urban Other Principal Arterial

2.2.4.3 Study Coverage

Figure 1 shows the distribution of SPS TPF WIM sites on a map. As can be seen, these sites provide good national coverage across the U.S. However, only two functional road types have adequate representation in the SPS TPF: Rural Principal Arterial Interstate and Rural Principal Arterial Other Non-Interstate Highways. No SPS TPF site is located on an urban interstates or on a minor arterial or collector, and only two sites are located on urban roads (Principal Arterial Other and Expressway). Florida, Tennessee, and Virginia are the closest States to Georgia that have LTPP SPS TPF sites, but none of these routes go through Georgia.

From an assessment of the LTPP data, it appears that load spectra for interstate roads have similarities across the country. Most of these load spectra have a balanced camel-back distribution for Class 9 tandems, with the loaded peak being at or slightly below the legal axle load limit. This distribution shape is similar to the ones observed at Georgia pilot permanent WIM sites.

FIGURE 1
Map of SPS TPF sites

2.2.4.4 LTPP Definition of Research Quality Traffic Data

LTPP defines research-quality traffic data as at least 210 days of data (in a year) of known calibration meeting LTPP's precision requirements for single axles, axle groups, gross vehicle weight, vehicle length (bumper-to-bumper), vehicle speed, and axle spacing, as detailed in table 8. [9] A similar requirement on the extent of data availability (but not accuracy) was included in the NCHRP 1-37A study.

TABLE 8
LTPP WIM system performance requirements

Pooled-Fund Site Factors	95 Percent Confidence Limit of Error
Loaded Single Axles	+/-20 percent
Loaded Axle Groups	+/-15 percent
Gross Vehicle Weights	+/-10 percent
Vehicle Length	greater of +/-1.5 ft or +/-3 percent
Vehicle Speed	+/-1 mph
Axle Spacing Length	+/- 0.5 ft [150 mm]

As a result of enforcing the criteria for research-quality data, the SPS TPF sites have had more direct calibration and performance monitoring reviews performed as part of the data collection effort than any other WIM sites in the U.S. Because LTPP requires the regional contractors to download and verify the collected traffic data periodically, anomalies are identified quickly and actions are taken to ensure the accurate performance of WIM systems. That is, if performance problems are noted in the equipment, the repair/calibration is performed, and no problem data are processed and stored. The SPS TPF WIM equipment is also installed in pavement that supports accurate WIM system performance, further ensuring the accuracy of the collected data. This means that the SPS TPF data set is among the most accurate WIM data available in the U.S. Thus, it is recommended that the NALS from this study be included in the Georgia MEPDG database or library of input values for potential use as defaults for pavement design.

2.2.4.5 LTPP Traffic Data QC Process

The LTPP data processing and quality assurance (QA) programs ensure that WIM data being collected at SPS TPF sites are reviewed in a timely manner using a systematic, comprehensive, and well-documented process. [8, 9] Implementation of the new, improved LTPP Traffic Analysis Software (LTAS) for traffic data quality control (QC) and processing, along with rigorous and systematic WIM scale validation and calibration process for SPS TPF sites, has greatly improved the quality of LTPP WIM data.

For equipment measurements, QC procedures include routine calibrations, data checks during acquisition, and data checks prior to loading data into the LTAS database. Once WIM data are downloaded to LTAS, the data undergo several levels of data quality checks for completeness and validity. [8]

2.2.4.6 LTPP Study to Develop New MEPDG Traffic Loading Defaults

The FHWA LTPP program has recently completed the study to develop updated MEPDG traffic loading defaults and supporting software using WIM data from the LTPP TPF 5(004) study. A major outcome of this study are new NALS defaults, which are available as two tiers:

- Tier 1 Global defaults representing average loading condition based on LTPP TPF 5(004) WIM data
- Tier 2 defaults representing different loading conditions observed in the LTPP TPF 5(004) WIM data

The methodology for developing LTPP Tier 1 NALS defaults is very similar to the methodology used to create the original NCHRP 1-37A defaults. However, data used to develop LTPP defaults are of higher quality but of lesser quantity (fewer WIM sites) than the original NCHRP 1-37A defaults.

Tier 2 defaults were developed based on statistical clustering of axle load data from multiple sites. Sites that had similar loading conditions were clustered together. Clusters were differentiated based on the differences that load spectra representing each cluster are likely to have on MEPDG outcomes. MEPDG pavement thickness and design life predictions were used as a means to determine what constitutes practical significance in pavement design outcomes to different load spectra alternatives. MEPDG sensitivity analyses conducted in this study, and in other studies, demonstrated the importance of heavy loads compared to light loads. As a result, clustering of load spectra was weighted greatly by the presence of heavy loads.

Several alternative default axle loading categories were identified for each vehicle Class and axle group and default normalized axle load spectra (NALS) were developed to represent these loading patterns. The most commonly observed loading pattern was identified as “typical” for each vehicle Class and load group. Statistically identified loading clusters were assessed, and statistical attributes were computed for each cluster. The definitions of different default traffic loading categories for NALS and their statistical attributes are provided in table 9.

TABLE 9
Summary of NALS categories by weight for different axle group types

Axle Loading Category by Weight	Average RPPIF per Cluster	Percent of Single Axles >= 15 kip	Percent of Tandem Axles >=26 kip	Percent of Tridem Axles >=39 kip	Percent of Quad Axles >=54 kip
Very Light (VL)	<0.05	<3%	0%	n/a	n/a
Light (L)	0.05-0.15	<10%	<10%	n/a	n/a
Moderate (M)	0.15-0.30	10-30%	10-30%	n/a	n/a
Heavy (H)*	0.30-0.50	>30%	30-50%	<50%	<30%
Very Heavy (VH)	>0.50	n/a	>50%	>50%	>30%

*For roads with high percentage of Class 9 vehicles, “Heavy” loading category was further subdivided to “Heavy 1” and “Heavy 2” based on observed high sensitivity of MEPDG outcomes to Class 9 tandem axle load spectra. “Heavy 1” category has RPPIF of 0.3-0.4 and percentage of heavy tandem axles between 30 and 40 percent. “Heavy 2” category has RPPIF of 0.4-0.5 and percentage of heavy tandem axles between 40 and 50 percent.

In addition to the defaults, guidelines for State highway agencies were developed showing how to apply the methodology from the LTPP study to develop State-specific traffic loading defaults for pavement design use.

The primary benefit of the new LTPP NALS defaults is that they were developed using research-quality WIM data. For GDOT, the usability of these defaults may be limited to rural interstates and high volume rural other principal arterials, as traffic loading conditions on moderate and low truck volume non-interstate highways is likely to be affected by the local industries and local weight regulations. It is recommended that the new LTPP NALS defaults be considered for potential use in Georgia.

2.2.4.7 Comparison of New LTPP and Original NCHRP 1-37A MEPDG Traffic Loading Defaults

The new LTPP NALS defaults were compared with the original NCHRP 1-37A NALS defaults. The results of the comparison using Tier 1 defaults indicated that significantly different MEPDG outcomes (structural pavement thickness difference over 0.5 inch or pavement service life difference of 20 percent or more) could be expected for some cases (JPCP slab cracking and total rutting of AC pavements). In addition, significantly different MEPDG outcomes are expected when different sets of Tier 2 NALS defaults are used ("light" vs. "heavy"). This conclusion highlights the importance of accurate measurement of the axle load spectra, along with the importance of the local knowledge of the expected axle loading conditions for pavement design and analysis. The comparison of outcomes (predicted distresses) between the different default NALS did not consider or compare the bias and standard error between the predicted and measured or observed distress values.

The newly computed NALS defaults had fewer very light and fewer very heavy loads compared to the original defaults. This is most likely due to the fact that the new defaults were collected with more consistently calibrated WIM equipment than the data set used for the development of the original NALS defaults under the NCHRP 1-37A project. The better calibration of the WIM scales used to develop the new defaults could result in fewer very light loads (caused by under calibrated scales observing light loads) and fewer very heavy loads (caused by over calibrated scales observing heavy loads) are observed in the new default database.

Assuming that the new LTPP defaults are more accurate, a conclusion could be drawn that pavement designs using the new defaults will be thinner than the designs using the original MEPDG defaults. However, from a practical perspective, the difference in the design thickness was significant only for a limited number of pavement scenarios tested.

2.3 ASSESSMENT OF CURRENT TRAFFIC LOAD PROGRAM PRACTICES IN SELECTED STATES

2.3.1 Overview

The traffic loading data collection practices of several agencies were reviewed. The review focused on practices in support of MEPDG implementation and on the availability of default values that may be applicable in Georgia. All of the information reviewed was current or published as of 2010, and it was obtained from the following State highway agencies: Arizona, Arkansas, Florida, Maryland, Mississippi, Missouri, Montana, North Carolina, Ohio, Utah, Indiana, Colorado, Virginia, and Wisconsin. The detailed results of the review were included in Interim Report #1; a summary is provided here.

2.3.2 WIM Program Options in Support of the MEPDG Identified Through Review

Nearly all of the agencies surveyed are using regional default values for most of the MEPDG truck traffic input variables, especially those related to the truck volume distribution and axle weight data. Just about all of the reviewed WIM programs in support of the MEPDG can be grouped into five major categories or "options" based on the type of traffic inputs selected by the State agency for routine MEPDG use:

1. Agency-specific default normalized axle load spectra determined using statewide load data (target MEPDG input Level 3).

   a. Statewide single default.
   b. Multiple defaults based on segregated State data (region, industry, road type), reflective of loading conditions observed in load data.
2. Default normalized axle load spectra based on load weight groups (target MEPDG input Level 3).
   a. Library of default NALS for truck weight road groups (TWRGs based on groups of roads with similar overall loading condition (non-vehicle Class dependent, location or road type loading dependent).
   b. Library of default NALS for different vehicle classes based on different truck loading conditions (vehicle Class loading dependent).
3. Default normalized axle load spectra based on load weight groups described in above Option #2, where default application is selected based on site-specific portable WIM data (target MEPDG input Level 2).
4. Virtual traffic loading site created from a limited number of NALS determined from multiple WIM sites across the State and supplemented by portable site-specific WIM data (target MEPDG input Level 2).
5. Expanded WIM program to capture commodity flow of goods within and through the State (target MEPDG input Level 1).

These options are summarized in table 10 along with some of the advantages and disadvantages of each option. Table 11 shows some of the agencies that are using specific options or combinations of the five basic options. The text following the tables provides additional discussion of these options related to their potential use in Georgia. Most of the agencies interviewed are using Option #1, and only a few are planning to use any of the other options at this time.

TABLE 10
Advantages and disadvantages of the five options for measuring truck weights for determining inputs to the MEPDG.

Options for Using Normalized Axle Load Distribution for MEPDG		Input Level	Georgia DOT Considerations for Implementing a WIM Program to Establish Traffic Inputs to the MEPDG	
No.	**Title**		**Advantage/Benefit**	**Disadvantage/Concern**
1	Agency-specific default normalized axle load spectra determined using statewide load data.	3	Does not require an expanded WIM program.	Must review NALS on some periodic basis to update or confirm default NALS.
			Implementation costs are low.	No site specific traffic load distributions are used.
			Maintenance and operational costs of WIM program are low.	Difficult to detect changes in load distribution caused by changes in local economy and commodity flow.
2	Default normalized axle load spectra based on load weight groups.	3	Once load groups are established (usually by "truck" or "road" loading condition), they are fixed unless some policy and/or legal weights change.	Engineer must decide which load group or Class to be used; traffic engineers or planning must be involved in decision making process.

Options for Using Normalized Axle Load Distribution for MEPDG		Input Level	Georgia DOT Considerations for Implementing a WIM Program to Establish Traffic Inputs to the MEPDG	
No.	**Title**		**Advantage/Benefit**	**Disadvantage/Concern**
			Pavement & rehab strategies are designed for specific loading groups or classes.	Least accurate than options 3-5; more error associated with this option.
			Requires the fewer number of WIM stations than options 4 and 5.	Must review NALS on some periodic basis to update load groups or classes.
3	Use portable WIMs to select normalized axle load spectra defaults developed based on the method described in option #2.		Used as an enhancement of Option 2 by providing site-specific data to aid in selection of best fitted defaults.	Accuracy is lower and bias can exist in NALS because of use of portable devices, if not properly calibrated.
		2	Provides site specific data for the purpose of identifying loading condition at lower costs.	Low accuracy of portable WIM data must be recognized and accounted for in defaults selection process.
4	Create virtual NALS for each roadway segment using a library of NALS determined from multiple permanent WIM sites across the State and supplemented by portable site-specific WIM data.	2	NALS inputs can be more site specific or representative of load truck traffic conditions, if done properly.	Requires the use of portable devices to supplement WIM data in establishing the NALS.
			Maintenance and operational costs are lower than Option 5, and program can be easily modified to fill in Georgiaps.	Requires continual revisions and updates by an individual knowledgeable in truck traffic flow and industry around the State.
5	Use permanent WIMs to determine segment-specific or surrogate NALS for design using expanded WIM program that captures commodity flow of goods within and through the State.	1, 2	Option with the highest accuracy in establishing the NALS as an input to the MEPDG.	Most costly of all options to maintain and operate the WIM program.
			Option with the ability to detect changes in load distribution across the State.	There will still be many designs that require Level 2 or 3 inputs for the NALS.

TABLE 11
Agencies using specific options or combination of option for determining truck traffic inputs to the MEPDG

Options for Using Normalized Axle Load Distribution for MEPDG		Input Level	Agencies That Use this Option	
No.	**Title**		**Agencies**	**Comment**
1	Agency-specific default normalized axle load spectra determined using State-wide load data	3	Arizona, Arkansas, Colorado, Florida, Indiana, Mississippi, Missouri, Ohio, Wisconsin, Wyoming	Indiana uses regional NALS default values, but they represent specific loading patterns for their local industries. Mississippi initially used this option, but is moving towards the use of the virtual WIM option.
2	Default normalized axle load spectra based on load weight groups	3	Indiana, Montana, Virginia, Maryland, North Carolina	Indiana developed four NALS loading groups based on the local industry and truck traffic flow. These are representative of the loads from specific commodities and are a cross between Options #1, 2 & 4. Montana proposed the use of 5 load classification groups, but postponed use of MEPDG until DARWin-ME is released.
3	Use portable WIMs to select normalized axle load spectra defaults developed based on the method described in Option #2.	2	Montana, Wisconsin, Maryland	Portable WIMs have been used to select defaults or surrogate data based on observed traffic loading conditions.
4	Create virtual NALS for each roadway segment from a library of NALS determined from multiple WIM sites across the State and supplemented by portable site-specific WIM data	2	Mississippi, Utah	Mississippi and Utah are using all available data to determine the NALS for specific roadway segments for design. These are continually updated as more and more data are collected. Portable WIM is also used to aid in decision making. Historically, Maryland used a "virtual traffic site" approach for selecting historical load spectra data for calculations of equivalent single axle loads (ESALs).
5	Use permanent WIMs to determine segment-specific or surrogate NALS for design using expanded WIM program that captures commodity flow of goods within and through the State	1, 2	Indiana	Indiana has 56 WIM locations, most of which are permanent bending plates, and is increasing the number of those sites over time.

2.3.2.1 Option #1 – Develop Agency-Specific Default Normalized Axle Load Spectra Using Statewide Load Data

Many agencies that plan to implement the MEPDG are basing their truck weight inputs on this option, especially if they have few WIM stations that provide little knowledge on trucks transporting commodities within and through their State, or if they have low confidence in the WIM data. Multiple agencies have reported that the global default NALS included in the MEPDG are reasonable and represent the NALS measured within their State. The number of default NALS that have been developed by individual agencies vary from one to four for each axle type and truck class. These defaults reflect average statewide or regional traffic loading conditions that are not specific to a type of loading condition associated with a certain road or truck type.

Using this option, the pavement design engineer selects the default NALS. If multiple default NALS are available, this is done in consultation with the Planning Department or Traffic Engineer to ensure that selection is consistent with local industry and the type of roadway. The agency periodically reviews and updates the default NALS. Once confidence in the defaults is established, these updates become less frequent and are triggered by changes in the State's traffic loading conditions. This option works best if the State's pavement designs are not very sensitive to changes in traffic loads, such as when terminal distress values are low, resulting in thicker pavement layers to delay the need for major rehabilitation.

The main advantage of this option for GDOT is that it requires fewer permanent WIM locations than any of the other options. In addition, the data collected by agencies in adjacent States and default NALS can be used to supplement the data collected in Georgia. The number of sites is determined based on the type of industries located in Georgia and the transport of commodities within and through the State.

The major disadvantage of this option is that it is difficult to detect changes in the NALS that are caused by changes in the local economy and commodity flow, especially if a single statewide set of defaults is established.

2.3.2.2 Option #2 – Establish Default Normalized Axle Load Spectra Based on Load Weight Groups

A few agencies have developed different load weight groups or TWRGs to be used within their State. Indiana, Montana, Virginia, North Carolina, and Maryland are a few agencies that are using this option and/or have developed NALS under this option. Two different approaches are used by the agencies to develop defaults:

- Default NALS for TWRG based on groups of roads with similar overall loading condition (non-vehicle Class dependent, location or road type loading dependent).
- Default NALS for different vehicle classes based on different truck loading conditions (vehicle Class loading dependent; same design location may have different loading conditions for different truck types).

These load weight classes are developed from local or regional WIM data collected over time.

In the first approach, each load weight classes or TWRG represents a specific traffic loading condition associated with a group of roads. Definitions of load weight classes or TWRG are based on the type of industry or commodities being transported over the roadway. Two to seven load weight classes or TWRGs have been identified for these agencies, and default NALS were developed. The challenge with this option is to identify groups of roads that have similar truck loading conditions among different classes. Since truck loading patterns are independent of the different vehicle classes, it is possible to have roads that will have fully loaded classes 6 or 7 (resource haulers) and light (cubed-out) Class 9s. This becomes a practical issue mostly for secondary roads with low percentage of the throughway traffic. Both Virginia and Maryland have acknowledged challenges with this approach.

In the load weight Class approach, the same vehicle type may have several default loading conditions. This option also recognizes that loading characteristics associated with different vehicle classes are independent of each other. Using this option, available WIM data and any other information on commodity flow through and within the State are analyzed and several representative loading patterns are established for each vehicle type, such as "typical," "heavier than typical," or "lighter than typical." The default NALS are then developed for each vehicle class, axle type, and defined loading pattern. The number of loading patterns (or categories) for each vehicle Class and axle type is determined through MEPDG sensitivity analysis. Classes and axle types for which the MEPDG shows very low sensitivity may have only one default NALS. This approach is being implemented for generation of the library of default NALS based on LTPP data from the SPS TPF. This option provides the most advantage if the State's pavement designs are very sensitive to changes in traffic loads because it provides the pavement designer with flexibility in selecting different loading patterns by vehicle Class and axle type. The disadvantage of this approach is that it requires knowledge of loading patterns at each design project location. For GDOT, this information is limited to about 90 locations within the State where portable WIM data have been collected. No consolidated corporate knowledge is available regarding loading patterns for Georgia State roads.

Using this option, the pavement design engineer, in consultation with the Planning Department or Traffic Engineer, identifies loading category for different truck classes or selects TWRG based on information available for the design project location. Using identified loading categories or TWRG, NALS are extracted from the State's traffic loading defaults library. This process becomes less subjective if portable WIM data are available to aid in selection of the expected loading pattern (see option #3).

This is the easiest option to use because the pavement design engineer selects the NALS that represents the truck flow over the roadway based on the definition of the load groups.

Use of this option for calibration purposes, however, can increase the error in the transfer function for predicting pavement distress and smoothness. The standard error is higher because the load weight group for a specific segment of roadway may not represent the actual NALS, which is also the case for option #1.

The number of permanent WIM sites needed to support this option depends on the number of load weight classes or TWRGs. As a rule of a thumb, the TMG recommends at least six Type I WIM sites with permanently installed sensors per each road group. The number of sites is determined based on accuracy of equipment and observed traffic loading variability associated with a given road group.

2.3.2.3 Option #3 – Use Portable WIMs to Select Normalized Axle Load Spectra Defaults Developed Based on the Method Described in Option #2

This option is an enhancement of Option #2. Using this option, default NALS are developed in the same way as in Option #2. Portable WIM equipment is used to collect truck weight data on a limited, short-term basis in preparation for a rehabilitation or reconstruction project. The short-term WIM data are used to aid in selecting a specific default NALS from the traffic default library or aid in selecting sites for virtual traffic loading site (refer to option #4). It can represent a cost-effective method to collect minimal site-specific truck weight data for using a quasi-input Level 1 approach. In addition, it provides additional data to ensure that the NALS used for pavement design is representative of the actual truck traffic.

Only a few agencies (Montana, Utah, and Wisconsin) are using the portable WIM equipment for determining and/or adjusting the NALS. Most agencies have abandoned the use of portable WIM equipment for determining the NALS. Montana uses portable WIM equipment to identify where the heavier loads are being applied around the State—primarily for enforcement and in selecting a specific NALS load weight group for use in design.

This option provides the greatest advantage if the State's pavement designs are very sensitive to changes in traffic loads by providing the pavement designer with the flexibility to select different loading patterns by vehicle Class and axle type. The major disadvantage of this option is that portable WIM equipment is less accurate and can include bias weight measurements if not properly calibrated.

Using this option, the pavement design engineer, in consultation with the Planning Department or Traffic Engineer, identifies loading category for different truck classes based on information available for the design project location and portable WIM data analysis. The supplemental site-specific data are then used as an aid to the pavement engineer in selecting the best fitted default from the NALS default library.

The number of permanent WIM sites needed to support this option depends on the number of TWRGs or load weight groups. As a rule of a thumb, the TMG recommends at least six Type I WIM sites with permanently installed sensors per each group. The number of sites is determined based on accuracy of equipment and observed traffic loading variability associated with a given road or load weight group. The number of portable sites per year is determined based on pavement design needs using a preliminary plan of projects for the future years.

Use of portable WIM equipment is recommended for Georgia, for determining if the selection of a specific default NALS is reasonable. A trained analyst should review portable WIM data to determine any potential bias in measurements prior to using these data in pavement design.

2.3.2.4 Option #4 – Create a Virtual Traffic Loading Site

This option requires more WIM sites than any of the previous options. In summary, multiple WIM stations are used to create a virtual site-specific NALS for the segment of roadway being rehabilitated or reconstructed, similar to creating a virtual climate site for the MEPDG. Data from several nearby sites are extracted from the traffic database and analyzed to determine NALS for a selected project location. This option also requires the use of portable WIM equipment to supplement the data from the permanent WIM sites.

The pavement design engineer asks the traffic engineer or planning department to provide the loading inputs to a specific segment of the roadway, or uses the available WIM data from selected sites and creates the input data for the virtual traffic loading site. The virtual traffic loading NALS for the specific segment of roadway is determined by the traffic engineer or individual most knowledgeable about the commodity flow and industry along the roadway.

This option can be difficult to implement because many decisions between the WIM sites need to be made. Combining sites to create a virtual site can be problematic when the amount of WIM data varies significantly between the WIM sites (permanent versus portable equipment) and different sites have significantly different truck volumes.

The number of sites is determined based on the accuracy of the equipment and observed traffic loading variability within the State. The number of portable sites per year is determined based on pavement design needs using a preliminary plan of projects for the future years.

2.3.2.5 Option #5 – Expanded WIM Program

This option requires a large number of permanent WIM locations for detecting changes in truck weights throughout the roadway system. No agency is using this option currently, although as Indiana continues to add permanent WIM sites to their program, they will approach this option. This option is considered the most accurate in using input Level 1 for the NALS, but obviously it is costly because of the number of WIM sites needed. It has been considered cost-prohibitive by many agencies that do not already have an extensive WIM program in place. As an example, Texas started to implement this approach with putting in 150 permanent WIM sensors across the State with bending beams and quartz-piezoelectric sensors. This approach was eventually abandoned because of installation and operational (including data analyses) costs.

Using permanent quartz piezoelectric WIM is less expensive than load cell or bending plate, however, the savings in the cost of the sensor is small comparing to the total cost of permanent WIM site that includes: installation, brining power supply and telecommunication sources to the site; WIM calibration, maintenance, and repair; data processing, analysis, and storage.

Using this option, the pavement design engineer selects a specific NALS that is consistent with the type of industry and truck flow for the specific roadway project.

2.4 ASSESSMENT OF AVAILABLE TRAFFIC LOAD DATA PROCESSING SOFTWARE

2.4.1 Overview

Traffic load data processing software products are designed to fulfill the following functions:

- Interpret WIM sensor inputs and develop records of axle weight, axle spacing, total vehicle weight, and vehicle type (or class) for each vehicle that traveled over the sensor.
- Conduct data QC and identify data anomalies or missing information.
- Summarize traffic loading data and develop summary statistics in a form of tables and reports based on user requirements.
- Analyze the data and develop computed parameters (such as axle loading defaults or site-specific axle loading inputs), user-defined reports, and input files used by other applications.

No single software product currently exists that provides all of this functionality in a single package, although some WIM vendors (like International Road Dynamics) claim their software products can be customized to accommodate all of these functions.

This section summarizes information about software packages available for processing WIM data and development of MEPDG traffic loading inputs and defaults. These software applications fall into four broad categories, as listed below:

1. Software developed to support FHWA functions.
    - Although designed with FHWA function in mind, this software also addresses basic State needs for WIM data processing and storage. This software is available for States free of charge. Limited or no customization of software to State-specific needs is available through FHWA.
2. Software developed by vendors of WIM systems to support WIM data collection by State agencies.
    - This software is free of charge with installation of WIM devices purchased by the vendor. It focuses mostly on data validation, quality control/quality assurance (QC/QA), processing and development of a set of standardized reports. This software also produces a W-file. The W-file is a standard file described in the FHWA TMG that contains per vehicle records (PVR) of axle weights and axle spacing for each vehicle captured by WIM system.
    - Customization of software to State-specific needs is provided by WIM vendors at additional cost.
3. Software developed by third parties focusing primarily on post-processing and analysis of data collected by WIM.
    - These software solutions cover various applications, although not necessarily in one package or by one vendor, and may include the following: WIM QC/QA functions, efficient data storage solutions, custom reports and statistics (like MEPDG loading inputs). There are several options in obtaining these software products: (1) purchase an off-the-shelf (OTS) version of the software, (2) initiate a special project for customization/implementation of vendor software, (3) get a free copy of software and purchase a support contract to maintain, update/customize, and/or operate software.
4. Software developed by States, either internally or through contract, to satisfy State-specific requirements for traffic data QC/QA, processing, and reporting.

The following software products were identified for the above listed four categories:

1. FHWA products:
    - FHWA VTRIS.
    - FHWA TMAS (Work-in-Progress for WIM component).
    - FHWA LTPP LTAS.
    - FHWA LTPP PLUG (Work-in-Progress).
2. WIM vendor products:
    - IRD iANALYZE.
    - PEEK TOPS.
3. Third party products:
    - NCHRP TRAFLOAD
    - Transmetric Traffic WIM Net.

   - PrepME (Work-in-Progress on major redesign).
   - ARA ATLAS.
4. State products:
   - MS-ATLAS (MS-ATLAS was developed for the Mississippi DOT. In summary, the ARA ATLAS program was modified for specific application and use in Mississippi, so it was not included as a separate software package in the detailed review.)

The following sections provide reviews of the identified software products.

2.4.2 FHWA Products

2.4.2.1 FHWA VTRIS

GDOT historically used VTRIS software to process WIM data. This software package was developed by the FHWA to support the FHWA Truck Weight Study (TWS) [7], which consists of vehicle classification and WIM data submitted to the FHWA by State highway agencies. VTRIS validates, summarizes, and generates reports on vehicle travel characteristics by lane, by direction, and by functional Class in the TMG format. The software flags vehicles over 80 kip gross vehicle weight (GVW), 20 kip single, and 34 kip tandem. In addition to FHWA reporting, States use the software to support pavement design (ESAL-based) and enforcement programs. Using this application, users can upload vehicle classification data, WIM data, and WIM station information and generate reports defined by FHWA TWS program. This software does not support development of load distribution files or tables in MEPDG-compatible format.

The VTRIS application uses the Microsoft FoxPro and Visual FoxPro development platforms. However, Microsoft no longer provides technical support for FoxPro, nor is FoxPro compliant with the Section 508 accessibility requirements mandated by FHWA. Therefore, the decision was made by FHWA to develop the new software called TMAS utilizing the Visual Studio.NET development platform, which provides support for Section 508 and allows for a web-based user interface. TMAS software is intended to replace VTRIS software.

Cost:	Free
Accessibility:	Through FHWA website
Owner:	FHWA
Data storage:	On FHW server
Support:	FHWA; on software changes, limited support only due to outdate software platform.
Future use:	VTRIS is to be replaced by TMAS in 2012
MEPDG file:	not applicable

2.4.2.2 FHWA TMAS

The TMAS software is a new software product developed by FHWA to support HPMS program and to replace the VTRIS system. GDOT is transitioning into using this software application for HPMS data submission. TMAS provides an interface to State users to load and validate volume, classification, weight, and station information. A query and export function is planned for the future to provide an interface to extract data. In addition to their own data, States will be able to download data from other States, which promotes data sharing.

TMAS has several built-in data QC and validation functions, including WIM QC checks. The primary purpose of these functions is to validate data for use in FHWA analyses. The system allows users to set-up site-specific validation and QC rules with ranges that are designed around specific traffic loading conditions observed at the sites within a given State. For example, a QC check for steering axle weight and axle spacing checks could be used to assure WIM system performance. No check on heavy axle loads is currently implemented (this check is important for pavement design applications).

The classification and weight information are used to generate W-Tables reports, which provide a standard format for presenting the outcome of the vehicle weighing and classification efforts at truck weigh sites. The W-4 report is designed to provide axle load spectra information. However, its current format is not directly compatible with the MEPDG input requirements for axle load distributions. TMAS version 3 will have an option to export data to the MEPDG. This version is scheduled for release in 2013.

The TMAS software is a web-based application utilizing SQL Server 2008 as the centralized data repository. TMAS provides States with a data entry interface, provides validations against the reported data, supplemental reports, and the facility to submit completed monthly volume data.

Cost:	Free
Accessibility:	Through FHWA website
Owner:	FHWA
Support:	FHWA
MEPDG file:	current version is not applicable. TMAS version 3 will have an option to export data to the MEPDG, to be released in 2015.

2.4.2.3 FHWA LTPP LTAS and PLUG

The LTPP Traffic Analysis Software (LTAS) [8] represents the industry benchmark with respect to WIM data QC/QA, processing, and storage. The LTAS was designed for traffic data QC, processing, and storage to assure that LTPP SPS TPF WIM sites produce research-quality WIM data. This software product is well documented and was subjected to rigorous testing before implementation to support LTPP SPS TPF WIM data collection efforts.

LTAS is an integral part of the LTPP data processing and quality assurance programs. It is used to ensure that WIM data are reviewed in a timely manner using a systematic, comprehensive, and well documented process. [8,9] Additional data checks are conducted during data acquisition by the WIM vendor, prior to loading data into the LTAS database. For WIM data downloaded to LTAS, QC checks consist of reviews of completeness and validity of the provided information.

LTAS is free for States to download and use. However, the support is limited and done through the FHWA LTPP customer support office. The software requires use of an Oracle database for data storage and setting up data tables in a format compatible with the data storage used for LTPP WIM data. This software can work with WIM data collected by a variety of WIM systems. The basic WIM data input is the W-file provided by the WIM vendor or State DOT.

Software output are axle load spectra tables. Loading bins used for reporting axle load spectra are compatible with MEPDG format. However, LTAS currently does not have ability to produce MEPDG load distribution input files.

To provide LTPP data users with means of developing axle load spectra files or user-defined loading defaults, LTPP recently completed a research project that produced the LTPP PLUG software application that could take data from LTAS or user supplied tables and produce MEPDG load distribution input files, as well as to compute NALS defaults. The LTPP PLUG software is free for States to use.

Cost:	Free
Accessibility:	Desktop installation
Owner:	FHWA, State receives executable software file for installation
Data storage:	Oracle server for LTAS, Access database for LTPP PLUG
Support:	FHWA; limited support only though LTPP Customer Service
MEPDG file:	LTAS in combination with LTPP PLUG could be used for processing of WIM data and development of MEPDG Level 1, 2, and 3 inputs NCHRP 1-37A MEPDG and AASHTO Pavement ME formats.

2.4.3 WIM Vendor Products

2.4.3.1 IRD iANALYZE

iANALYZE is a data analysis software package that is provided as a part of WIM system installation by the vendor. It provides a means for data QC/QA, reporting, viewing, and converting traffic data collected by each type of IRD traffic monitoring device. The three primary functions of the software are to:

- Generate reports, which can be viewed or stored.
- Display individual vehicle records.
- Convert data to ASCII format for importing into external programs such as Microsoft Excel.

Data can be imported for analysis after the data collection sites and user-defined parameters have been set up using the software’s Settings menu. Various types of pre-formatted reports of the raw data contained in the files can be produced. The standard reports provide tables showing the class, weight, volume, speeds, and error values on a lane, time period, or Class basis with row and column totals. The reports also can be customized to provide charts and graphs of selected data. The reports may be provided in a format that is in accordance with the FHWA TMG.

There are also several custom comma-delimited ASCII outputs available. These provide lists of a large set of individual vehicle records, such as per vehicle truck records. The CSV data files can be stored and then imported into external software programs such as Microsoft Excel for further analysis. This software works only with IRD WIM systems.

The iANALYZE software can generate load spectra on a daily and monthly basis. However, the limitation of the standardized reports is that they are set for 16 load ranges while the MEPDG software utilizes 39 load ranges for single and tandem axles and 31 for tridem and quad axles. As such, iANALYZE software cannot produce load spectra in MEPDG compatible format. However, IRD States that custom reports can be added as a part of an installation contract for an additional fee.

Cost:	Software – Free with purchase of IRD Traffic Monitoring Device
Accessibility:	Desktop installation
Owner:	Purchaser (not licensed)
Support:	Initial training provided by IRD included. Continuing support provided by telephone at no charge.
MEPDG file:	standard version is not applicable. Custom reports such as MEPDG input files can be added and will be priced by type of modification requested.

2.4.3.2 PEEK TOPS

The PEEK TOPS system combines a variety of automatic data recorder software tools into a single environment. TOPS provides a database as part of its functions (i.e., tables of compiled/summarized WIM data) than can be queried based on customer requests. It uses a built-in reporting capability into which Automated Data Recorder (ADR) data can be imported, stored, and managed, as well as reporting and export tools for analysis of the data. The program provides multiple reporting capabilities for PVR WIM data. However, it does not have the capability to generate load spectra for MEPDG.

ADR data can be exported as comma-delimited text files suitable for importation into Excel spreadsheets which can be used in other database applications, TMG-compliant report W-cards, or PRN files. Customized exports are possible, although TOPS cannot be customized to include agency QC/QA rules and custom report/tables of data at this time.

The available reports for providing QA/QC of data collected from WIM equipment include:

- PVR Weekly GVW Report: For each vehicle class, this report creates a page showing how many vehicles fit into a set of GVW bins for an entire week.
- GVW Summary Report: Provides a concise listing of how vehicles in a particular Class fit into a set of GVW bins. Similar to the PVR Weekly GVW Report, but only shows a single day's data on each report page.
- PVR Weight Violations Report: This report allows one to define what constitutes a variety of weight violations, and then see how many vehicles were detected that failed the test. The report displays a separate page for each date and vehicle class, each showing the number of vehicles that violated the configured weight rules.

This software works only with PEEK systems.

Cost:	Software – Free download from PEEK website
	Custom reports – not available
Accessibility:	Desktop installation
Owner:	User (not licensed)
Support:	Telephone support provided at no charge.

MEPDG file: not applicable

2.4.4 THIRD PARTY PRODUCTS

2.4.4.1 NCHRP 1-39 TRAFLOAD

This software was developed under the NCHRP 1-39 project but is not being supported by NCHRP or FHWA. The agencies that have used this software have reported difficulties in processing large quantities of WIM data, so this product is not included in the detailed review and is not recommended for GDOT use.

2.4.4.2 Transmetric Traffic WIM Net

WIM Net is the Transmetric Traffic module dedicated to managing WIM data. It contains data storage and quality control functions to properly maintain WIM devices to provide reports for WIM data customers. WIMNet is built on a scalable database architecture engineered to store vast quantities of individual axle weights and dimensions—up to 20 years of individual axle data. Highlighted capabilities of WIM Net include:

- Comply with the chapter 5 requirements for WIM in the TMG – W-file.
- Automatic, day-by-day QC functions.
- WIM "post-calibration": salvage out-of-calibration data.
- Tag invalid vehicles.
- Analyze weight trends.
    - Steer weights of Class 9s.
    - B-C axle spacing.
    - Gross weights.
- Caters to user-defined vehicle classes.
- Supports MEPDG:
    - Create TWRG.
    - Export axle load factors for Level 1, 2, and 3 design inputs.
    - Compatible with MEPDG software.
- Reports for users in enforcement, pavement engineers.
- Calculate bridge formula overloading.
- Web-based, multi-user.

Cost: Negotiable

Accessibility: Unknown

Owner: State receives executable software file for installation

Data storage: Unknown

Support: On contract basis

MEPDG file: supports NCHRP 1-37A MEPDG format. Compatibility with AASHTO Pavement ME product is unknown.

2.4.4.3 PrepME by University of Arkansas

PrepME in its original version was developed as a Microsoft Access database software application to support the MEPDG effort of the Arkansas State Highway and Transportation Department (AHTD). This application includes the capability to create and prepare design data sets that can be used in the usable in NCHRP 1-37A MEPDG software. Traffic is one of the PrepME software modules. For traffic data processing, PrepME uses W-file or per-vehicle-records (PVR) records (called "raw data" by PrepME developers) to summarize WIM data and to validate data summaries (QC of compiled and summarized data). Other modules include climate, material, and other capabilities specific to AHTD business practices.

PrepME is being redesigned as part of a Pooled-Fund Study project, and is expected to be fully compatible with AASHTO Pavement ME application. The redesigned version was unavailable at the time of this study. Some of the limitations of the original version were related to exclusion of large quantities of usable data:

- If a WIM site contains data for less than 12 months per year, this site's data is not processed. For example, none of GDOT's portable WIM data would qualify for processing by PrepME.
- If WIM equipment was not installed in January, the remaining months from the first calendar year will be excluded from processing.
- If vehicle classification counts deviated by more than two standard deviations from annual average, data is excluded from further processing. This makes application limited for any seasonal routes or low volume roads that exhibit this kind of variation due to the nature of the traffic flow.

The developers of PrepME acknowledge these limitations and provide means of relaxing the rule, by circumventing the QC process without providing a sound QC alternative. Other limitations with QC approach is that PrepME does not provide means for routine daily WIM data checks. The user must download 12 months of data before any QC checks could be applied. This creates a need for another software application to do routine data checks using periodically downloaded PVR records.

To make this product a viable solution for GDOT and other users, the developers acknowledge that a major re-write of software is needed and are seeking support through States Pooled-Fund Project. This project is currently underway with funding from six States. It is likely that some level of software customization at the agency level will be required in the future due to differences in WIM technologies, corporate databases, and agency-specific geo- and linear referencing systems and site identification processes. As of early 2013, however, this software tool has yet to be completed and tested.

Cost:	Arkansas version of software is free; Pooled Fund Version requires State's contribution to Pooled-Fund Study
Accessibility:	Desktop installation
Owner:	State receives executable software file for installation
Data storage:	MS Access for Arkansas version
Support:	On contract basis

MEPDG file:	pooled-fund study product is expected to be compatible with AASHTO Pavement ME application.

2.4.4.4 ARA ATLAS and MS-ATLAS

Advanced Traffic Loading Analysis Software (ATLAS) was developed by ARA to support MEPDG implementation efforts. This software is designed to download W-card, C-card, and volume files developed in TMG formats, process and summarize traffic data, and develop traffic inputs for MEPDG use. In addition, ATLAS has capabilities in developing defaults and selecting Level 1, 2, and 3 traffic inputs for design using built-in filters that provide flexibility to users in selecting alternative traffic inputs for design or forensic studies.

ARA has used this software as part of MEPDG implementation efforts in Missouri, Maryland, Mississippi, and to some degree in Utah and Arizona. Mississippi also received a custom version of ATLAS (MS-ATLAS) tailored to the State's practices, as part of project deliverables.

ATLAS has the following capabilities:

- Process traffic data (TMG standard data files) from volume, classification, and WIM sites and develop MEPDG inputs (both portable and permanent).
- Implement agency-specific QC/QA procedures (as an add-on option).
- Prepare traffic input files for MEPDG.
- Prepare and manage searchable traffic input data library for MEPDG pavement design.
- Conduct analysis of AADTT, monthly average daily traffic, monthly and hourly truck volume trends, analysis of axle loading changes by season, year, truck type, and axle types.
- Conduct truck volume and load projections using both MEPDG and ESAL approaches.
- Aid in developing traffic defaults or traffic inputs based on "virtual traffic sites."
- House library of MEPDG traffic inputs and defaults with GUI for data retrieval and import to MEPDG.
- Manage permanent WIM site inventory.

Cost:	ATLAS is free with custom implementation package (package cost is negotiable based on extent of customization)
Accessibility:	Desktop installation
Owner:	State receives executable software file for installation
Data storage:	MS Access
Support:	On contract basis
MEPDG file:	supports NCHRP 1-37A MEPDG format and AASHTO Pavement ME *.alf format. Does not support *.xml format.

2.4.5 RECOMMENDATIONS FOR SOFTWARE SELECTION

Based on the summary of information included in this chapter, the following actions are recommended with respect to WIM data processing and the development of MEPDG traffic loading inputs and defaults in Georgia:

1. Use WIM vendors that include WIM data QC as part of their WIM data processing software to assure accuracy of axle weight data, specifically as it relates to the accuracy of heavy axle load measurements. Use this software to check WIM data on a daily basis (internally or through contractual support).
2. Use FHWA TMAS software to process and summarize WIM data and develop site-specific daily, monthly, and annual axle load spectra in AASHTOWare Pavement ME Design software compatible format (the TMAS version capable of this task is expected in 2015). This is recommended because GDOT currently uses TMAS to submit traffic volume and classification data to FHWA. Alternatively, GDOT may obtain and use the free LTPP LTAS software to accomplish these tasks. While MEPDG-related data processing is planned to be added to TMAS in the near future, the LTPP LTAS software (in combination with the LTPP PLUG software) already has these capabilities; this software has been thoroughly tested and used for many years in the LTPP TPF 5(004) study.
3. Obtain the LTPP PLUG database application and customize it for GDOT use. Use GDOT PLUG database application as a library to store GDOT's representative site-specific and default normalized axle load spectra (NALS), axle per-class coefficients (APC), and normalized vehicle Class distributions (NVCD). Use this software to determine appropriate NALS defaults for pavement design projects and to generate MEPDG traffic loading input files. Use this tool to periodically review and update GDOT NALS defaults.

CHAPTER 3 – OVERVIEW OF GDOT'S PRACTICES RELATED TO TRAFFIC DATA COLLECTION AND USE FOR PAVEMENT DESIGN

3.1 PAVEMENT DESIGN PROCEDURES AND TRAFFIC REQUIREMENTS

Currently, GDOT designs pavements based on the 1972 AASHTO Design Guide for flexible pavements and the 1981 supplement for rigid pavements. These procedures are described in the GDOT Pavement Design Manual (draft revised 12/6/2005). Based on this manual, GDOT uses 18-kip ESALs determined through the use of truck equivalency factors derived from the AASHTO equivalency factors based on the serviceability index. These truck equivalency factors are based on statewide averages established for different pavement types (flexible and rigid pavements) and different types of vehicles (passenger cars and pickup trucks (FHWA classes 1-3); SU trucks (FHWA classes 5-7); MU or combination trucks (FHWA classes 8-13)). Truck equivalency factors were computed based on WIM data collected in 1980's on Georgia roads, and have not been updated for many years.

GDOT's Procedure for Development of Traffic Inputs for Pavement Design is the following:

1. The project manager (PM) requests traffic diagrams from Office of Planning, Traffic Analysis Section (OP TAS) for the project on hand.
2. OP TAS requests a special traffic count at the project location to obtain traffic volumes by vehicle class. Based on collected data, 24-hour truck percentages and a breakdown between SU and MU trucks are developed.
3. OP TAS predicts traffic growth using current and historical traffic volume data.
4. Adjustments for directional distribution and lane distribution are made by OP TAS or, if desired, the unadjusted data can be obtained and the distribution percentages provided.
5. OP TAS submits data on truck volume and growth to PM or pavement designer at OMR.
6. The PM/pavement designer determines the base year (opening day), considering the number of years for construction (usually 2 years) and adds 20 years for the design year.
7. The pavement designer develops traffic projections based on counts or the traffic diagrams provided by OP TAS.
8. The pavement designer converts projected truck volumes to ESALs using table with statewide equivalency factors for three aggregated vehicle classes: (1)passenger cars and pickup trucks (FHWA classes 1-3); (2) SU trucks (FHWA classes 5-7); (3) MU or combination trucks (FHWA classes 8-13).
9. The traffic data input, in the form of ESALs, is used in the pavement design procedure.

GDOT is considering MEPDG implementation to gain flexibility in new pavement design, rehabilitation design, and forensics studies, because truck equivalency factors depend on the distress type and magnitude. MEPDG design criteria are based on pavement failure defined as certain magnitudes of pavement distress (e.g., cracking, rutting, faulting, etc.).

3.2 TRAFFIC DATA COLLECTION FOR PAVEMENT DESIGN

As discussed in the previous section, GDOT currently collects project-specific traffic volume and vehicle classification data for pavement design. It is likely that with implementation of the MEPDG design procedures GDOT will continue collecting project-specific traffic volume and vehicle classification data. The only change anticipated with these data types is reporting of vehicle Class data using 10 truck classes (FHWA vehicle classes 4-13) instead of 3 aggregated classes described above.

Load spectrum is also required for Georgia's current design method and for the MEPDG procedure. Load spectrum is defined as the frequency distribution of axle load counts by load magnitude, and data needed to generate a load spectrum are collected using WIM devices. Currently, GDOT conducts two types of WIM data collection: short-term WIM samples using portable WIM devices and continuous monitoring using permanently installed WIM sites.

3.2.1 Portable WIM Data Collection

GDOT collects portable WIM data primarily to support the FHWA Truck Weight Study [(7)]. Currently, these data are not being used for pavement design.

This type of data collection is well established at GDOT and consists of 2-day WIM data samples collected at about 30 sites annually using PEEK ADR 1000 equipment with piezoelectric Brass Linguini (BL) sensors. All portable WIM data are collected by GDOT's contractor. There is no formal (ASTM-based [(5)]) calibration of the portable WIM equipment, although the contractor uses in-situ calibration without a calibration truck, by using the steering wheel weight. There is no clause in the current contract with GDOT about QC-ing the data. As a result, very little QC is done for portable WIM data. Based on the type of the device and procedures used, it is likely that these data are not reliable as an input for MEPDG pavement design; however could be used to estimate attributes of traffic loading pattern (i.e. proportion of light vs. heavy axles).

There are 88 sites for which portable WIM data were collected in the past years. The majority of the sites are located on the interstate and State routes, as summarized in table 12.

TABLE 12
Distribution of portable WIM sites by route type

Route Type	Number of WIM sites
I– Interstate	29
US – US Route	1
SR – State Route	49
CR – County route	9

The contractor processes the collected WIM samples using WIM vendor software to generate W-files. These files are sent to GDOT, and then GDOT uploads the files to the FHWA VTRIS website for further processing and analysis by FHWA.

3.2.2 Existing Permanent WIM Sites

Currently, GDOT does not have formally established permanent WIM program (i.e. program supported by WIM data collected at permanently installed WIM sites). However, GDOT has installed two pilot permanent WIM sites using two different vendors, IRD and PEEK.

- Site 067-2373 is located on I-285 at Orchard Road in Cobb County. This site utilizes the IRD iSync data collection system with the iAnalyze software. Kistler WIM sensors are installed in the outside three northbound lanes, and Class I BL sensors are installed in inside northbound passing lane. There are no WIM sensors in the southbound lanes.

- Site 207-0222 is located on I-75 between Pate Road and I-475 in Monroe County. This site utilizes the PEEK ADR WIM device with the TOPS software. Kistler WIM sensors are installed in all northbound and southbound lanes.

Assessment of data collected from these sites (presented in Chapter 4 of the report) indicates that both provide good quality data usable for development of Georgia-specific axle load spectra for MEPDG analyses. The issue with the permanent WIM sites is that there are only two sites for the entire State of Georgia.

3.2.3 WIM-Ready ATR Sites

In addition to the two pilot permanent WIM sites, seven of the existing ATR sites have WIM Type I Kistler piezoelectric sensors or Class I BL piezoelectric sensors installed and are WIM-ready. The following list identifies ATR IDs and location of WIM-ready sites:

1. 021-0334 - I-75 between I-475 & SR-247 Pio Nono (Jennifer Overpass 6-PCC) – Kistler WIM sensors in outside lanes in each direction.
2. 089-3354 - I-285 between Memorial Dr. & Church St. MP 44.4 – Class I BL piezo sensors in two (2) outside lanes in each direction.
3. 089-3363 – I-285 between Chamblee Tucker & North lake Pkwy MP 34.9 at the Henderson overpass - Class I BL piezo sensors in two (2) outside lanes in each direction.
4. 143-0126 – I-20 between Alabama State line & SR100 Veterans Mem Hwy – Kistler WIM sensors in the outside lanes.
5. 127-0312 - I-95 between SR-27 & Golden Isles Parkway SR-25 Spur MP 36.6 – Kistler WIM sensors in outside lanes.
6. 301-0196 – I-20 between SR-12 and East Cadley Road - Class I BL piezo sensors in two (2) outside lanes in each direction.
7. 245-0218 – I-20 between SR-104 RR and Georgia/South Carolina State Line - Kistler WIM sensors in outside lanes.

All of these sites are located on interstate roads.

3.2.4 Proposed Permanent WIM Sites for FHWA Study

In 2010, GDOT investigated the feasibility of developing permanent WIM sites to support the FHWA Truck Weight Study [(7)]. As a result, 20 potential site locations have been identified. This list was revised in 2013 to include inputs from GDOT Office of Planning. The revised list is shown in table 13. As can be seen from this list, all but one of the proposed sites are located on interstate roads.

For MEPDG implementation purposes, road functional classes other than interstates also would require permanent WIM coverage, as traffic loading patterns on these roads are expected to be different from the loading patterns observed on interstates. Based on information from the GDOT road inventory database, there are over 18,000 center line miles of State routes, of which only 1,246 center line miles are interstates.

TABLE 13
Potential site locations for permanent WIM sites

#	TC_NUMB	County	Route ID	Location	WIM Type
1	0021-0334	Bibb	I-75	I-75 btwn I-475 & SR-247 Pio Nono (Jennifer Overpass 6-PCC)	KISTLER WIM**
2	0039-0218	Camden	I-95	I-95 btwn Florida Line & St Marys Rd CR-61 North of welcome ctr	BL CLASS I WIM
3	0051-0368	Chatham	I-16	I-16, 0.6 mi. East of SR-307 Dean Forest Rd	KISTLER WIM
4	0051-0387	Chatham	I-95	I-95, 2 mi N. of SR-21 @ SC State line SB	KISTLER WIM
5	0067-2373	Cobb	I-285	I-285 @ Orchard Road	KISTLER WIM*
6	0081-0101	Crisp	I-75	I-75 1.5 M So SR-33 connector(Rock House Rd)	KISTLER WIM
7	0081-0347	Crisp	SR-300	SR-300 btwn SR-300CO Old Albany & SR-7 Bridge MP 9.3	KISTLER WIM
8	0089-3354	DeKalb	I-285	I-285 Btwn Memorial Dr. & Church St. MP 44.4	KISTLER WIM**
9	0089-3363	Dekalb	I-285	I-285 btwn Chamblee Tucker & North lake Pkwy MP 34.9 @ Henderson overpass	KISTLER WIM**
10	0127-0312	Glynn	I-95	I-95 btwn SR-27 & Golden Isles Parkway SR-25 Spur MP 36.6	KISTLER WIM**
11	0143-0126	Haralson	I-20	I-20 btwn Alabama State line & SR100 Veterans Mem Hwy	KISTLER WIM**
12	0147-0287	Hart	I-85	I-85 btwn Hart/Franklin Co line & SR77 Whitworth Rd	BL CLASS I WIM
13	185-0227		I-75	at Georgia/FL State line	BL CLASS I WIM
14	0207-0222	Monroe	I-75	I-75 between Pate Road and I-475	KISTLER WIM*
15	245-0218	Richmond	I-20	SR-104 RR and Georgia/SC State line	KISTLER WIM
16	0265-0163	Taliaferro	I-20	I-20 btwn SR-22 & Warren Co Line MP 148.8	KISTLER WIM
17	0277-0256	Tift	I-75	I-75 btwn Willis Still Rd & Turner Co line	KISTLER WIM
18	0285-0234	Troup	I-85	I-85 btwn SR-219 & SR-1	KISTLER WIM
19	0289-0183	Twiggs	I-16	I-16 (SR-404) btwn SR-96 & SR-358 Homer Change Hghwy	KISTLER WIM
20	0301-0196	Warren	I-20WB	I-20WB btwn SR-12 & E Cadley Rd CR-185	KISTLER WIM**

* Pilot WIM Sites
** Sites with WIM-ready sensors

3.3 TRAFFIC DATA STORAGE

The current traffic database is managed by the Data Reporting & Quality Control Branch of the Office of Transportation Data (OTD). GDOT uses TPAS (Traffic Polling and Analysis System) to poll, extract, and store vehicle classification and volume data. Traffic summary statistics (AADTT, truck percentage, vehicle classification) from about 4,000 traffic sites are stored in an Oracle database. Georgia STARS, a web-based GIS application, is used by GDOT to view traffic data on a map.

Currently, GDOT does not have a database to store processed WIM data. Raw WIM data are collected by a contractor, converted to PVR records, saved to flat files in FHWA W-format, and sent to GDOT for further submission to FHWA. The load spectra summaries based on these data are made available to GDOT through the FHWA VTRIS website (currently, transitioning to FHWA TMAS website). These load spectra summaries do not conform to MEPDG load spectra format.

For implementing new MEPDG procedures, a new database (or new tables within the existing traffic database) is needed to store site-specific load spectra summaries (daily, monthly, annual and representative NALS). It would be beneficial to set up the table structure in a format compatible with MEPDG, such as the table structure used by LTPP program. GDOT's intention is that site-specific WIM data be stored by the traffic data collection office of the Data Reporting & Quality Control Branch. This includes raw data polled from WIM and QC-ed data summaries. MEPDG default inputs are to be developed from processed (summarized) traffic data that have been quality checked and stored in the MEPDG traffic library database (such as the GDOT PLUG database).

CHAPTER 4 – REVIEW AND ANALYSIS OF GDOT'S TRAFFIC DATA AND ITS APPLICABILITY FOR MEPDG IMPLEMENTATION

The purpose of this assessment was to investigate the usability of GDOT's historical and current WIM data for developing MEPDG loading inputs and defaults. The scope of analysis included:

- Assessment of WIM data from Georgia permanent and portable WIM sites for MEPDG implementation.
- Development of MEPDG Level 1 traffic inputs using Georgia permanent WIM sites.
- Assessment of historical WIM data for LTPP study sites located in Georgia and development of MEPDG input Levels 1 and 2.
- Analysis of vehicle classification data from automated vehicle classification (AVC) sites and categorization by MEPDG truck traffic classification (TTC) groups.

4.1 ASSESSMENT OF GDOT'S PERMANENT WIM DATA

As discussed in chapter 3, GDOT conducts two types of WIM data collection: short-term WIM samples using portable WIM devices and continuous monitoring using permanent WIM sites. Result of WIM data assessment are presented in this and the following sections.

4.1.1 GDOT's Pilot Permanent WIM Sites

Currently, GDOT collects continuous WIM data at two pilot permanently installed WIM sites:

- Site 067-2373; located on I-285 at Orchard Road in Cobb County.
- Site 207-0222; located on I-75 between Pate Road and I-475 in Monroe County.

These sites have multiple lanes instrumented with WIM sensors. Analysis of daily truck volumes, loading patterns, and vehicle Class distributions between different lanes led to identification of the following lanes with the heaviest truck traffic (i.e., "truck" lanes):

- Site 067-2373; Lane 2 in the northbound direction.
- Site 207-0222; Lane 1 in the northbound direction and lane 2 in southbound direction.

Load spectra from these lanes were used in the analyses.

4.1.2 Data Used for Analysis

WIM data for 2010 were obtained and processed using ARA's ATLAS software to develop daily, monthly, and annual axle load spectra. These spectra were QC-ed for possible system bias and evaluated for data reasonableness. It was determined that both sites produce good quality data for Class 9 trucks, which is the dominant heavy truck type observed on Georgia roads.

For site 067-2373 located on I-285, data were collected only in the northbound direction. For site 207-0222 located on I-75, data were available for both directions. Since site 207-0222 had WIM sensors in both directions, data in each direction were analyzed separately, resulting in two different directional load spectra.

It was observed that axle load spectra for Class 8 vehicles for both sites show a high percentage of light vehicles. Unless Georgia allows classification of pickup trucks pulling a light trailer as FHWA Class 8, this could be a misclassification issue.

Class 9 trucks were found to be the dominant heavy vehicle class, representing 68 to 70 percent of all trucks at these sites. A more detailed analysis of axle loading trends for Class 9 trucks was carried out, as described in the following sections.

4.1.3 Analysis of Monthly Loading Patterns

Monthly axle load spectra for Class 9 trucks were analyzed to determine consistency in monthly loading patterns. This type of analysis is used frequently to detect WIM sensor calibration drifts over time. For this type of analysis, normalized axle load spectra (NALS) were computed because they allow evaluation of changes in percentages of light or heavy axle loads between different time periods for the same site or between different sites by eliminating the influence of changes in truck volumes.

Based on an analysis of monthly NALS, neither WIM site had evidence of seasonal changes in truck loading patterns that would result in either increase or decrease in the percentages of heavy axles. However, monthly NALS analysis points out that one of the directions (direction code 1, lane 1) for site 207-0222 shows evidence of calibration drift which happened in October 2010 and affected all the following months, as shown in figure 2 and figure 3. WIM equipment malfunction in October 2010 was further confirmed by GDOT. The load spectra for these months are shifted to the right by 1,000 to 2,000 lb, showing higher loads across all load ranges. GDOT conducted WIM system calibration in 2011 to remedy this issue. Pre-calibration results collected using test truck in the field confirm the positive bias (over prediction by 1,000 to 2,000 lb).

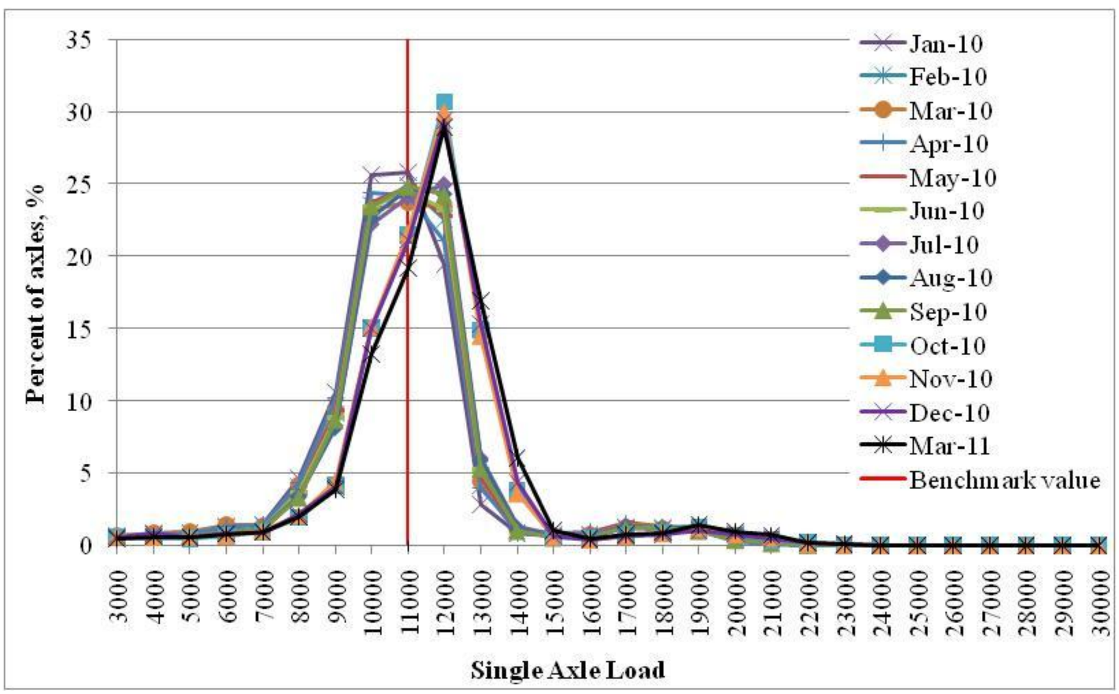


FIGURE 2
Monthly single axle load spectra for site 207222, lane 1, direction 1

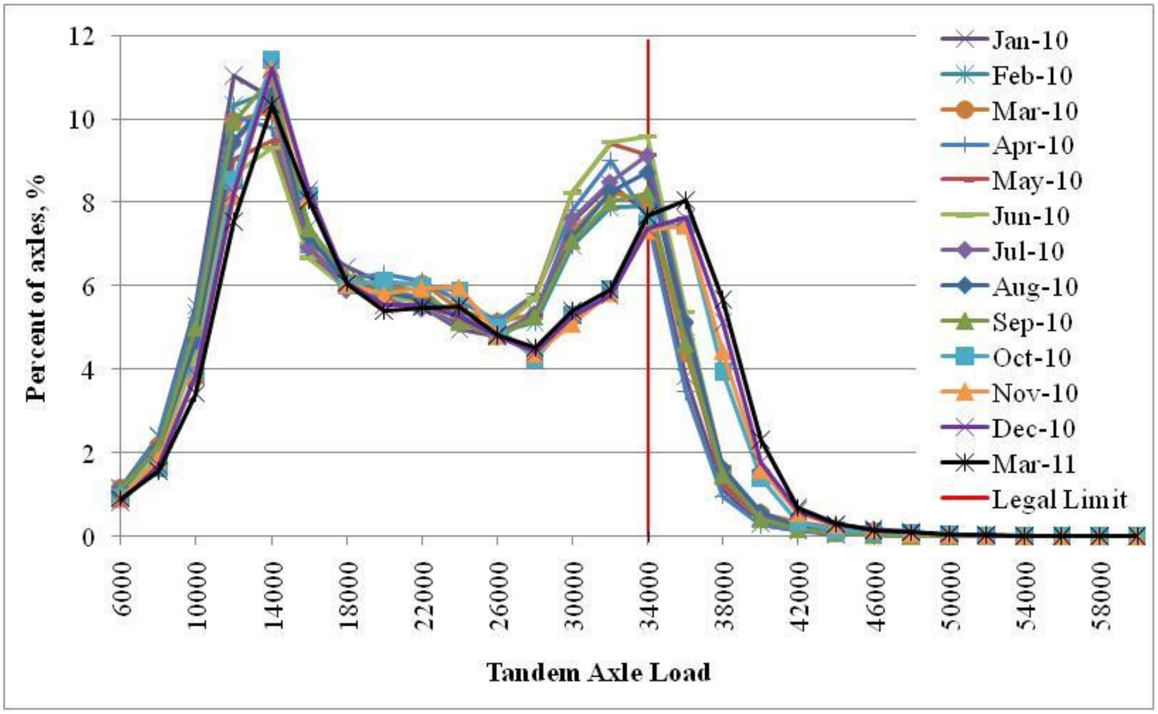


FIGURE 3
Monthly tandem axle load spectra for site 207222, lane 1, direction 1

4.1.4 Tandem Axle Data Analysis

To analyze loading condition associated with heavy truck type, average annual normalized tandem axle load spectra for Class 9 trucks were computed using data from each “truck” lanes for both WIM sites. Computed annualized NALS are shown in figure 4.

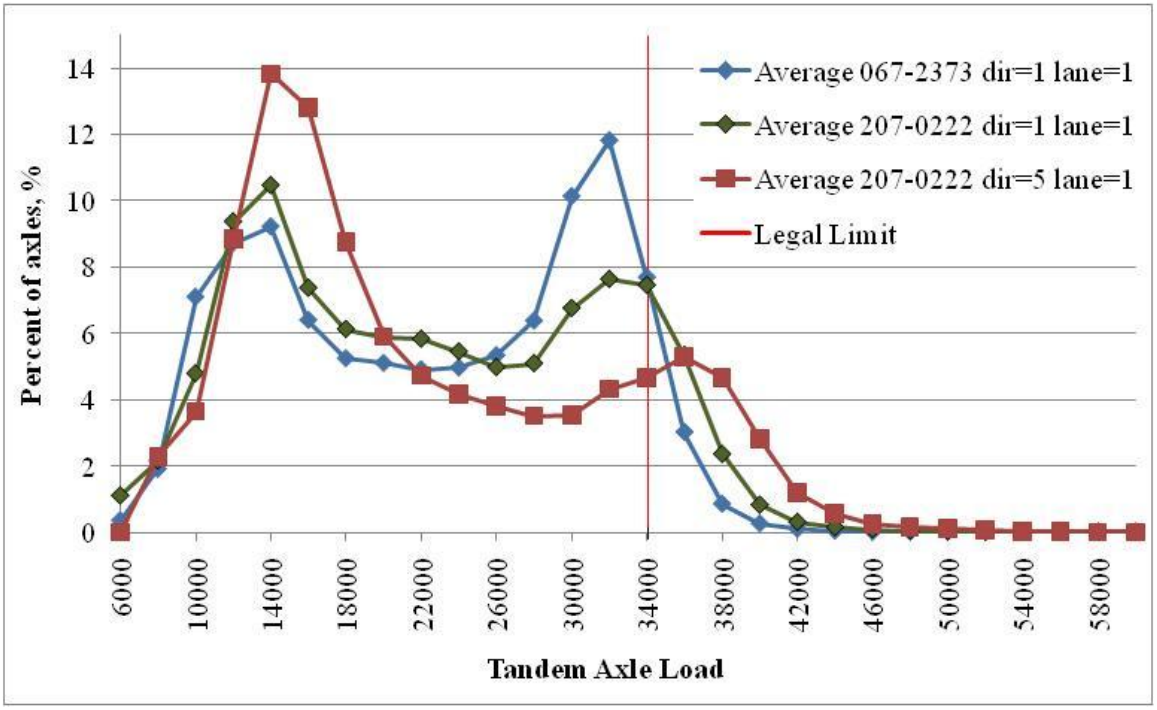


FIGURE 4

Load spectra for Class 9 tandem axles for permanent WIM sites.

4.1.4.1 Comparison between Georgia WIM Sites

All tandem load spectra show bi-modal distribution of Class 9 tandem axles. This distribution frequently is observed near metropolitan areas and reflects a large variety of goods being carried, as well as the local pick-up and delivery pattern, resulting in distributions that have both heavily loaded and lightly loaded axles. The site on I-285 has a higher percentage of heavily loaded Class 9 tandem axles than lightly loaded tandem axles (loaded peak near legal limit line is higher than unloaded peak located between 10,000 and 14,000 lb).

An interesting observation is that axle load distributions observed in the opposite directions on I-75 (WIM site 207-0222) have significant differences in distribution of heavy axles: one direction has loaded peak to the left of the legal limit (legal limit is identified by the red vertical line on the plot) while the other direction has lower loaded peak that is located beyond the legal limit line, in the overload portion of the plot. This could be a true loading characteristic or a sign of differences in equipment setting/calibration for the two directions, potentially resulting in "stretching" or "shifting" axle load spectra for the sensor identified as 207-0222 dir=5 lane=1 on the plot.

4.1.4.2 Comparison with MEPDG National Defaults

All computed load spectra were compared with the original MEPDG default load spectra and load spectra defaults that are being developed by LTPP using SPS TPF WIM sites. The main difference between the two sets of national default is the data used to develop the defaults. In the case of the original NCHRP 1-37A defaults, data were obtained from more than 150 WIM sites located in many different States; these sites are maintained by States, using a variety of local maintenance and calibration procedures, equipment, and vehicle classification schemes. In the case of LTPP defaults, data were obtained from a smaller number of sites (26 sites located in different States) that are maintained by FHWA, using uniform rigorous maintenance and calibration procedures, with WIM equipment that conforms to certain accuracy standards, and a uniform vehicle classification scheme.

A graphical comparison is shown in figure 5 and figure 6, which reveal that, overall, GDOT load spectra follow the same bi-modal distribution as the national defaults. The largest differences between national default spectra and spectra for GDOT sites are observed at site 207-0222 dir=5 lane=1 that has the highest percentage of lightly loaded tandem axles. NALS based on Georgia permanent WIM sites are more similar to the new LTPP defaults than to the original defaults.

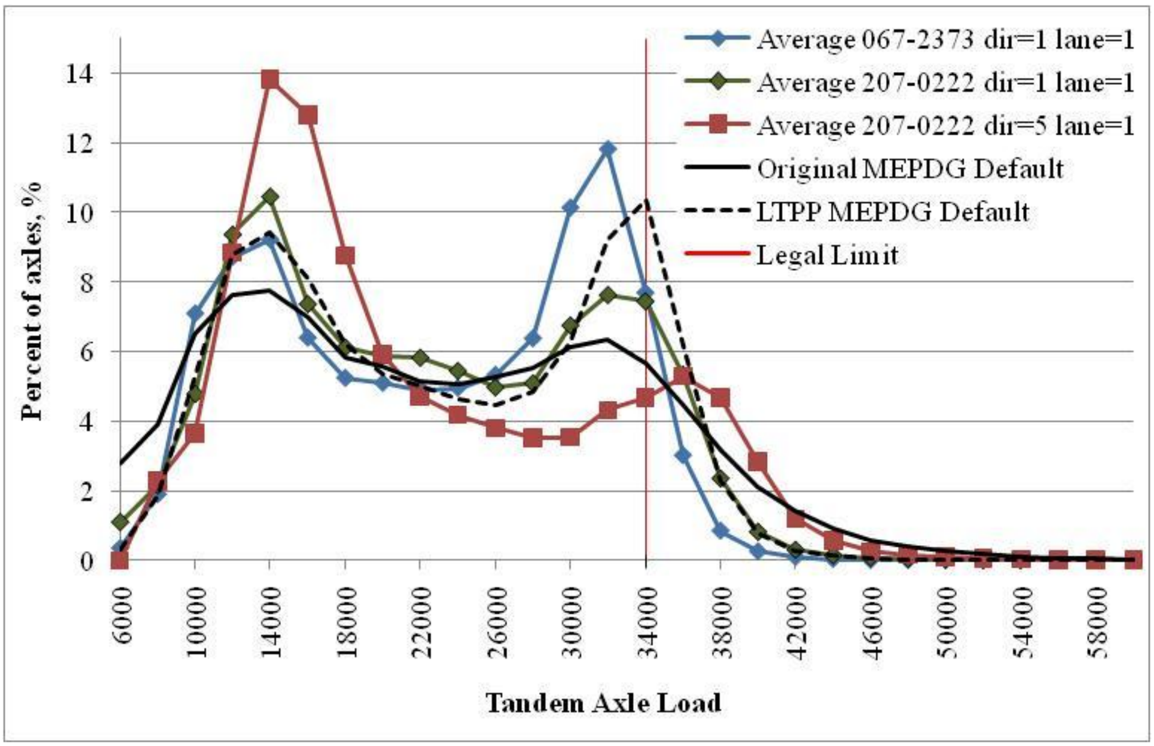


FIGURE 5
Tandem load spectra comparison by site

Average GDOT load spectra were computed and compared with MEPDG defaults (NCHRP 1-37A and LTPP SPS TPF). GDOT averages were computed with and without data for site 207-0222 dir=5 lane=1. Results of that comparison are shown graphically in figure 6. Both computations of GDOT average spectra match closer with LTPP-based MEPDG defaults than with the NCHRP 1-37A default. GDOT average spectra computed without data for site 207-0222 dir=5 lane=1 show the closest match with the LTPP-based MEPDG default. In summary, the original MEPDG default NALS exhibit a higher percentage of overloads, which will result in more distress predicted by the MEPDG software.

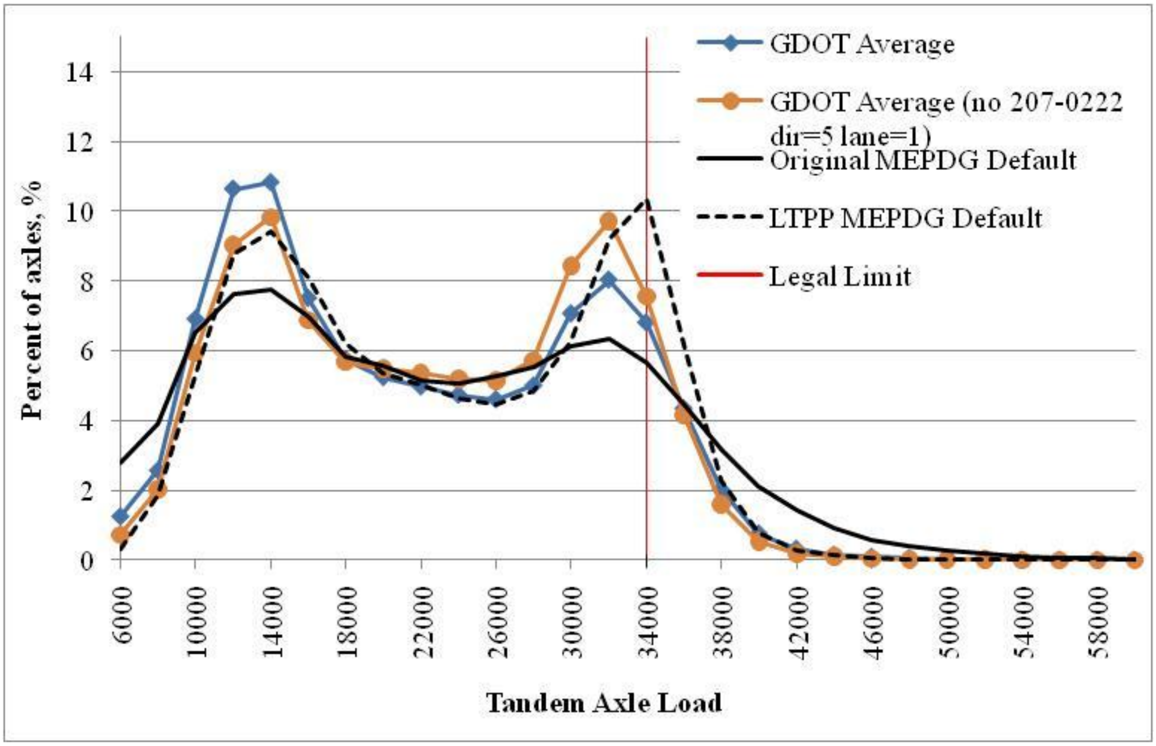


FIGURE 6
Tandem load spectra comparison using GDOT averages

4.1.5 Single Axle Data Analysis

From analysis of tandem axles, it became evident that data for site 207-0222 dir=5 lane=1 show the highest percentage of loads exceeding federal load limit. To determine whether this could be attributed to an over calibrated WIM sensor, an analysis using data for Class 9 single axles was conducted. Single axle load data for Class 9 frequently are used to evaluate WIM system performance because single axle weight for Class 9 trucks is closely associated with steering axle weight, which on average is about 10,500 lb.

Figure 7 shows the comparison of single axle load distributions for Class 9 single axles. As can be seen on the plot, site 207-0222 dir=5 lane=1 has a distinct shift of its peak value (13,000 lb) to the right compared to the other distributions, as well as a benchmark value identified by the vertical red line. This additional information further supports the hypothesis of WIM system over calibration for site 207-0222 dir=5 lane=1.

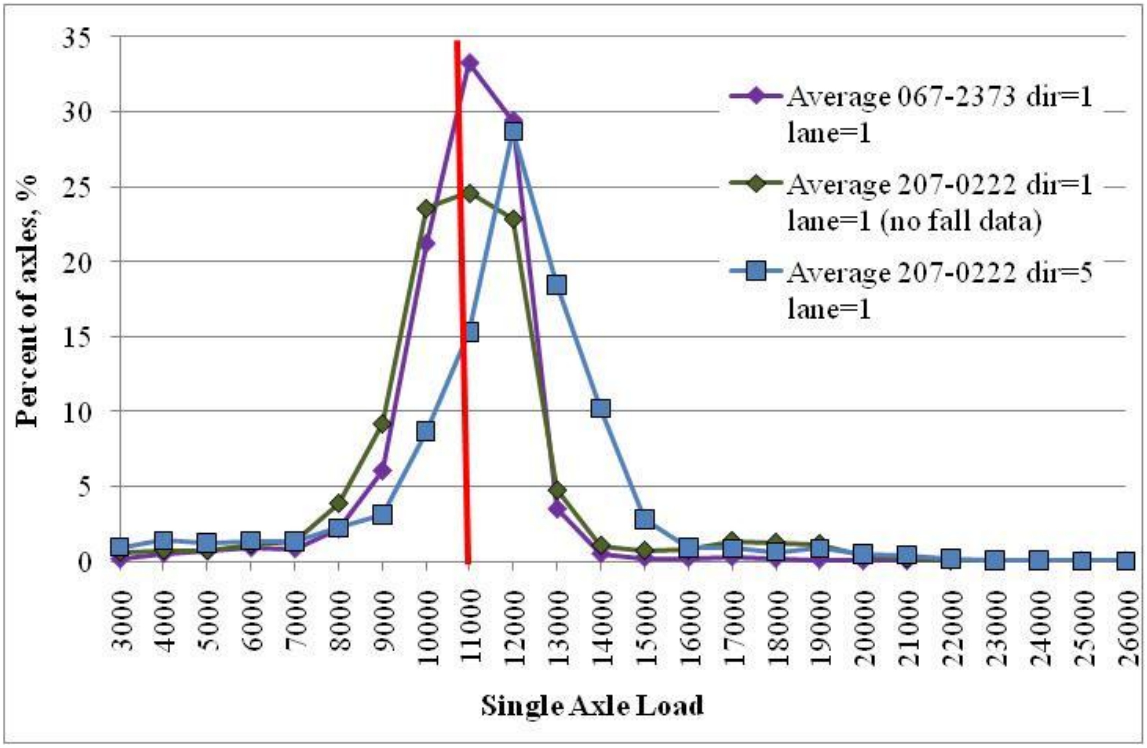


FIGURE 7
Load spectra for Class 9 single axles

4.1.6 Conclusions from Permanent WIM Data Assessment

- Assessment of a year's worth of WIM data from GDOT's two pilot permanent WIM sites indicates that different loading patterns are likely to exist on interstate roads with respect to heavy load percentages. The significance of these differences for pavement design should be evaluated using MEPDG sensitivity analysis and through the bias and standard error terms comparing predicted and observed distresses. This evaluation will provide insights on how many default NALS are needed to adequately represent differences in traffic loading conditions on Georgia roads.
- Comparison of WIM data from Georgia pilot permanent WIM sites indicates that overall loading patterns observed at these sites are in line with the available national loading defaults: they follow the same bi-modal distribution. The distribution of heavy loads observed at Georgia permanent WIM sites are closer to the default values based on the LTPP SPS TPF WIM sites than to values developed under the NCHRP 1-37A project. Therefore, new MEPDG traffic loading defaults developed by the LTPP program seem to be more applicable than the original MEPDG defaults; at least for these two WIM sites.
- In addition to the existing permanent WIM sites in Georgia, it would be beneficial to have more permanent WIM sites installed on interstate roads passing through rural areas or on interstates leading to/from port facilities, as well as close to State borders to investigate differences in loading patterns.
- Non-interstate roads with significant truck traffic should also be included in the WIM data collection plan. In the short-term, this could be accomplished using GDOT portable WIM data. If differences in loading patterns are observed, then this information should be considered in the development of the installation plan for permanent WIM sites.

- At site 207-0222, a likely calibration drift (for data with direction code 1) and over calibration (for data with direction code 5) were observed. To assure high-quality WIM data throughout the year, procedures for WIM calibration and systematic WIM data review should be established. This will allow Georgia to catch and correct WIM calibration drifts in a timely fashion.
- No seasonal changes in traffic load distribution patterns for heavy trucks were observed at the GDOT permanent WIM sites located on the interstates. When more permanent WIM sites are established, seasonal variation in loading should be further investigated. In the meantime, loading defaults based on the annualized data representing an "average day of the year" are recommended.

4.2 MEPDG LEVEL 1 TRAFFIC INPUTS FOR GDOT'S PERMANENT WIM SITES

Data (from 2010) from pilot permanent WIM sites was processed and used to develop MEPDG Level 1 inputs for the truck lanes of WIM sites. The amount of data available at the time of this analysis is believed to be sufficient and representative of the truck traffic at these locations for the purpose of characterizing loading conditions and use in local calibration. As more data become available, it is recommended that GDOT periodically update these Level 1 site-specific inputs and track possible changes in loading conditions over time.

The Level 1 inputs developed based on the data from GDOT permanent WIM sites include:

- Normalized axle load spectra (NALS).
- Normalized vehicle Class distribution (NVCD).
- Axle per Class coefficients.
- Hourly truck volume distributions.

These MEPDG traffic input files are provided on a CD included with this report.

Although monthly truck volume distributions for these sites were developed based on WIM data, these distributions are not recommended for use because daily data availability for individual months was limited (i.e., not all days of data were in the acceptable format for data processing) to produce unbiased monthly distribution. MEPDG default monthly distribution of no seasonal changes could be used for these sites, as no strong seasonality in heavy truck volumes was observed based on the analysis of available truck volume data for Class 9 vehicles, which is dominant heavy truck type at these WIM sites. It is recommended that site-specific monthly (seasonal) truck volume distribution factors for use in the MEPDG should be derived from vehicle classification data collected at continuous monitoring sites across Georgia. These data can also be used to develop defaults for sites that do not have adequate vehicle classification data.

4.3 ASSESSMENT OF GDOT'S PORTABLE WIM DATA

4.3.1 Data Used

For this study, axle weight data (48-hour samples) collected by GDOT's contractor using portable WIM devices were obtained for all the sites that have daily volume of FHWA Class 9 vehicles over 100 vehicles per lane. WIM samples collected for the roads with fewer than 100 Class 9 vehicles per day were found to be too small and of questionable quality to use for axle load spectrum analysis. This evaluation and analysis was explained in Interim Reports #3 and #4.

Because GDOT monitors only one direction of travel during any given data collection cycle, different directions are monitored during different data collection cycles. For the sites where WIM data were available for both directions of travel, the analysis was conducted separately for each direction of travel and different loading patterns were observed for a number of sites.

WIM data from 2002 to 2012 annual data collection cycles were obtained and 107 directional WIM data samples analyzed. These samples represent 56 unique locations on 31 different roads (multiple samples were available along several major roads).

The available WIM data sample covers different geographical locations within the Georgia roadway network and different road functional classes. 54 WIM data samples were identified for interstate roads, and 53 for non-interstate roads. Table 14 provides distribution of portable WIM samples used in this study by road functional Class and GDOT's district.

TABLE 14
Distribution of portable WIM samples by road functional Class and GDOT district

Road Functional Class	District							Total by Functional Class
	1	2	3	4	5	6	7	
1		10	6	2		4		22
2				8	8	2		18
6		3	2			2		7
11		2	8	2	8	2	10	32
12		2				1	2	5
14	2		6	2	2	8		20
16				2			1	3
Total by District:	2	17	22	16	18	19	13	107

4.3.2 Analysis Approach

The purpose of the data analysis was to determine whether these data can be used for MEPDG pavement design, and development of the defaults.

Several limitations associated with GDOT's portable WIM data were known from the start, and these limitations probably limit the usability of portable WIM as a direct input to the MEPDG:

1. These data were collected using WIM devices that were not calibrated in the field using heavily loaded Class 9 trucks (did not follow ASTM 1318 recommendations).
2. Accuracy of collected data was not validated in the field beyond auto calibration based on weight of the steering axles on Class 9 vehicles (i.e. accuracy of heavy loads is unknown).
3. Type of technology used has limited accuracy (not to exceed +/- 30 percent of true weight for loaded single axles and +/- 20 percent for loaded tandem axles, per ASTM 1318 using 95% conformance criteria).

4. The duration of sampling (48 hours) was too short to develop a representative annual axle load spectrum for the site.

In view of very short sampling period, the minimum data quantity criterion was set to be at least 100 Class 9 trucks per day per study lane based on the following (portable WIM data samples based on fewer than 100 Class 9 vehicles were excluded from the analysis):

- Axle load distributions of Class 9 vehicles have well known characteristics and typically are used to evaluate the accuracy of collected WIM data. Without a sufficient sample of Class 9 vehicles, it is difficult to assess data reasonableness.
- Axle load distributions constructed based on fewer than 100 trucks tend to be highly variable. This does not mean the data are incorrect; it is just difficult to analyze and/or explain the variation, especially when the axle weight data are collected over a short time period.
- Class 9 trucks were found to be by far the most dominant heavy truck Class in Georgia that carry the highest percentage of the cumulative pavement load.
- Portable WIM equipment is calibrated in the field using Class 9 trucks. A sample of 100 Class 9 vehicles is recommended for setting the system in auto-calibration mode.

Accounting for the known data quality limitations, a tiered approach was used for portable WIM data assessment. Data assessment focused on identifying whether axle load distributions constructed based on WIM samples exhibit expected distribution attributes, and if so, whether they exhibit strong calibration drifts (or bias in axle weight measurements). The following procedure was used to evaluate the reasonableness of portable WIM data samples and to determine the axle weight distributions and descriptive truck loading conditions:

1. For each portable WIM site, use available WIM data to construct single and tandem NALS for Class 9 vehicles (i.e., distribution of axle loads by MEPDG load bins). Class 9 is used because it was found to be the dominant *heavy* truck observed on majority Georgia State routes.

2. Conduct initial visual and quantitative assessment of axle load distributions using criteria listed below. Sites that exhibit axle weights that deviate from the following criteria may, in fact, represent the actual axle weights. However, not knowing specific details on the commodities being transported, and not wanting to base the designs on axle weight anomalies that do not represent typical loading conditions, it is important to identify and flag the sites with atypical distribution. These criteria were used to identify expected attributes of load spectra for Class 9 vehicles:
    a. For single axles:
        i. Bell-shaped distribution with peak percentage of loads within 9,000-11,999 lb (10,500 lb is expected value for most trucks).
        ii. Less than 3 percent loads exceeding 18,000 lb and less than 1 percent of axle loads over 20,000 lb.
    b. For tandem axles:
        i. "Camel-back" distribution is expected with two peaks. It is possible but uncommon to see only one peak (either loaded or unloaded) at the location of either the first or second peak described below.
        ii. First peak around 10,000 to 16,000 lb (optional check).
        iii. Second peak around 28,000 to 35,999 lb.

iv. Less than 20 percent of loads exceeding the legal limit of 34,000 lb. The majority of sites are expected to have less than 10 percent.
v. Less than 3 percent loads exceeding 40,000 lb.

Examples of atypical load spectra for Class 9 trucks are shown in Figure 8 and Figure 9. These data were collected using portable WIM on a low truck volume road (SR-10 between SR-28 Broad St & South Carolina line) with ADTT of 200 during the observed data collection period. The single axle plot in Figure 8 shows an atypical low peak of Class 9 single axles; typically, a steering axle peak load between 10,000 and 11,000 lb is expected. The tandem axle plot in Figure 9 shows atypical heavy Class 9 tandem axles—34,000 lb is the weight limit, and the probability of axles much higher than 34,000 lb is low due weight regulations and operational vehicle characteristics.

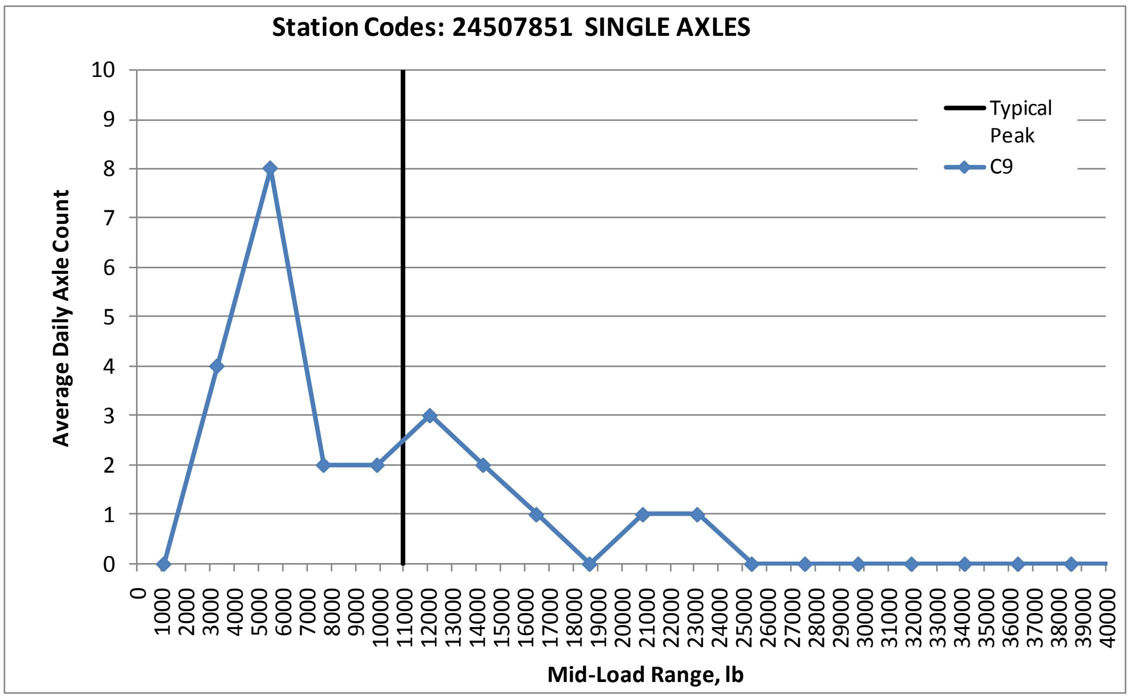


FIGURE 8
Class 9 single axle load spectra example (atypically low peak)

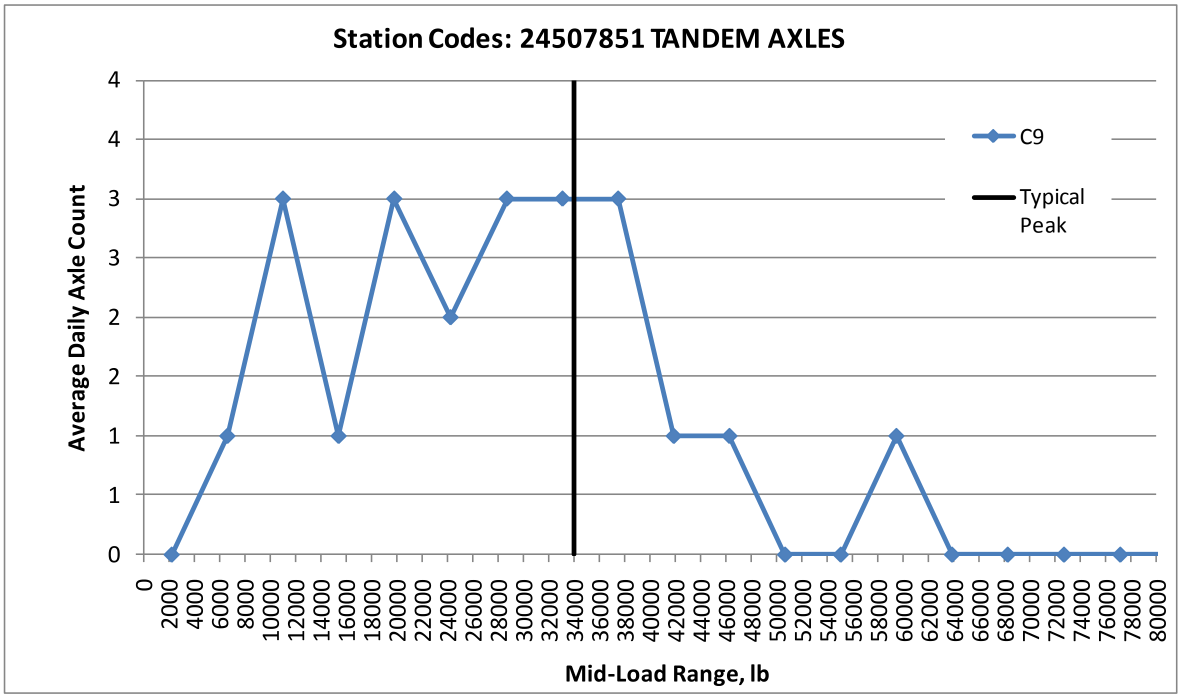


FIGURE 9
Class 9 tandem axle load spectra example (atypically heavy axles)

Another example is shown in figures 10 and 11 for the spectra developed from the data collected using WIM equipment with calibration drift. These data were collected using portable WIM on a moderate truck volume road (SR-520 between Terrell Co line & Cookville Rd CR-228) with ADTT of 850 during the observed data collection period. Both the single and tandem axle plots show characteristic shapes of Class 9 axle load distributions but with a significant shift to the right along the x-axis. The single axle peak shown in figure 10 is shifted from the expected value of 10,000-11,000 lb to 17,000 lb, and the loaded tandem axle peak shown in figure 11 is shifted from the expected 34,000 lb to 56,000 lb, far beyond the legal weight limit and operational vehicle characteristics. In addition, both single and tandem axle weight distributions look “stretched” over the x-axis, covering a much wider range of loads than typically observed for these types of distributions.

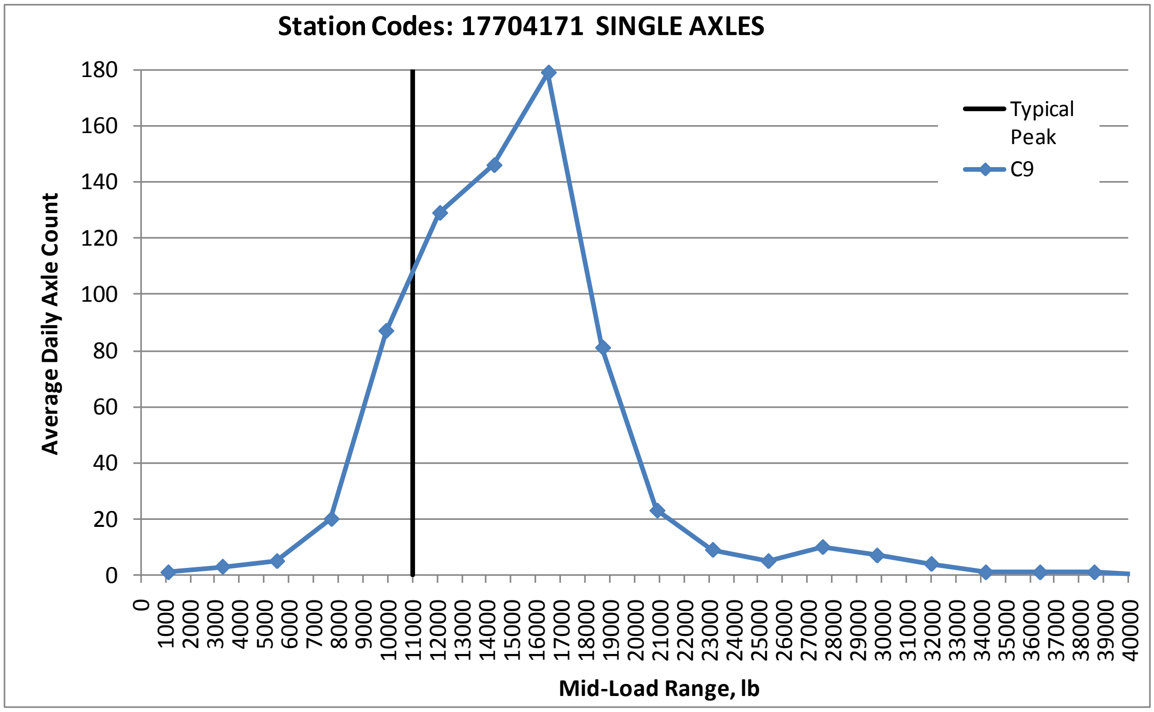


FIGURE 10
Class 9 single axle load spectra example (Over-Calibration)

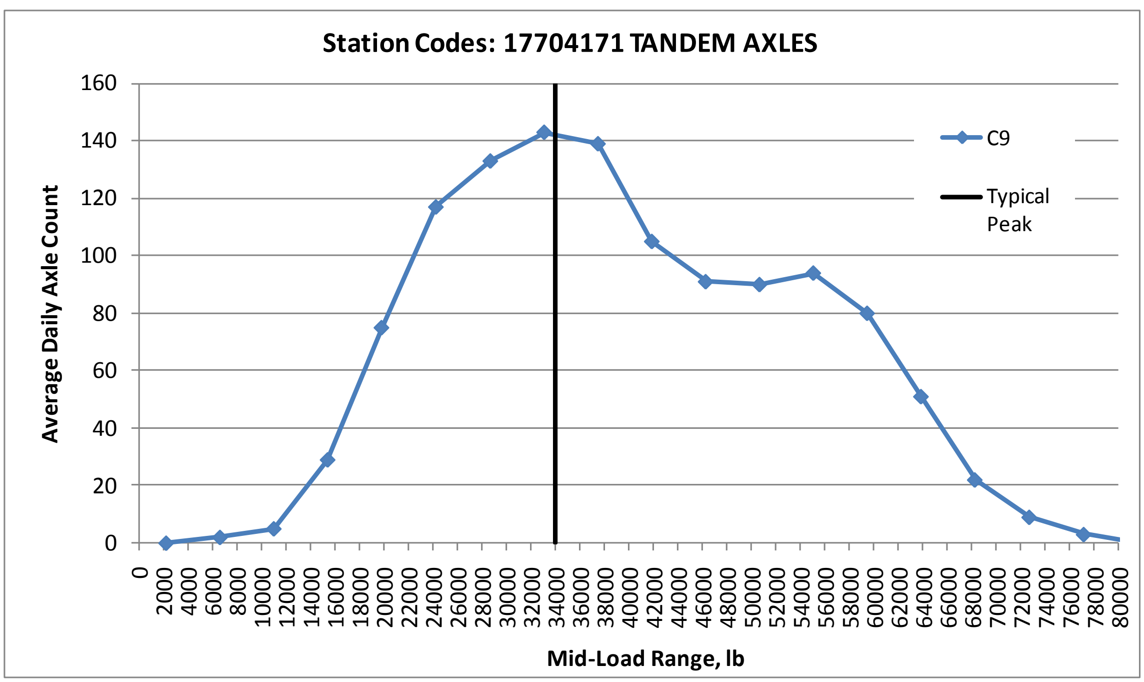


FIGURE 11
Class 9 tandem axle load spectra example (Over-Calibration)

Examples of load spectra with under-predicted weights for Class 9 trucks are shown in figures 12 and 13. These data were collected using portable WIM on a low truck volume road (SR-280 between Cooper Lake Rd CR-1892 & King Spring Rd CR-1891) with ADTT of 350 during the observed data collection period. The single axle plot in figure 12 shows the characteristic shape of Class 9 axle load distributions but with a significant shift to the left along the x-axis, to 4,000 lb. The tandem axle plot in figure 13 shows an atypical shape of Class 9 axle load distributions—a bi-modal shape with unloaded and loaded peaks is expected. The tandem axle distribution also show a significant shift to the left along the x-axis, with a peak around 16,000 lb, much lower than the legal weight limit.

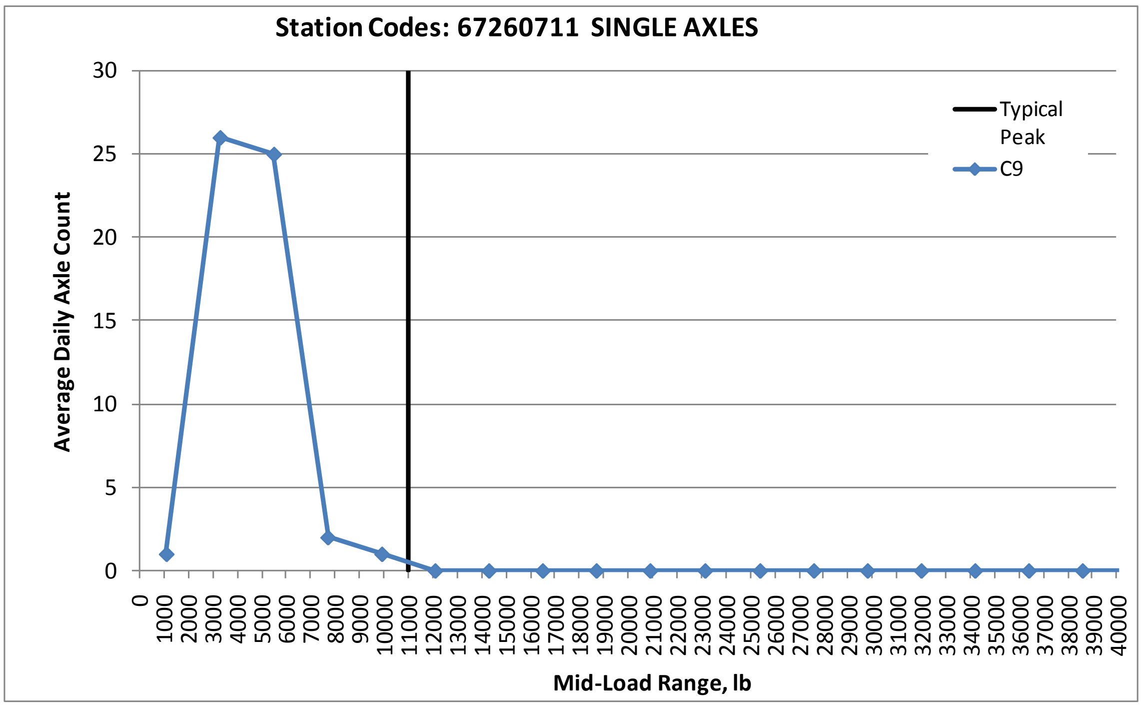


FIGURE 12
Class 9 single axle load spectra example (Under-Calibration)

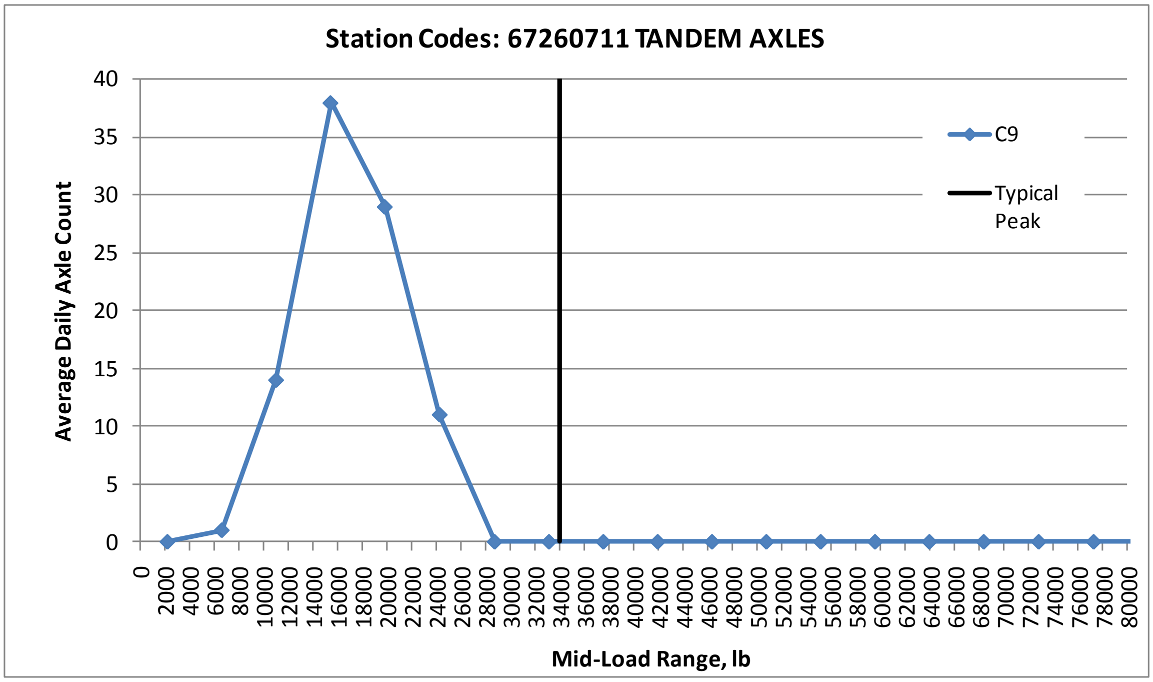


FIGURE 13
Class 9 tandem axle load spectra example (Under-Calibration)

3. If the initial assessment does not indicate anomalies in axle load distribution (i.e., the expected Class 9 tandem shape is observed, as outlined in step 2), assume that WIM equipment collects data without significant bias. As a result of the lower precision of the portable WIM, however, the percentages of very heavy loads may be overestimated. In other words, axle load spectra developed based on portable Type II WIM data tend to have a shape similar to load spectra developed based on Type I WIM data but with heavier tails of distribution and lower peaks. Table 15 is used to assign loading category for the site based on the percentage of heavy loads computed for the Class 9 tandem NALS.

TABLE 15
Percentages of heavy tandem axle loads for different loading categories (for portable WIM data only)

Loading Category	% Heavy Loads (>26,000 lb)
Light – L	<20
Moderate – M	20-40
Heavy 1 – H1	40-50
Heavy 2 – H2	50-60
Very heavy 1 – VH1	60-80
Very heavy 2 – VH2	>80

The labels used to describe loading categories in table 15 are consistent with the labels used by the LTPP study that led to development of the new LTPP MEPDG loading defaults. However, because a wider spread of load distributions due to the lower precision of portable WIM devices was observed in GDOT's portable WIM data, compared to the LTPP WIM data from continuously operated and well calibrated permanent WIM systems, the values in table 15 were increased by 5 to 10 percent to account for consistent differences in load distributions observed between the permanent (both LTPP and GDOT) and portable WIM data. If GDOT implements procedures for calibrating portable WIM systems based on loaded axles, values in table 15 may be changed in the future to be more closely aligned with values used in the LTPP study.

Data that passed this check can be used as a short-term solution for MEPDG Level 1 inputs in the absence of data from permanent WIM sites; however, pavement designers should be aware that accuracy of portable WIM systems is limited and 48-hour sample may not be representative of loading condition observed at a site over long period of time.

4. If initial assessment indicates that axle load distribution does not have expected attributes, two outcomes are possible:
    a. Site location represents unusual loading conditions due to local or regional commodities. In this case, obtain information from the freight/planning office about the nature of truck movements at the site and document this information. If loading condition information is warranted and weights are representative of freight being moved, these data may be used as site- or segment-specific NALS, as a short-term solution in the absence of data from permanent WIM sites. Use table 15 to assign the loading category. These NALS should not be used to develop the default NALS.
    b. WIM equipment set-up, sampling duration, and/or site conditions resulted in an axle load spectrum of limited quality. In this case, check if the tandem axle load spectrum at least has the expected "camel-back" shape with two peaks corresponding to light and heavy loads (see step 2).
        i. If the distribution has the expected shape, proceed with identification of loading category based on the analysis of the ratio between unloaded and loaded peaks of tandem axle distribution: find the percentage of axle loads that correspond to unloaded (generally for loads less than 26,000 lb) and loaded (generally for loads greater than 26,000 lb) peaks and compute load ratio (unloaded peak percentage/loaded peak load percentage). Use table 16 to find loading category for computed load ratio.

TABLE 16
Unloaded to loaded peak ratios in tandem axle load distributions for different loading categories

Loading Category	Load ratio (Unloaded Peak/Loaded Peak)
Moderate – M	1.3-2.7
Heavy 1 – H1	0.8-1.3
Heavy 2 – H2	0.4-0.8
Very heavy 1 – VH1	0.4-0.1
Very heavy 2 – VH2	<0.1

ii. If shape of distribution is unexpected, stop further analysis and label this WIM data set unusable for determination of site loading condition. These NALS should not be used as site-specific inputs or to generate the default NALS.

4.3.3 Analysis Summary

Procedures outlined in the previous section were used to evaluate the available portable WIM data. Of 107 WIM samples analyzed, 90 (82+ percent) were found usable for assigning truck axle loading category. Among these 90 samples, 37 were used to determine loading category based on the analysis of the percentages of heavy loads. In other words, WIM samples from sites with no apparent WIM calibration issues, as it relates to heavy load measurements. For the rest of the WIM samples, traffic loading categories were determined based on the analysis of unloaded to loaded peak load ratios. Seventeen WIM samples were found to be unusable based on either limited data quantity or atypical/unexplained axle load distributions for Class 9 vehicles.

Using the NALS for Class 9 trucks and loading categories described in tables 15 and 16, loading conditions were identified for 90 portable WIM samples. Table 17 summarizes the loading categories observed based on the analysis of portable WIM data samples.

TABLE 17
Summary of loading categories based on analysis of portable WIM data samples

Loading Category	Number of WIM samples
Light	2
Moderate	31
Heavy 1	35
Heavy 2	20
Very Heavy 1	2
Total	90

The most frequently observed loading category on Georgia roads is “Heavy 1,” followed by “Moderate” and “Heavy 2” conditions. These categories were also identified as the most frequently observed in the national LTPP SPS TPF study. The LTPP study recommends the LTPP “Heavy 1” category as the new MEPDG loading default for roads with unknown loading conditions. This recommendation seems to be applicable to Georgia roads based on information presented in table 4.

The number of Georgia WIM sites in the "Very Heavy" or "Light" category for Class 9 vehicles was very low—two sites each. Figure 14 shows examples of the average NALS for Class 9 tandem computed using Georgia portable WIM data for the axle loading categories presented in Table 16. NALS labeled as "SP" in figure 14 represent special or atypical cases that are based on a limited number of sites. These distributions are not recommended for direct MEPDG use. For example, the "Light" category has a lot more overloaded axles than does the "Very Heavy" category. These overloads are critical, and the difference in predicted distresses between the "Light" and "Very Heavy" categories will be much less than expected.

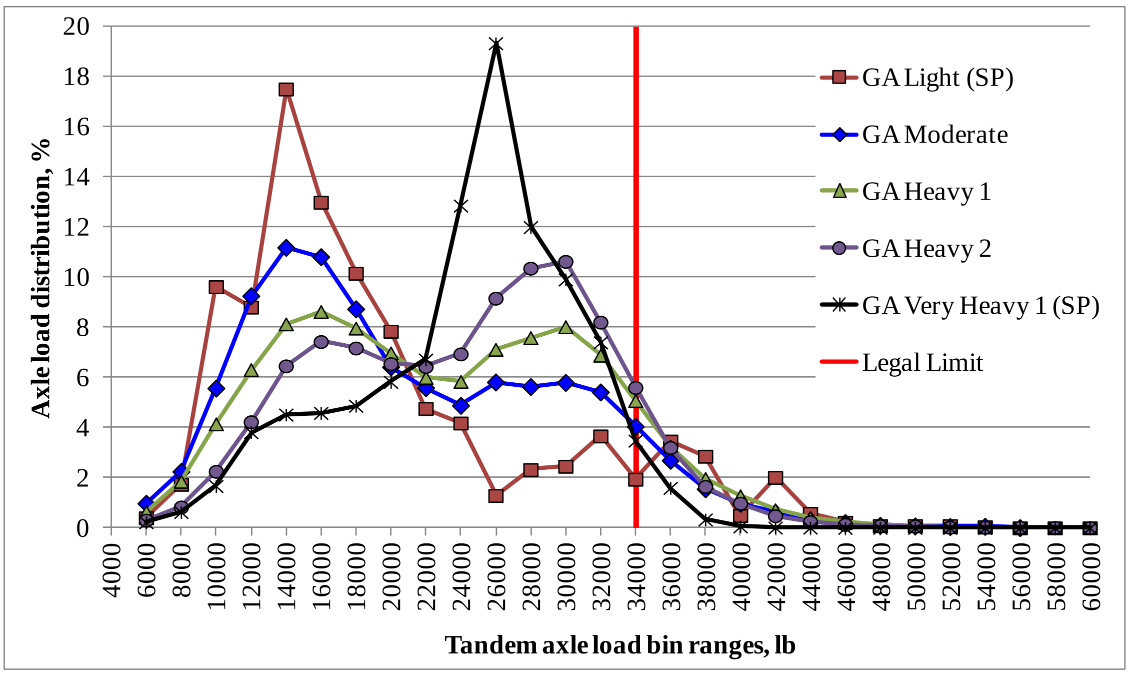


FIGURE 14
NALS for Class 9 tandems based on GDOT's portable WIM data

4.3.4 Disclaimer

As a result of the lower precision of the portable WIM measurements, the values used to evaluate percentages of heavy loads for determination of loading conditions were adjusted from LTPP recommended percentages to account for "stretched" axle load distributions that had lower peaks and heavier tails compared to distributions that would have been developed based on data from WIM system with higher precision, creating some subjectivity in these assignments. As GDOT improves the precision of WIM measurements, either through the use of heavy loaded calibration trucks or by installing Type I WIM systems, the values used to define percentages of loads corresponding to different loading conditions should be revised.

4.3.5 Conclusions from Portable WIM Data Assessment

The following conclusions can be drawn from this initial assessment of the portable WIM data:

- Overall, portable data could be used as a valuable source of information on expected loading patterns. However, most of these data would provide descriptive rather than quantitative information about expected loading patterns, due to the limitation of equipment accuracy and challenges with field calibration of the portable WIM system.
- Portable WIM data samples collected over 48-hour sampling period for the sites with high Class 9 volume are more likely to have data that closely resemble the true axle load distribution than data for sites with low Class 9 volume.
- Portable WIM generates higher-than-expected percentages of overloaded Class 9 vehicles. This is more likely attributable to the limited accuracy of portable WIM devices than to true traffic loading characteristics. High overloads are not supported by the data from GDOT's permanent WIM sites. NALS based on these data would result in overdesign of pavement structures.
- The NALS from portable WIM equipment were found to be similar to, but less accurate than, the NALS obtained from the permanently installed WIM equipment. Further, they were found to be somewhat similar to those generated under the NCHRP 1-37A study that used to develop the global NALS in the earlier versions of the MEPDG software.
- Due to limited information about portable WIM data quality and considering accuracy limitations associated with portable WIM devices, analyst's judgment is required for interpreting portable WIM data. The procedure presented in this section could be used to limit subjectivity in interpreting portable WIM data. For low truck volume roads, a 48-hour sample was found to be insufficient to construct an axle load spectrum. It is recommended that a week-long sample should be collected for the roads that have less than 100 Class 9 vehicles per day. This recommendation is supported by the FHWA Traffic Monitoring Guide.
- NALS developed based on portable WIM equipment could be useful in identifying overall traffic loading condition. This information could aid in selecting NALS defaults that best describe the identified loading condition. It is not recommended, however, that portable WIM data be used to generate truck traffic Level 1 MEPDG inputs or to compute default NALS. Once locally calibrated MEPDG pavement performance models are available, sensitivity study is recommended to evaluate the impact of using portable WIM data vs. permanent WIM data as a source for determining input Level 1 values.

4.4 ASSESSMENT OF WIM DATA FOR LTPP SITES LOCATED IN GEORGIA

The LTPP truck traffic data was assessed to determine if historical WIM data for Georgia LTPP sites could be used to develop axle load spectra for MEPDG sensitivity analysis of designs specific to Georgia conditions and if these data could be used to develop axle loading defaults for Georgia. The results of this assessment are presented in the following sections.

4.4.1 WIM Data for Sites in Georgia

The LTPP database includes historical WIM data for eight sites in Georgia. Sites with loading data are shown in table 18.

TABLE 18
Summary of Georgia LTPP WIM sites locations

State Code	SHRP ID	County	Functional Class	Route Type	Route No	Location Info
13	1001	Walton	Rural Principal Arterial - Other	State Route	10	Test section begins approx 1.79 miles west of W. Abutment, Alcovy River Bridge, 475 ft west of Sardis Church Rd. and ends approx 435 ft east of Tipperary Ct. STA 896- STA 891.
13	1004	Spalding	Rural Minor Arterial	State Route	16	STA 328 +50 - 323 +50. Approx. 4.9 miles east of Griffin WBL. 1200' west of High Falls Rd. Mile post (MP) estimated from map.
13	3017	Taliaferro	Rural Principal Arterial - Interstate	Interstate	20	STA 726+00 - 731+00.
13	3018	Warren	Rural Principal Arterial - Interstate	Interstate	20	STA 273-278 imprinted in concrete. Begins approx. 4.44 mi east of SR12 & 6.27 mi east of Taliaferro/Warren County line.
13	3020	Crisp	Rural Principal Arterial - Other	State Route	300	STA 550-545 MP 9.9 estimated, assuming that MP 0 is at Worth/Crisp County line.
13	4111	Oconee	Rural Major Collector	U. S. Route	78	Begins at the Walton County line to SR-8.
13	4118	Monroe	Rural Principal Arterial - Interstate	Interstate	401	Test section begins at STA 693+20+/-; STA 695 is imprinted at the edge of pavement, approx. 2.76 miles north of Rumble road and 0.9 miles north of I-475.
13	7028	Franklin	Rural Principal Arterial - Interstate	Interstate	85	Approx. 7.17 mi north of Banks-Franklin County line and 1.9 mi north of rest area.

4.4.2 Analysis Summary

All historical data were collected between 1993 and 1998. No information about the WIM technology used or WIM equipment calibration status was found in the LTPP database. Based on the number of days for which data were available, it was estimated that, at five of the sites, data were collected using portable WIM devices, and at three of the sites, data were collected using permanent WIM devices, most likely with piezo ceramic sensors (based on input from GDOT's traffic monitoring personnel). A summary of data availability is shown in table 19.

TABLE 19
Summary of WIM data availability for LTPP Georgia sites

State Code	SHRP ID	1993	1994	1995	1996	1997	1998
13	1001				3		
13	1004			1			
13	3017				255		169
13	3018				163		
13	3020		277	236	1		
13	4111		1				
13	4118	3	5		13		
13	7028				10		

Under NCHRP Project 1-37A, in which the MEPDG was developed, minimum data availability criteria were defined for developing the MEPDG traffic loading default values. These criteria include:

- The availability of not less than 1 week day and 1 weekend of WIM data per quarter, preferably 1 week per quarter, as a minimum.
- Availability of this amount of data for at least 2 years in a 5-year period.

Based on historical data availability assessment, only two of eight Georgia LTPP sites satisfy these criteria.

In addition to assessing data availability, data quality and reasonableness were evaluated. All available axle loading data for Georgia sites were extracted from the LTPP database and reviewed. Since no documentation was available through LTPP on the accuracy of WIM systems used to collect historical data, the basis for assessment was an evaluation of single and tandem axle load distributions for Class 9 vehicles. These distributions were chosen because Class 9 distributions have well known and understood characteristics. The following checks were used in the assessment of axle load distribution reasonableness:

Class 9 Single Axles:

- Distribution should have one clearly primary peak within a range bounded by 11,000 lb +/-2,000 lb.
- Secondary heavy loaded peak between 16,000 lb and 22,000 lb is acceptable (split tandem classified as 2 singles).

Class 9 Tandem Axles:

- Distributions can exhibit the two typical peaks (camel-back distribution) corresponding to lightly loaded (or empty semitrailer) and heavily loaded axles. Peaks do not have to be similar in size. However, distributions can have no clearly defined either light or heavy peaks. These sites apply to road segments where there are known reasons why all Class 9 vehicles are either fully loaded or empty.
- The peak load bin for loaded axles should be within a range bounded by 30,000 lb ± 4,000 lb.

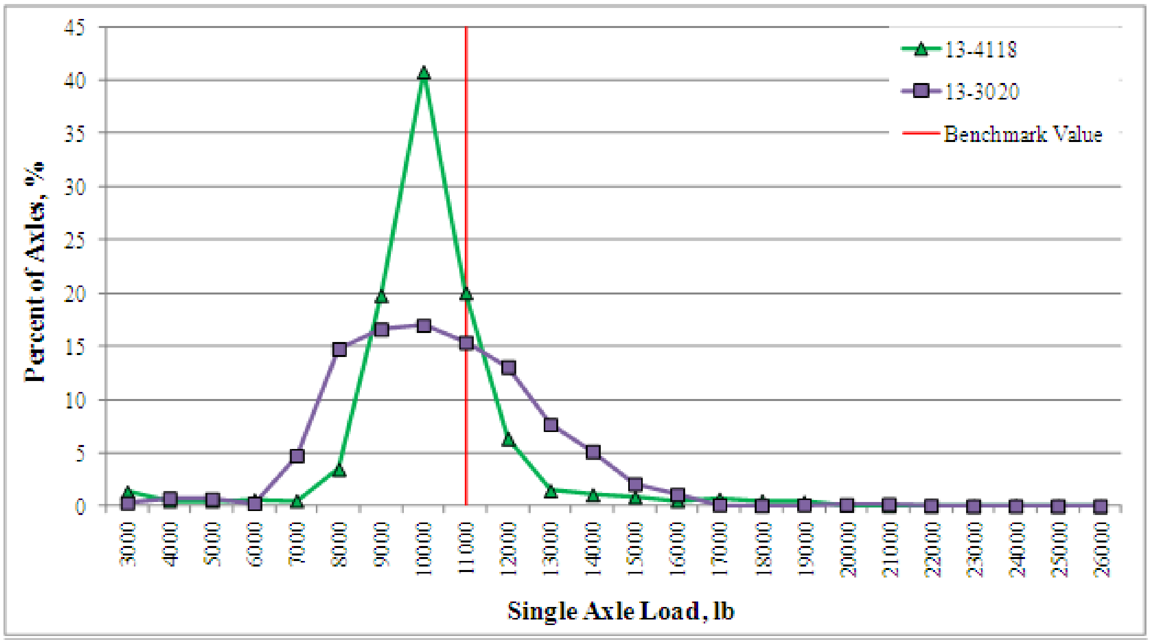
- The peak load bin for unloaded or partially loaded axles should be greater than 8,000 lb and less than 26,000 lb.

These ranges were established based on an analysis of peak loads for LTPP WIM sites included in development of the new LTPP traffic loading defaults. Based on the above checks, only two of eight sites (13-4118 and 13-3020) were found to have the expected axle weight distribution for Class 9 vehicles.

The first site is 13-4118 in Monroe County, located on State Route 401, which is a shared name with I-75 at the LTPP site location. These data were collected using portable equipment over short periods of time spanning several years. Because the availability of the good quality data for this site was limited to 7 days over a 2-year period, these data are insufficient for developing the loading defaults. Moreover, GDOT has a new WIM site on I-75 in Monroe County that provides high-quality continuous data that will be used for defaults and can be used for LTPP site 13-4118.

The second LTPP site is 13-3020 in Crisp County, located on State Route 300, Georgia-Florida Parkway. This site has about 2 years of data, but loading trends show a lot of variation between days and months. A similar observation was found from the data analysis completed under NCHRP Project 1-37A, which was largely based on analysis of the data collected using piezo electric sensors from the 1980s and 1990s. The nature of the shifts in load spectra is indicative of temperature-sensitive sensor output. As a result, only a small amount of data from that site had the loading characteristics expected for Class 9 trucks. Because of questionable data quality, data from this site were excluded from the development of the Georgia loading defaults; however, Level 1 MEPDG inputs were developed based on a limited subset of data for the site to use for sensitivity analysis of axle loading inputs. This subset has larger-than-expected percentages of overloaded axles for Class 9 vehicles, compared to Class 9 data from the national data sample.

Examples of axle load spectra for these two sites are shown in figure 15. The spread-out shape of axle load distributions for LTPP site 13-3020 can indicate unstable WIM sensor output, as high variability in axle weights of Class 9 single axle loads is not expected or can be explained based on truck type information. A summary on the data assessment of historical data for the eight LTPP WIM sites is presented in table 20.



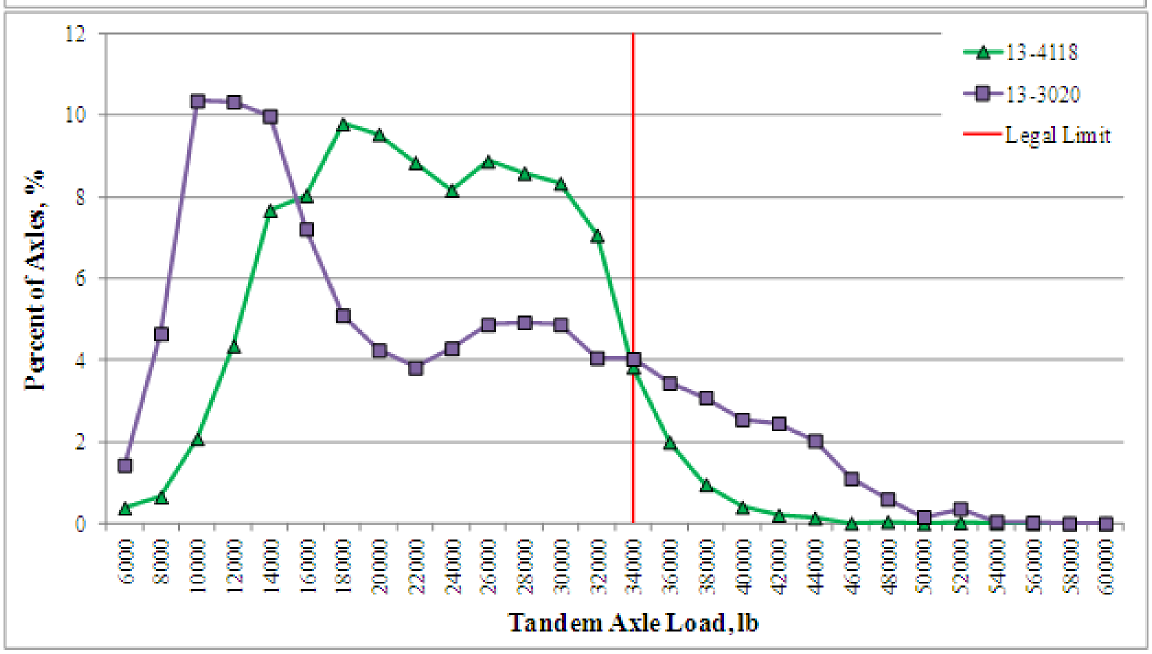


FIGURE 15
MEPDG Level 1 axle load spectra for Class 9 vehicles for Georgia LTPP sites

TABLE 20
Data assessment summary for Georgia LTPP sites

State Code	SHRP ID	Year	Class 9 Single Axle Assessment Note	Class 9 Tandem Axle Assessment Note	Use for MEPDG? (Y/N)	Use for Defaults? (Y/N)
13	1001	1996	Only first 3 bins have data resulting in atypical load distribution, insufficient data, or misclassification issue.	Only first 3 bins have data resulting in atypical load distribution, insufficient data, or misclassification issue	N	N
13	1004	1995	Only bins 3 and 4 have data resulting in atypical load distribution, insufficient data, or misclassification	Only bin 8 has data resulting in atypical load distribution, insufficient data, or misclassification	N	N
13	3017	1996	Distribution is atypical for Class 9 single: peaks have unexpected load ranges, and shape of distribution is stretched. This could be indicative of significant calibration drifts over time.	Distribution stretched over 80,000 lb and unrealistic for tandem axle loads, possible unit conversion problem or significant calibration drifts over time.	N*	N
13	3017	1998	Distribution is atypical for Class 9 single: peaks have unexpected load ranges, and shape of distribution is stretched. This could be indicative of significant calibration drifts over time.	Distribution stretched over 80,000 lb and unrealistic for tandem axle loads, possible unit conversion problem or significant calibration drifts over time.	N*	N
13	3018	1996	Distribution is atypical for Class 9 single: peaks have unexpected load ranges, and shape of distribution is stretched. This could be indicative of significant calibration drifts over time.	Distribution stretched over 80,000 lb and unrealistic for tandem axle loads, possible unit conversion problem or significant calibration drifts over time.	N*	N
13	3020	1994	Distribution is atypical for Class 9 single: peaks have unexpected load ranges, and shape of distribution is unexpected, most likely due to temperature-sensitive outputs from WIM sensor. Only March data had expected distribution.	Only March data was used. Distribution has classical unloaded shape but stretched into overloads; peak that usually corresponds to legal limit is shifted into overloads. Possible calibration issue or temperature-sensitive sensor output.	N*	N*
13	3020	1995	Distribution is atypical for Class 9 single: peaks have unexpected load ranges, and shape of distribution is unexpected, most likely due to temperature-sensitive outputs from WIM sensor.	Distribution has classical unloaded shape but stretched into overloads –peak that usually corresponds to legal limit is shifted into overloads. Possible calibration issue or temperature-sensitive sensor output.	N*	N*

State Code	SHRP ID	Year	Class 9 Single Axle Assessment Note	Class 9 Tandem Axle Assessment Note	Use for MEPDG? (Y/N)	Use for Defaults? (Y/N)
13	3020	1996	Only 1 bin has data resulting in atypical load distribution, insufficient data, or misclassification	Only bins 6 and 7 have data resulting in atypical load distribution, insufficient data, or misclassification.	N	N
13	4111	1994	Only bins 8 and 10 have data resulting in atypical load distribution, insufficient data, or misclassification	Only bins 2-4 have data resulting in atypical load distribution, insufficient data, or misclassification.	N	N
13	4118	1993	Expected loading distribution for Dec 93-Jan 94 data cycle.	Balanced loading distribution, no clear separation between loaded and unloaded peaks for Dec 93-Jan 94 data cycle.	Y	N
13	4118	1994	Strong calibration shift (under-calibration is a likely cause) during Mar 94-Apr 94 data cycle	Strong calibration shift (under-calibration is a likely cause) during Mar 94-Apr-94 data cycle.	N	N
13	4118	1996	Extreme volumes in the first bin resulting in atypical load distribution, likely misclassification or wrong equipment set-up.	Extreme volumes in the first bin resulting in atypical load distribution, likely misclassification or wrong equipment set-up.	N	N
13	7028	1996	Extreme volumes in the first bin resulting in atypical load distribution, likely misclassification or wrong equipment set-up.	Extreme volumes in the first bin resulting in atypical load distribution, likely misclassification or wrong equipment set-up.	N	N
Note: *These sites and their data use will be discussed with GDOT personnel in deciding whether to use the sites. In all probability, these data exhibit errors or have calibration issues with the equipment.						

1.4.3 Conclusions from WIM Data Assessment of LTPP Georgia Sites

1. Based on historical LTPP WIM data availability assessment, only two of eight Georgia LTPP sites satisfy MEPDG input Level 1 data availability criteria.
2. Since no documentation was available through LTPP on the accuracy of WIM systems used to collect data for Georgia LTPP sites, the basis for assessment was an evaluation of single and tandem axle load distributions for Class 9 vehicles. No LTPP Georgia sites passed the criteria outlined in this report.
3. Historical WIM data collected at Georgia LTPP sites is not recommended for local calibration or development of the defaults due to lack of data quality documentation and unusual axle load distributions observed for these data when compared to national defaults or recent Georgia portable and permanent WIM data.

4.5 ANALYSIS OF GDOT's VEHICLE CLASSIFICATION DATA

4.5.1 Purpose of the Analysis

The purpose of this analysis was to evaluate characteristics of vehicle Class distribution (VCD) specific for different Georgia roads (functional classes). The analysis focused on FHWA vehicle classes 4-13 that play important role in pavement design.

The analysis was based on data from GDOT's permanent AVC sites. VCDs were computed for each site and evaluated against default MEPDG Truck Traffic Classification (TTC) groups. As a result of this analysis, each of the AVC sites was categorized by MEPDG TTC.

4.5.2 Analysis Data Set

This analysis was based on 2010 vehicle classification data provided by GDOT. Data from 195 sites (or 390 directional sites) were analyzed. Daily truck volume data were used to compute average annual daily truck traffic (AADTT) values by vehicle Class for each site using the AASHTO AADT procedure. Using AADTT by Class values, normalized annual VCDs were created for 390 directional sites (i.e., all lanes in the same direction combined).

4.5.3 Observations from Georgia Vehicle Class Distributions

From the normalized annual VCDs observed for Georgia sites, the following observations were made:

- Class 9 is the dominant heavy truck type observed on Georgia roads. This is the primary reason the NALS for Class 9 trucks was used in explaining and illustrating the analysis of the WIM data.
- A vast majority of the sites had a very low percentage of multi-unit trucks (classes 11-13).
- The VCDs show a very low presence of Class 7 vehicles in Georgia (less than 0.5 %).

4.5.4 TTC Analysis for MEPDG

All sites with classification data were analyzed to find the best matching MEPDG TTC. To conduct this analysis, computed NVCDs were compared with MEPDG defaults distributions developed for 17 TTC groups. Table 21 shows NVCDs and descriptions for the MEPDG default truck traffic classifications. Table 22 shows the criteria used to assign TTCs for all the Georgia sites.

The following observations were made based on TTC analysis:

- There were no sites assigned to TTC groups 3, 5, 7, 8, 10, 11, 13, and 16.
- Most Rural Interstates were assigned to TTC 1.
- Most Urban Interstates were assigned to TTC 4.
- Most Rural Other Principal Arterials were distributed almost equally between TTC 2, 4, 6, and 9.
- Most Urban Other Principal Arterials and Minor Arterials were assigned to TTC 14.
- Site 311-0198 eastbound was the only site that could not be classified under any of the available TTC groups. This could be caused by cross classification between classes 5 and 8 creating unusually high volumes of Class 8 trucks.

TABLE 21
MEPDG TTC defaults

TTC Group	TTC Description	Vehicle/Truck Class Distribution (percent)									
		4	5	6	7	8	9	10	11	12	13
1	Major single-trailer truck route (Type I)	1.3	8.5	2.8	0.3	7.6	74	1.2	3.4	0.6	0.3
2	Major single-trailer truck route (Type II)	2.4	14.1	4.5	0.7	7.9	66.3	1.4	2.2	0.3	0.2
3	Major single- and multi- trailer Truck route (Type I)	0.9	11.6	3.6	0.2	6.7	62	4.8	2.6	1.4	6.2
4	Major single-trailer truck route (Type III)	2.4	22.7	5.7	1.4	8.1	55.5	1.7	2.2	0.2	0.4
5	Major single- and multi- trailer Truck route (Type II)	0.9	14.2	3.5	0.6	6.9	54	5	2.7	1.2	11
6	Intermediate light and single-trailer Truck route (I)	2.8	31	7.3	0.8	9.3	44.8	2.3	1	0.4	0.3
7	Major mixed truck route (Type I)	1	23.8	4.2	0.5	10.2	42.2	5.8	2.6	1.3	8.4
8	Major multi-trailer truck route (Type I)	1.7	19.3	4.6	0.9	6.7	44.8	6	2.6	1.6	11.8
9	Intermediate light and single-trailer Truck route (II)	3.3	34	11.7	1.6	9.9	36.2	1	1.8	0.2	0.3
10	Major mixed truck route (Type II)	0.8	30.8	6.9	0.1	7.8	37.5	3.7	1.2	4.5	6.7
11	Major multi-trailer truck route (Type II)	1.8	24.6	7.6	0.5	5	31.3	9.8	0.8	3.3	15.3
12	Intermediate light and single-trailer Truck route (III)	3.9	40.8	11.7	1.5	12.2	25	2.7	0.6	0.3	1.3
13	Major mixed truck route (Type III)	0.8	33.6	6.2	0.1	7.9	26	10.5	1.4	3.2	10.3
14	Major light truck route (Type I)	2.9	56.9	10.4	3.7	9.2	15.3	0.6	0.3	0.4	0.3
15	Major light truck route (Type II)	1.8	56.5	8.5	1.8	6.2	14.1	5.4	0	0	5.7
16	Major light and multi-trailer truck route	1.3	48.4	10.8	1.9	6.7	13.4	4.3	0.5	0.1	12.6
17	Major bus route	36.2	14.6	13.4	0.5	14.6	17.8	0.5	0.8	0.1	1.5

TABLE 22
TTC criteria

TTC Group	TTC Description	Percent of AADTT			
		Class 9	Class 5	Class 13	Class 4
1	Major single-trailer truck route (Type I)	> 70	< 15	< 3	-
2	Major single-trailer truck route (Type II)	60 - 70	< 25	< 3	-
3	Major single- and multi- trailer Truck route (Type I)	60 - 70	5 - 30	3 - 12	-
4	Major single-trailer truck route (Type III)	50 - 60	8 - 30	0 - 7.5	-
5	Major single- and multi- trailer Truck route (Type II)	50 - 60	8 - 30	> 7.5	-
6	Intermediate light and single-trailer Truck route (I)	40 - 50	15 – 40	< 6	-
7	Major mixed truck route (Type I)	40 - 50	15 – 35	6 - 11	-
8	Major multi-trailer truck route (Type I)	40 - 50	9 - 25	> 11	-
9	Intermediate light and single-trailer Truck route (II)	30 - 40	20 - 45	< 3	-
10	Major mixed truck route (Type II)	30 - 40	25 - 40	3 - 8	-
11	Major multi-trailer truck route (Type II)	30 - 40	20 - 45	> 8	-
12	Intermediate light and single-trailer Truck route (III)	20 - 30	25 - 50	0 - 8	-
13	Major mixed truck route (Type III)	20 - 30	30 - 40	> 8	-
14	Major light truck route (Type I)	< 20	40 - 70	< 3	-
15	Major light truck route (Type II)	< 20	45 - 65	3 - 7	-
16	Major light and multi-trailer truck route	< 20	50 - 55	> 7	-
17	Major bus route	-	-	-	< 35

Table 23 shows the distribution of Georgia sites by TTC and functional class.

TABLE 23
Distribution of Georgia sites by TTC and functional class

Functional Class	Truck Traffic Classification Group (TTC)							
	1	2	4	6	9	12	14	Unassigned
1	37	16	7	2				
2	3	11	9	11	10	1	5	
6	6	5	5	11	5	5	13	
7			2	3	1	5	6	1
11	5	19	35	15		17	11	
12		1	1	2	2	6	2	
14			2	6	10	6	36	
16						1	31	
17			1	1				

4.5.5 Conclusion

Based on analysis of GDOT's vehicle classification data, it can be concluded that truck compositions on Georgia roads could be represented by MEPDG TTCs 1, 2, 4, 6, 9, 12, and 14. For TTC 9, the Georgia data indicate fewer Class 6 vehicles than the MEPDG default. It is recommended that the Georgia NVCD values be used for TTC 9.

Not all default MEPDG TTCs were observed in Georgia, which has been a finding by many other agencies that have completed some type of traffic volume study in comparison to the TTC groups. There were no sites assigned to TTC groups 3, 5, 7, 8, 10, 11, 13, and 16. These TTCs require a significant presence of multi-trailer trucks (FHWA classes 11, 12, 13) in the traffic stream. These TTCs are not recommended for use in Georgia, unless future Georgia vehicle classification data show the presence of multi-trailer trucks. If there are localized areas in Georgia where these TTCs apply, they should be identified by GDOT traffic data collectors.

Based on this vehicle classification data assessment, there are two viable options for GDOT's MEPDG implementation with regard to vehicle classification data:

- Option #1: Continue with the current practice of conducting site-specific vehicle classification counts and development of Level 1 MEPDG NVCD inputs. This would assure that limitations with site-specific axle weight data are minimized by using highly accurate truck volume by Class data.
- Option #2: Assign MEPDG TTCs to all roadways and use defaults from the MEPDG for routine design utilizing MEPDG software. Because GDOT NVCDs for different TTCs match very closely with MEPDG default TTCs, MEPDG defaults can be considered Level 2 inputs for Georgia.

Option #1 is recommended for future use in pavement design, especially because of the limited availability of site-specific axle weight data.

CHAPTER 5 – ANALYSIS OF TRAFFIC LOADING CONDITIONS OBSERVED ON GEORGIA ROADS

Understanding of traffic loading conditions is important for development of traffic loading defaults for use in pavement design. Several methods were used to develop an understanding of traffic loading conditions on Georgia State roads, including:

- Surveys of GDOT personnel.
- Review of freight analysis results from FHWA studies.
- Assessment of loading conditions from Georgia WIM data.

5.1 SUMMARY OF GDOT SURVEY RESULTS

A survey was developed and distributed to GDOT personnel responsible for:

- Monitoring and analysis of traffic loads transported over Georgia road network,
- Development of traffic inputs for pavement design,
- Analysis of traffic data for planning purposes.

The results of the survey are summarized below.

5.1.1 Heavy Traffic Load Generators

Several areas within the State may have different or unique truck traffic due to industries that are served by these routes. Roads that are likely to be carrying heavier loads than others in the same road functional Class are:

1. Roads affected by truck traffic to and from port facilities near Savannah:
    - I-95, I-20.
    - Intermodal or principal arterial routes along the coastal areas like I-516, I-16, SR-25, and I-95.
2. Timber logging routes in South Georgia (Districts 4 and 5).
3. Roads near industrial distribution on the west side of Atlanta (I-20 at I-285).
4. Roads carrying significant traffic from military bases, but no super heavy trucks expected.
5. SR-21 Spur in Chatham County located in the middle of several distribution plants.

5.1.2 Seasonal Truck Traffic Generators

No significant seasonal truck traffic generators were identified through the survey, with one possible exception: Georgia State Fair in Perry.

5.1.3 Traffic Loading at State Boundaries or State Points of Entry

Several roads located close to Georgia borders were identified as likely to be heavier than others based on types of goods transported to Georgia from other States:

1. Predominantly Interstates
2. Routes in proximity to I-16 and I-95 in Chatham County.
3. I-20 near the Alabama State line

5.2 SUMMARY OF FINDINGS FROM FHWA'S FREIGHT DATA ANALYSIS

5.2.1 FHWA's Freight Analysis Framework Data Assessment

The FHWA's Freight Analysis Framework (FAF) data were obtained and analyzed. These data are gathered through surveys of a sample of the motor carrier industry conducted every 5 years. FAF provides estimates for tonnage and value, by commodity type, mode, origin, and destination. It also provides national and State-level estimates of the total number by type of trucks.

Figures 16 and 17 show FAF3-based (2007) truck flow maps by AADTT in northern and southern Georgia, respectively. This information is useful in identifying routes used for freight movement. As can be seen from the figures, the heaviest truck volumes are carried by interstate roads leading to and from the Atlanta area and I-95 along Georgia's eastern seaboard. For the secondary roads system, higher truck volumes generally are observed close to the urbanized centers.

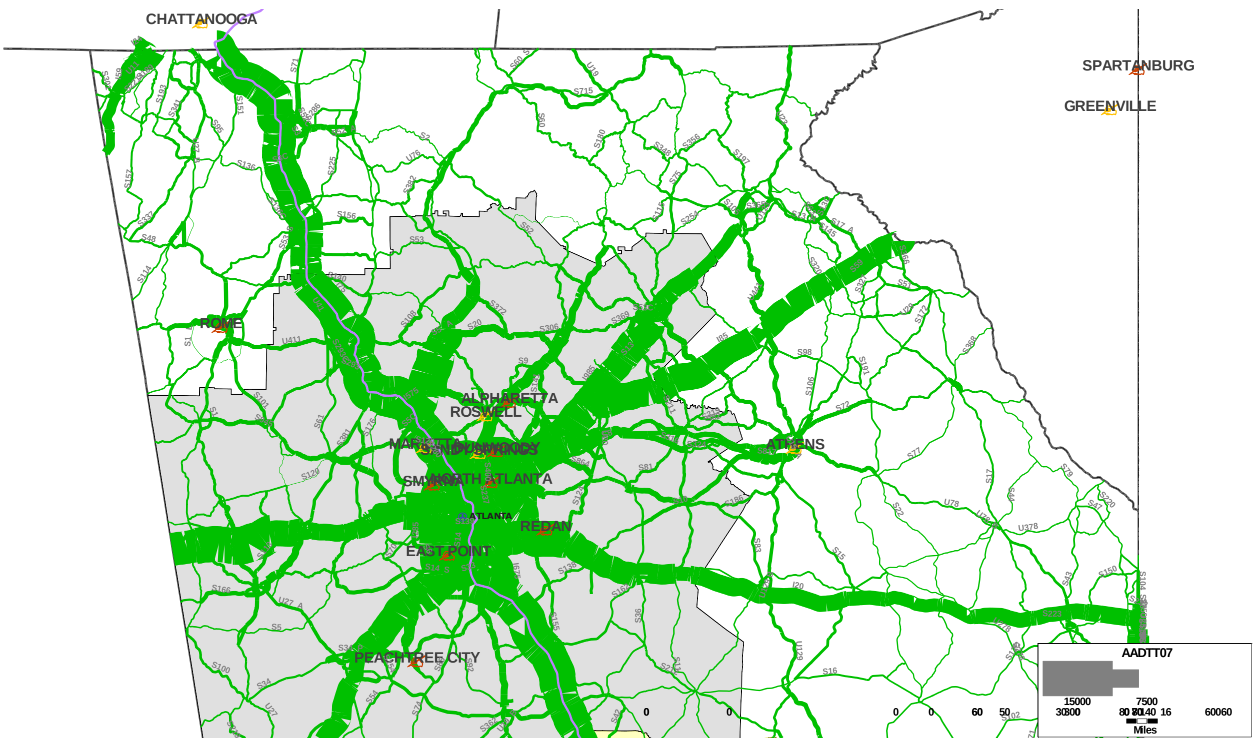


FIGURE 16
FAF3 truck flows, northern Georgia

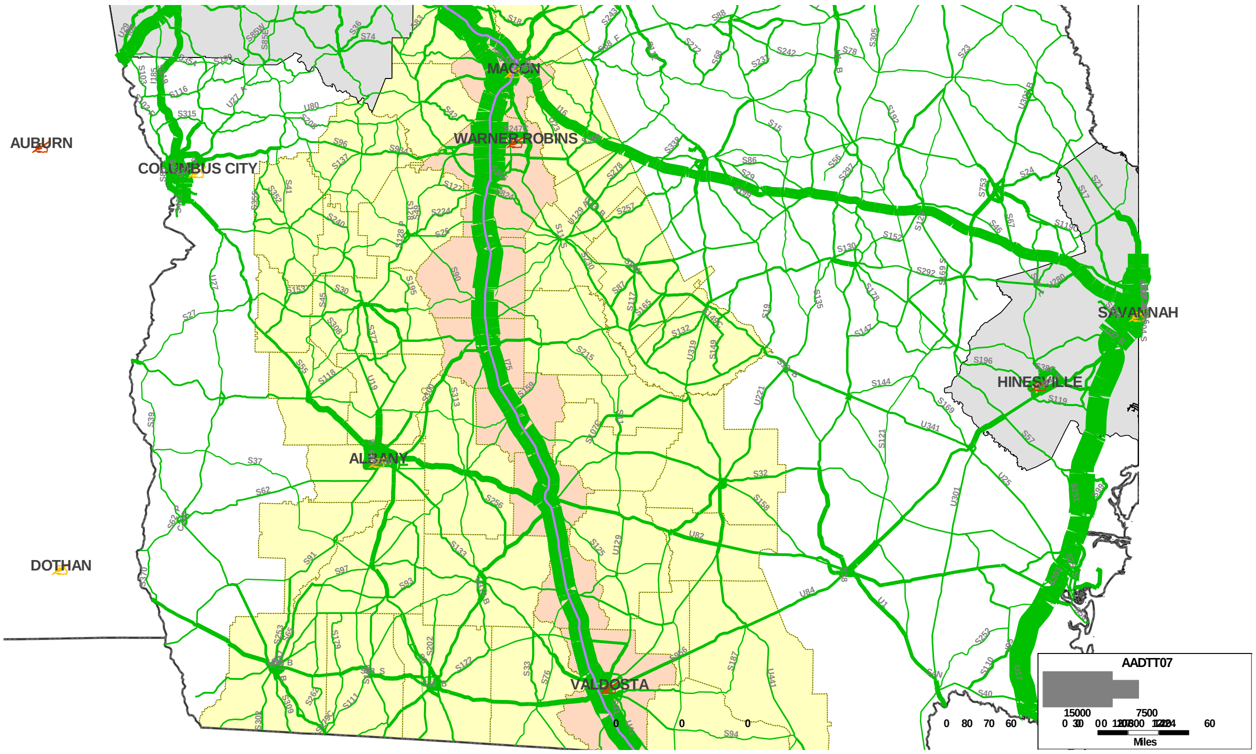


FIGURE 17
FAF3 truck flows, southern Georgia

The limitation of the FAF data is that it is based on limited information from the Vehicle Inventory and Use Survey (VIUS), rather than measured truck weights. Figure 18 is a comparison chart between data used in the analysis based on VIUS and VTRIS (WIM-based) information for Class 9 typical payloads from the 2007 FHWA Report, *Development of Truck Payload Equivalent Factor (TPEF).*[(122)] As can be seen from FIGURE 18, there are significant differences between payloads based on measured data (WIM data) and data obtained from surveys. Therefore, while useful in identifying the routes that are likely to have high truck traffic volume, FAF data is limited in characterizing traffic loading on these roads.

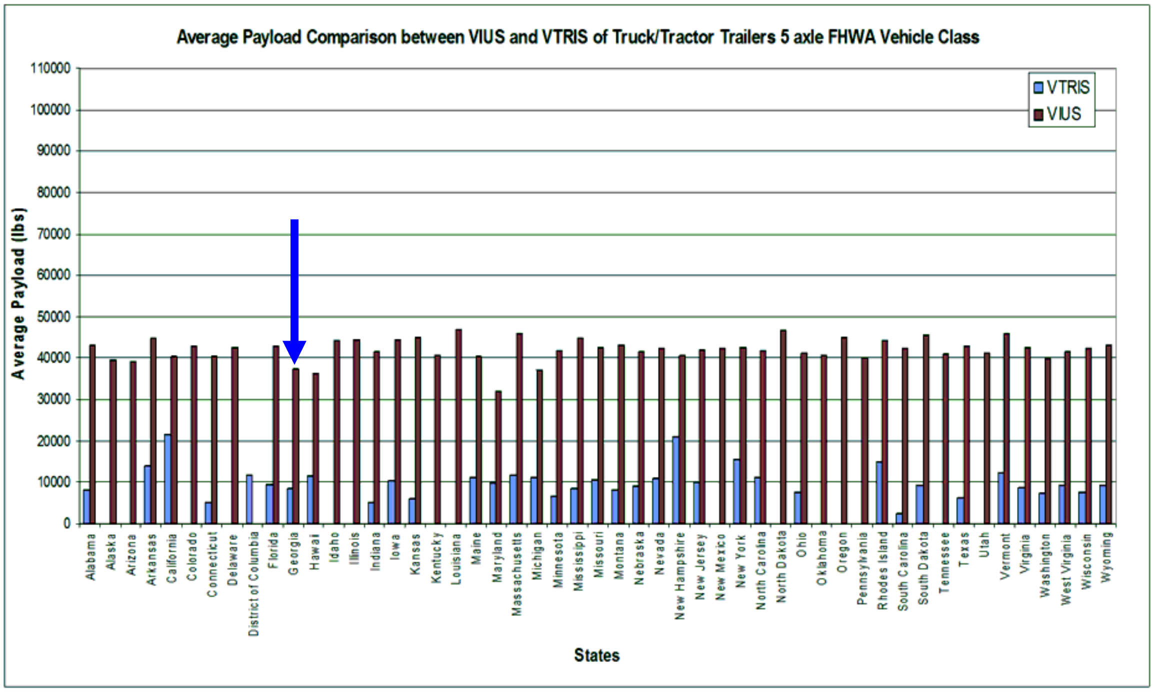


FIGURE 18
Payload comparison based on VIUS and VTRIS[(12)]

5.3 ASSESSMENT OF TRAFFIC LOADING BASED ON GEORGIA WIM DATA

5.3.1 Analysis Approach

Loading conditions identified from permanent and portable WIM data analysis were used to study similarities in loading conditions for different groupings of Georgia roads. The purpose of this analysis was to define characteristics that could be used to identify roads with similar loading conditions.

No information about the nature of freight movement and types of goods being transported by trucks on the specific roads or corridors across Georgia was available at the time of the study. Therefore, the analysis was based on assessing similarities in loading for groups of roads using available road characteristics, such as:

- Road functional class.
- Rural vs. urban location.
- Interstate vs. non-interstate road type.
- Roads in different GDOT districts (representing different geographical regions).
- Roads with different truck volume (FHWA Classes 4 through 13).
- Roads with different percentages of Class 9 trucks.

5.3.2 Data Used for Analysis

Loading condition assignments for 93 WIM samples (90 portable and 3 permanent WIM sites) were used in the analysis. As noted in the previous chapter, most of the 90 portable WIM sites were believed to be inadequate for developing MEPDG NALS defaults. Nonetheless, information from these sites was used in the interim to categorize the loading characteristics of these roadways because it represents the majority of available axle weight data in Georgia. These assignments are based on the loading categories observed for Class 9 trucks, identified as the dominant load carrying trucks in Georgia. Table 24 shows the distribution of WIM samples by loading category when all 93 WIM samples were considered. The loading categories listed in table 24 are based on loading category definitions developed for the new LTPP MEPDG loading defaults.

TABLE 24
Summary of loading categories based on analysis of all WIM data samples

Loading Category	Expected Percentage of Heavily Loaded (>26 kip) Tandem Axles*	Number of Directional Sites
Light	<10	2
Moderate	10-30	31
Heavy 1	30-40	38
Heavy 2	40-50	20
Very Heavy	>50	2
Total		93

* Load ranges are for measurements using Type I WIM systems calibrated using ASTM 1318 performance criteria.

5.3.3 Loading Conditions Observed for Different Road Functional Classes

Distribution of loading categories by road functional Class is shown in table 25. As can be seen, more than one loading condition was observed within each road functional Class (except FC 16, which had a very small sample of two sites only, both in the Moderate category).

TABLE 25
Distribution of loading categories by road functional class

Loading Condition	Functional Class							
	FC 1	FC 2	FC 6	FC 11	FC 12	FC 14	FC 16	Total
Light			1			1		2
Moderate	1	7	1	6	4	10	2	31
Heavy 1	11	4	1	15	1	6		38
Heavy 2	10	4		6				20
Very Heavy 1			1	1				2
Total	22	15	4	28	5	17	2	93

For some road functional classes, it was possible to identify loading categories representing a majority of sites, while for other road functional classes, more than one loading category was frequently observed. Therefore, functional Class alone is a poor indicator of loading category. Nonetheless, some conclusions regarding expected loading can be drawn:

- Moderate loading was most frequently observed for urban functional classes 12, 14, and 16 (i.e., non-principal arterial roads). It was also observed for about 20 percent of urban interstates (FC 11) and for 47 percent of rural non-interstate principal arterials. This loading condition had at least one occurrence in each road functional class.

- Heavy 1 loading was most frequently observed for urban and rural interstates (FC 1 and 11). About half of the sites in these road functional classes had Heavy 1 loading. It was also observed for about 35 percent of urban non-interstate principal arterials (FC 14) and 27 percent of rural non-interstate principal arterials (FC 2). This loading category had at least one occurrence in each road functional class, except urban minor arterial (FC 16).
- Heavy 2 loading was observed only in three road functional classes: FC 1, FC 2, and FC 11. All three classes represent principal arterial roads. It was most frequently observed for rural interstates (FC 1)—45 percent of all rural interstates sites. It was observed for 29 percent of rural non-interstate principal arterials (FC 2) and about 20 percent of urban interstates (FC 11).
- Both Light and Very Heavy loading categories were observed on rural minor arterial roads (FC 6). This road functional Class had the greatest variability in loading conditions, with no category identifiable as dominant. The sample of WIM sites for this functional Class was too small to draw strong conclusions.
- No sites in this study were located on FC 7, 8, 9, 17, or 19.

5.3.4 Loading Categories Observed on Rural vs. Urban Roads

The distribution of sites by loading categories for rural versus urban routes is tabulated in table 26. More than one loading category was observed within urban and rural road categories. Therefore, the rural versus urban designation by itself is not enough to define loading condition.

The majority of urban sites had either Moderate or Heavy 1 loading conditions, while the two most frequently observed loading conditions for rural roads were Heavy 1 and Heavy 2. On average, lighter loads per truck were observed for urban roads than for rural roads. This is expected, as a larger percentage of trucks on urban roads is engaged in local deliveries and, therefore, have partial loads or empty conditions more frequently than trucks on rural roads that are more frequently engaged in long hauls. It is recommended that heavier loading defaults be applied for rural roads, if no other information about loading is available.

TABLE 26
Distribution of loading conditions for rural vs. urban roads

Loading Category	Rural	Urban
Light	1	1
Moderate	9	22
Heavy 1	16	22
Heavy 2	14	6
Very Heavy 1	1	1
Total	41	52

5.3.5 Loading Categories Observed on Interstate vs. Non-Interstate Roads

The distribution of sites by loading categories for interstate versus non-interstate roads is tabulated in table 27. More than one loading condition was observed within interstate and non-interstate categories. Therefore, interstate versus non-interstate designation by itself is not enough to define loading condition. Some differences in loading characteristics, however, can be identified. The majority of non-interstate sites were in the Moderate loading category, followed by Heavy 1, while the majority of interstate roads were in the Heavy 1 loading category, followed by Heavy 2. On average, lighter loads per truck were observed for non-interstate roads than for interstate roads. It is recommended that heavier loading defaults be applied for interstate roads than for non-interstate roads, if no other information about loading is available.

TABLE 27
Distribution of loading categories for interstate vs. non-interstate routes

Loading Category	Interstate	Non-Interstate
Light	0	2
Moderate	7	24
Heavy 1	26	12
Heavy 2	16	4
Very Heavy 1	1	1
Total	50	43

Table 28 is a comparison of loading categories through a combination of rural versus urban and interstate versus non-interstate roads. The following conclusions can be drawn from this comparison:

- Rural interstates are likely to be in either the Heavy 1 or Heavy 2 loading category. Two loading defaults may be needed to define loading conditions for this Class of roads. This assumption should be confirmed by studying sensitivity of locally calibrated MEPDG models to load spectra representing Heavy 1 and Heavy 2 categories.
- Urban interstates are likely to be in the Heavy 1 loading category, although Moderate and Heavy 2 are possible in some cases. Heavy 2 category are more likely to be seen on urban interstates that are part of GDOT's designated freight road network or at locations that serve major industrial facilities, distribution facilities, or major multi-modal transportation hubs or have a high percentage of throughway trucks.
- Rural non-interstate roads show a variety of loading conditions. Moderate loading conditions are most frequent, followed by Heavy 1 and then Heavy 2. Up to three loading defaults may be needed to define loading condition for this Class of roads. This assumption should be confirmed by studying sensitivity of locally calibrated MEPDG models to load spectra representing Moderate, Heavy 1, and Heavy 2 categories.
- Urban non-interstate roads are likely to be in the Moderate loading category, although Heavy 1 is also possible in some cases. One or two loading defaults may be needed to describe loading conditions for this Class of roads.

TABLE 28
Distribution of loading categories for interstate vs. non-interstate roads and rural vs. urban

Loading Category	Interstate		Non-Interstate	
	Rural	Urban	Rural	Urban
Light	0	0	1	1
Moderate	1	6	8	16
Heavy 1	11	15	5	7
Heavy 2	10	6	4	0
Very Heavy 1	0	1	1	0
Total	22	28	19	24

5.3.6 Loading Categories Observed in Different GDOT Districts

The distribution of loading categories by GDOT district is tabulated in table 29. This designation was analyzed to see if loading characteristics differ geographically across the State. Based on the available data, no strong differences with respect to loading were observed for GDOT districts. The sample for District 1 was too small to draw any conclusions. As such, it is recommended that more loading data be collected for District 1.

TABLE 29
Distribution of loading categories by GDOT district

Loading Category	District							
	D 1	D 2	D 3	D 4	D 5	D 6	D 7	Total
Light		1	1					2
Moderate	1	2	5	6	6	9	2	31
Heavy 1	1	9	9	5	6	3	5	38
Heavy 2		5	3	4	3	2	3	20
Very Heavy 1			1			1		2
Total	2	17	19	15	15	15	10	93

5.3.7 Loading Categories Observed for Roads with Different Levels of Truck Volume

The distribution of sites by loading categories for routes with different levels of truck volumes in the design lane is tabulated in table 30. In summary, there appears to be a correlation between the truck volume in the design lane and the loading condition of the Class 9 trucks, as shown in figure 19. For the sample of GDOT WIM sites, roads with AADTT less than 1,000 vehicles most frequently were in the Moderate loading category, while roads with AADTT over 1,000 most frequently were in the Heavy 1 loading category. The percentage of roads in the Heavy 2 loading category increases as AADTT values increase. Roads with AADTT over 3,000 in the design lane had the heaviest loading conditions, with half of all sites in either the Heavy 2 or Very Heavy 1 category and no sites in the Moderate category. The greatest variability in loading conditions is observed for the roads with AADTT less than 500 trucks in the design lane; the most frequently observed loading category for these roads is Moderate.

TABLE 30

Distribution of loading categories for routes with different levels of truck volumes in the design lane

Loading Category	AADTT Design Lane					Total
	<500	500-1000	1000-2000	2000-3000	>3000	
Light	1	1				2
Moderate	16	11	1	3		31
Heavy 1	7	5	8	11	7	38
Heavy 2	2	3	3	6	6	20
Very Heavy 1	1				1	2
Total	27	20	12	20	14	93

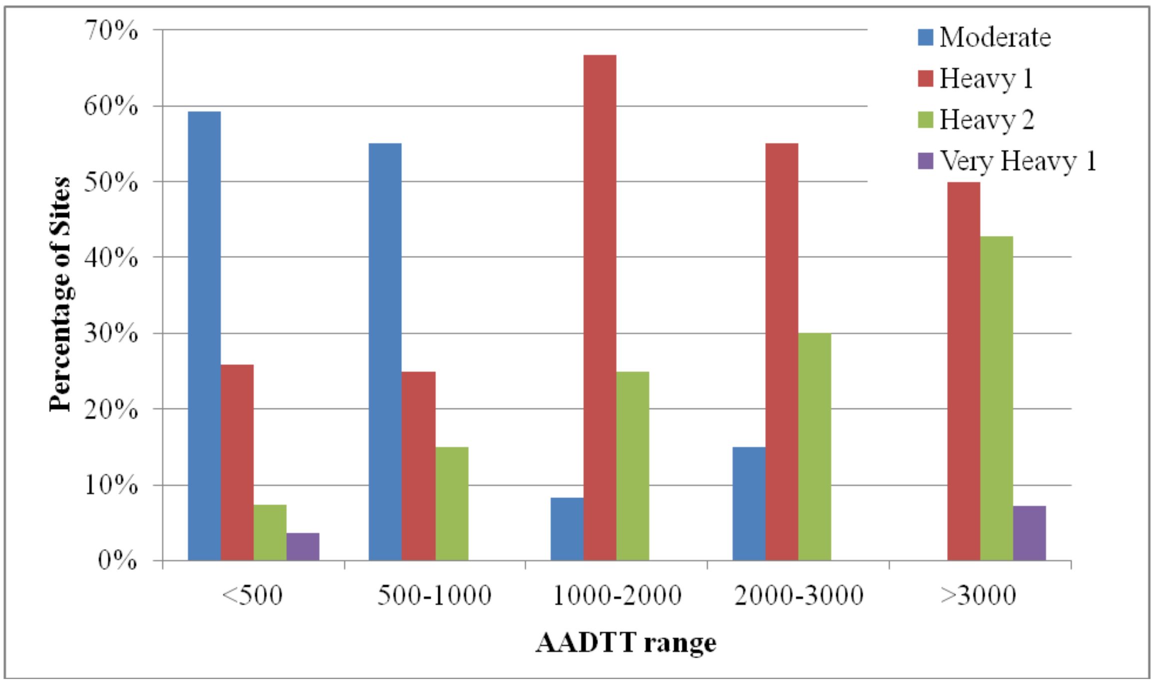


FIGURE 19

Percentages of sites in different loading categories observed for routes with different design lane AADTT values

5.3.8 Loading Categories Observed for Roads with Different Percentages of Class 9 Trucks

The distribution of sites by loading categories for roads with different percentages of Class 9 trucks (in truck distribution) for the design lane is tabulated in table 31. There appears to be a correlation between the percentage of Class 9 trucks in the design lane and the loading condition of the Class 9 trucks. For the sample of GDOT WIM sites, loads carried by Class 9 trucks are generally heavier for roads where higher percentages of Class 9 trucks are observed (i.e., “truck routes”). Only one occurrence of the Heavy 2 loading category was observed for roads with less than 50 percent Class 9 trucks in the design lane. Heavy 2 loading category was most frequently observed on roads that carried more than 80 percent of Class 9 trucks (in the truck distribution for the design lane). Moderate loading was most frequently observed for roads with less than 50 percent of Class 9 trucks (in the truck distribution for the design lane). Heavy 1 loading was observed on roads with a broad spectrum of Class 9 percentages but was most frequently observed on roads with 50 to 80 percent of Class 9 trucks in truck Class distribution for the design lane.

TABLE 31
Distribution of loading categories for roads with different percentages of Class 9 trucks in the design lane

Loading Category	% Class 9 for Design Lane							Total
	<30	30-40	40-50	50-60	60-70	70-80	80-90	
Light		1	1					2
Moderate	5	5	5	6	6	3	1	31
Heavy 1		2	4	9	7	10	6	38
Heavy 2		1		3	3	5	8	20
Very Heavy 1					1		1	2
Total	5	9	10	18	17	18	16	93

Loading trends observed with respect to percentages of Class 9 trucks can be explained by the following. Class 9 trucks serve as the main carrier of commercial loads in the U.S on highways. Therefore, roads that have high percentages of Class 9 trucks are likely to be major freight routes. A high percentage of Class 9 trucks also means a low percentage of Class 5 trucks, and low percentages of Class 5 trucks indicate that local trucking and economic activity is limited. Therefore, it is possible to assume that the majority of Class 9 trucks are on the long haul. Long haul Class 9 trucks are more likely to be fully loaded compared to the Class 9 trucks that are making local deliveries. This theory supports observations from the Georgia WIM sample: roads with a low percentage of Class 9 trucks are likely to have lighter loading conditions (assuming no special industry generating heavy truck loads identified near the site) than roads that have a high percentage of Class 9 trucks.

The distribution of loading categories for roads with different AADTTs and percentages of Class 9 trucks (in truck distribution) for the design lane is tabulated in table 32. From this table it can be seen that roads with high AADTT levels are more likely to have high percentages of Class 9 trucks, and these trucks are more likely to be heavily loaded. For roads with lower AADTT (fewer than 1,000 trucks per design level), a moderate loading condition is most frequently observed regardless of the percentage of Class 9 trucks.

TABLE 32
Distribution of loading categories for roads with different AADTT and percentage of Class 9 trucks in the design lane

AADTT Design Lane	Loading Category	% Class 9 for Design Lane							Total
		<30	30-40	40-50	50-60	60-70	70-80	80-90	
<500	Light		1						1
	Moderate	4	3	2	2	3	2		16
	Heavy 1		2	3	2				7
	Heavy 2				2				2
	Very Heavy 1					1			1
500-1000	Light			1					1
	Moderate	1	2	3	1	3	1		11
	Heavy 1				2	1	1	1	5
	Heavy 2						2	1	3
1000-2000	Light								0
	Moderate				1				1
	Heavy 1				2	2	2	2	8
	Heavy 2		1			1	1		3
2000-3000	Light								0
	Moderate				2			1	3
	Heavy 1			1	3	3	3	1	11
	Heavy 2					2	1	3	6
>3000	Light								0
	Moderate								0
	Heavy 1					1	4	2	7
	Heavy 2				1		1	4	6
	Very Heavy 1							1	1

5.3.9 Conclusions

Information about loading conditions derived from GDOT's WIM data was used to identify similarities in truck loading for different groupings of Georgia roads. Loading category based on load spectrum characteristics of Class 9 trucks was used to characterize loading at each WIM site. No information about the nature of freight movement and types of goods being transported by trucks on specific roads or corridors across Georgia was available at the time of study; therefore, the analysis was limited to available road characteristics and truck traffic statistics that included road functional class, urban or rural location, GDOT district, AADTT, and percentage of Class 9 trucks in the design lane.

Based on this analysis, traffic loading on majority of roads maintained by GDOT could be represented by the following three loading categories:

- Moderate loading category (10 to 30 percent of Class 9 trucks are heavily loaded). This loading is most likely to be observed on roads with AADTT less than 1,000 trucks in the design lane and roads with less than 50 percent of Class 9 trucks in truck distribution. Most of these roads are likely to be urban non-interstate roads, as well as some rural principal and minor arterials. This condition is likely to be applicable to routes that primarily are used for local movements of goods (i.e., local distribution).
- Heavy 1 loading category (30 to 40 percent of Class 9 trucks are heavily loaded). This loading is observed on Georgia arterial roads with a wide range of AADTT and percentage of Class 9 trucks. It is likely that over half of urban interstates and about half of rural interstates will have this loading condition, especially roads with design lane AADTT between 1,000 and 3,000 trucks and between 50 and 80 percent of Class 9 trucks in truck distribution. This condition could be observed on both rural and urban non-interstate principal arterials (FC 2 and FC 14). This condition is likely to be applicable to routes that combine both local (local distribution) and state-to-state freight movements.
- Heavy 2 loading category (40 to 50 percent of Class 9 trucks are heavily loaded). This loading is most likely to be observed on principal arterial roads with AADTT over 2,000 trucks and more than 80 percent of Class 9 trucks in truck distribution. Most of these roads are likely to be rural interstate roads, as well as some urban interstates and rural principal arterial non-interstate roads. This condition is likely to be observed on major freight routes serving multiple States.

CHAPTER 6 – COMPARISON OF LOADING CATEGORIES OBSERVED IN GEORGIA WITH THE AVAILABLE LOADING DEFAULTS

6.1 ANALYSIS PURPOSE

NALS representing different loading conditions on Georgia roads were compared with the available traffic loading defaults from a few State and national studies. The purpose of this comparison was to see if loading conditions observed on Georgia roads are similar to the loading defaults developed by other studies and whether defaults from these studies can be used in the short-term until sufficient good-quality WIM data are collected at permanently installed Georgia WIM sites.

6.2 DATA SOURCES

6.2.1 NALS Defaults from National Studies

Two sources of the national defaults were available for use at the time of the study:

1. The original NALS defaults developed by NCHRP 1-37A study, a review of which was provided in section 2.2.
2. New LTPP defaults based on SPS TPF 5(004) WIM data.

6.2.2 NALS Defaults from Other States

Several nearby States were found to be in the process of developing or modifying their WIM programs to support the development of MEPDG axle loading defaults: Virginia, North Carolina, Mississippi, Missouri, Colorado, Wyoming, Idaho, and Florida. However, Florida was the only State adjacent to Georgia that had WIM-based axle loading defaults available at the time of this study.

The Florida DOT concluded that loading conditions vary significantly between different road types in Florida. As a result, several different default NALS were developed to use for pavement design of different road types. Florida NALS default developed for rural and urban interstates were used in this comparison. Defaults developed for non-interstate roads were not used in this study because State truck weight and size regulations are different between Georgia and Florida.

6.2.2 NALS Based on Georgia WIM Data

Data from both portable and permanent Georgia WIM sites were used for this study. Permanent WIM data were available for three directional WIM sites. These data were found to be of sufficient quality and quantity to accurately represent axle loading distributions at WIM site locations. Portable WIM data from 90 directional sites were used in the analysis. These data were collected using less precise WIM equipment over short periods of time and may be limited in the accuracy of representing the actual loading distributions, as previously stated.

Average axle loading distributions for each loading category were developed based on Georgia WIM data. This was accomplished using two data selection approaches. One approach is based on all 93 WIM samples (3 from permanent WIM and 90 from portable WIM), called “GA ALL” in the following sections. The other approach is based only on WIM samples where no calibration issues in heavy axle load measurements were identified (40 WIM samples: 3 from permanent WIM and 37 from portable WIM), called “GA MEPDG” in the following sections.

6.3 GRAPHICAL COMPARISON OF NALS REPRESENTING DIFFERENT LOADING CATEGORIES

NALS for Class 9 vehicles were used as a basis for comparison. These NALS represent the majority of heavy axle loads observed on Georgia roads. Average Georgia NALS were computed for each loading category and compared with the national and Florida NALS defaults. The purpose of this comparison was to assess similarities and differences between those default load distributions and the Georgia load distributions.

Prior to the analysis, it was acknowledged that some differences in axle load distributions are likely to be seen due to the differences in the equipment and procedures used to collect Georgia WIM data compared to the LTPP and FL data. The majority of Georgia WIM data were collected using low quality portable WIM systems over short periods of time, while LTPP and Florida data were collected using high-quality continuously monitoring permanent WIM systems subjected to rigorous data quality control and calibration procedures. Therefore, this comparison was designed to be more qualitative than quantitative.

6.3.1 Light Loading Category

The “Light” loading category was recognized as a special case. Only two sites in the Georgia WIM sample had this condition, and both locations were on non-interstate arterial roads. No LTPP or Florida interstate defaults with a similar loading pattern were available for comparison. NALS in this loading category should be used with caution because it may not represent the expected loading condition for the majority of Georgia roads.

6.3.2 Moderate Loading Category

The “Moderate” loading category was the second most commonly observed loading condition in the Georgia WIM sample. This category was also the most frequently observed in the LTPP study used to develop new LTPP MEPDG loading defaults. Figure 20 shows examples of the NALS for Class 9 tandem axles with moderate loading conditions observed in Georgia, LTPP, and Florida studies. The dashed rectangle shows heavy axles that are of most importance to pavement design.

As shown, the NALS for the Georgia ALL Moderate category has a lower percentage of heavy loads compared to all other plots (this is likely due to calibration issues). Georgia MEPDG Moderate has heavy load distributions similar to the Florida urban interstates default and the original MEPDG default. The LTPP moderate default has the most defined peak in heavy loads and the lowest spread in distribution of heavy axle loads, compared to all other distributions.

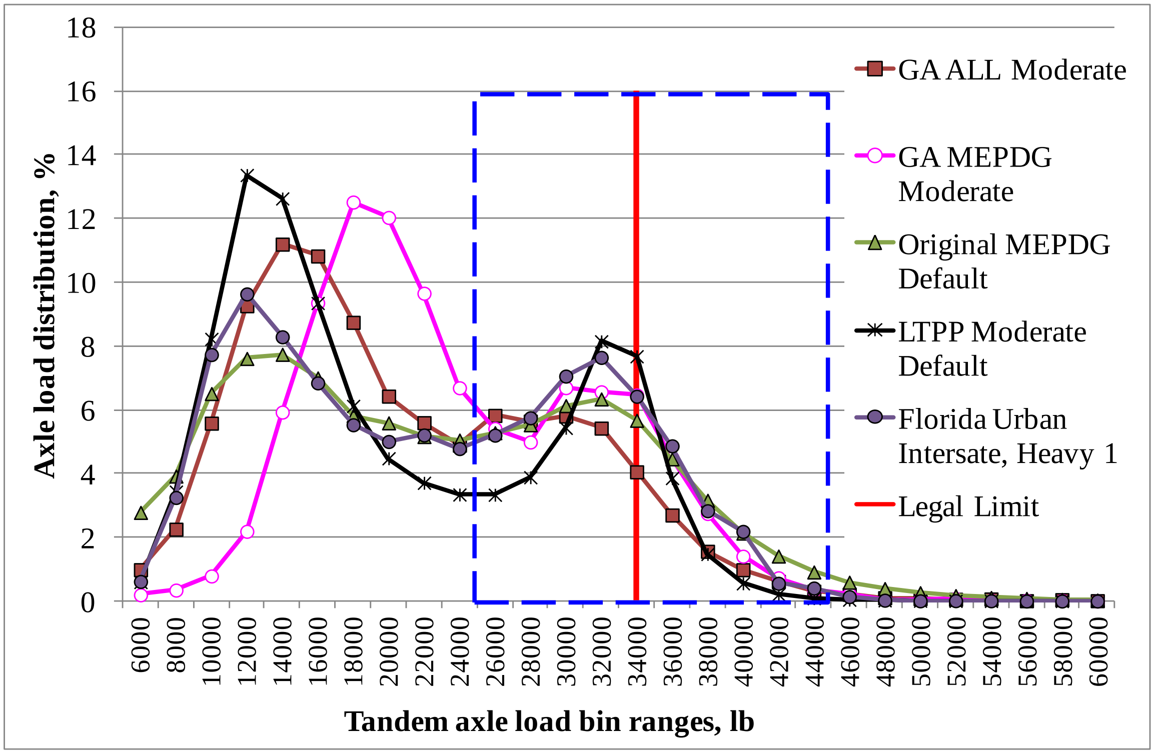


FIGURE 20
NALS for Class 9 tandems in the Moderate loading category

Overall, the shape of Georgia moderate NALS distributions (ALL and MEPDG) is similar to the Florida and LTPP moderate default distributions. All distributions have the characteristic camel-back shape with two peaks; the lightly loaded peak is 30 to 50 percent higher than the heavily loaded peak. For the short-term solution, either the Florida urban interstate or the LTPP moderate default axle load spectra could be used to represent Georgia sites in the Moderate loading category.

6.3.3 Heavy 1 Loading Category

The "Heavy 1" loading category was the most commonly observed loading condition in the Georgia WIM sample. This category was also frequently observed in the LTPP MEPDG loading defaults study and is recommended by LTPP as a default category when no information about traffic loading is available for the site. Figure 21 shows examples of the NALS for Class 9 tandem axles representing the Heavy 1 loading categories in the Georgia, LTPP, and Florida studies. The dashed rectangle shows heavy axles that are of most importance to pavement design.

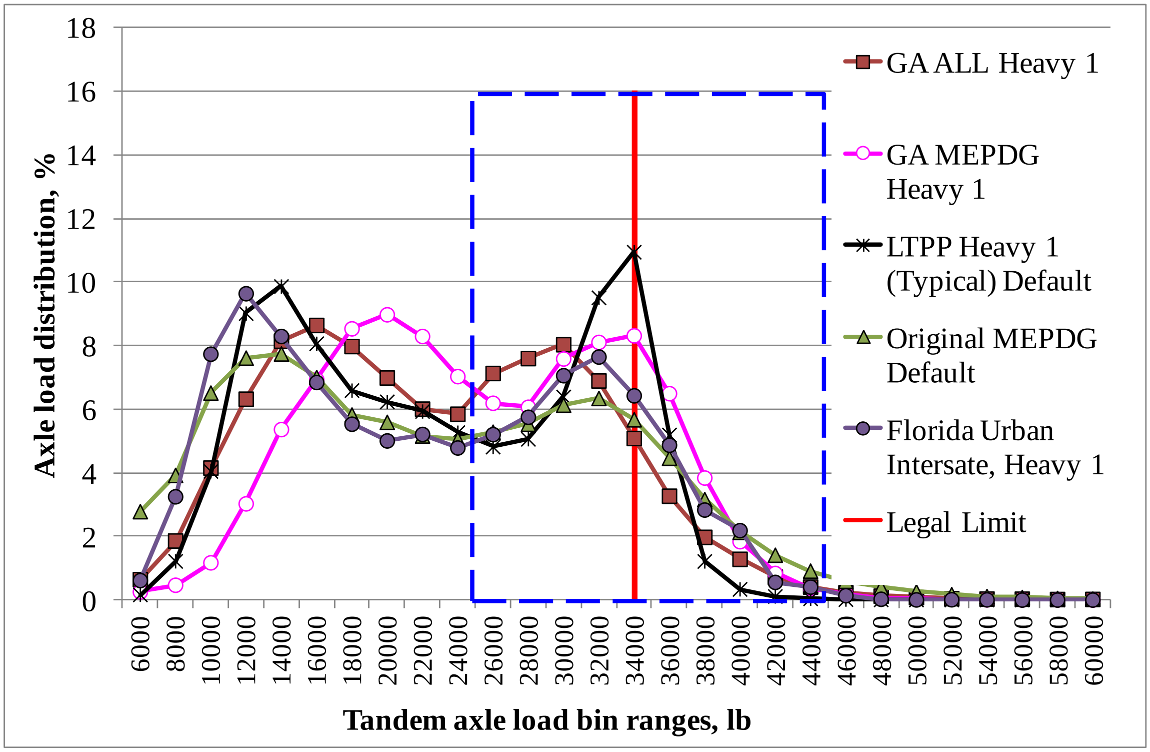


FIGURE 21
NALS for Class 9 tandems in the Heavy 1 loading category

As shown the Georgia ALL Heavy 1 category has a lower percentage of heavy loads compared to all other plots (likely due to calibration issues). The Georgia MEPDG Heavy 1 NALS has higher percentages of heavy loads than the Florida urban interstates default and the original MEPDG default but lower heavy peak loads compared to the LTPP Heavy 1 default. However, the LTPP Heavy 1 default has fewer overloads compared to the Georgia MEPDG Heavy 1 NALS. The LTPP Heavy 1 default has the most defined peak in heavy loads and the lowest spread in distribution of heavy axle loads, compared to all other distributions.

Overall, the shape of Georgia Heavy 1 distributions (ALL and MEPDG) falls between the Florida urban interstates default and the LTPP Heavy 1 default. Georgia Heavy 1 distributions have larger spread of heavy loads but a lower peak compared to the LTPP Heavy 1 default. This can be explained by the lower precision of portable WIM data used to collect Georgia data. As a short-term solution, LTPP Heavy 1 default axle load spectra could be used to represent Georgia sites in the Heavy 1 loading category until more precise WIM data from Georgia permanent WIM sites become available to verify or update this default.

6.3.4 Heavy 2 Loading Category

The Heavy 2 loading category was frequently observed in the Georgia WIM sample, especially for rural interstate roads. This category was also frequently observed in the LTPP SPS TPF study. The Heavy 2 category also best describes the Florida loading default for rural interstates. Figure 22 shows examples of the NALS for Class 9 tandem axles with Heavy 2 loading conditions observed in the Georgia, LTPP, and Florida studies. The dashed rectangle shows heavy axles that are of more importance to pavement design.

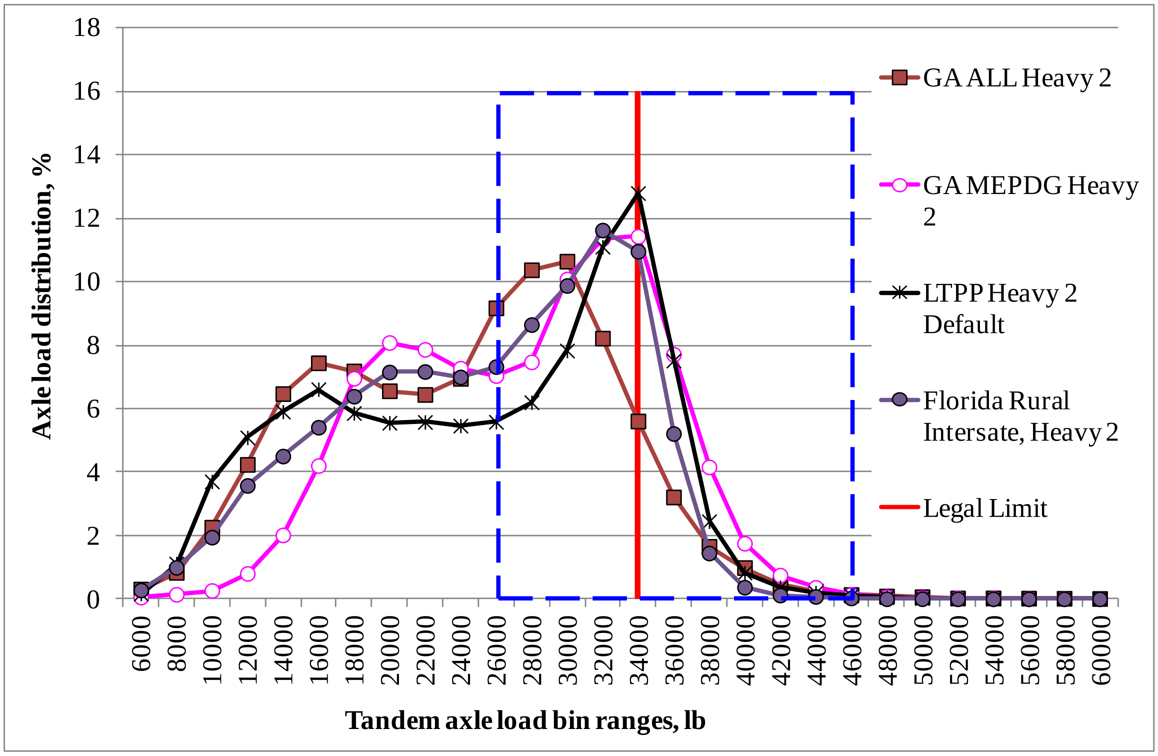


FIGURE 22
NALS for Class 9 tandems in the Heavy 2 loading category

As shown, the Georgia ALL Heavy 2 condition has a lower percentage of heavy loads compared to all other plots (likely due to calibration issues). Georgia MEPDG Heavy 2 NALS has a distribution shape and peak percentages of heavy loads similar to Florida rural interstates but a higher percentage of overloaded axles. Compared to the LTPP Heavy 2 default, the Georgia MEPDG Heavy 2 NALS has a higher spread of heavy loads and a slightly lower peak load percentage.

Overall, the shape of the Georgia Heavy 2 distributions (ALL and MEPDG) is similar to the Florida rural interstates default and the LTPP Heavy 2 default. As a short-term solution, the LTPP Heavy 2 default axle load spectra could be used to represent Georgia sites in the Heavy 2 loading category until more precise WIM data from Georgia permanent WIM sites become available to verify or update this default.

6.3.5 Very Heavy Loading Category

“Very Heavy” loading conditions were observed in only two Georgia WIM samples. This category was observed in the national study only for one case at an Arizona site with low truck volume serving a specific industrial facility. One of the Georgia sites in the Very Heavy category is also located on a road with low truck volume (annual average daily truck traffic [AADTT] for the study lane was less than 200). The other location is on I -75, which experiences very heavy truck volume and a very heavy percentage of Class 9 trucks. No Florida defaults are available to represent this loading.

Since this loading category was not typical in the national, Florida, or Georgia studies, no further comparison was conducted. However, it is recommended that GDOT investigates other rural locations with very heavy volume and percentage of Class 9 trucks to see if other instances of very heavy loading of Class 9 tandems can be observed, especially for rural interstates with high percentages of throughway truck traffic.

6.4 STATISTICAL COMPARISON OF NALS REPRESENTING DIFFERENT LOADING CATEGORIES

A statistical test was carried out to check if statistically significant difference exists between NALS representing different loading categories or different data sources (LTPP and GDOT).

The Relative Pavement Performance Impact Factor (RPPIF) statistic (developed by the LTPP for comparison of different NALS) was used as a summary statistic to represent NALS in the statistical tests. It should be understood this is a relative factor similar in concept to the AASHTO load equivalency factors based on serviceability. The RPPIF value was computed for each NALS and represents a specific loading category (Moderate, Heavy 1, and Heavy 2) using the following formula:

$$RPPIF_{jk} = \sum_{i=1}^{n} (F_{ijk} * W_{ij})$$

Where:

i	=	load bin
j	=	type of axle (tandem used in this analysis)
k	=	class of vehicle (Class 9 was used in this analysis)
W_{ij}	=	impact factor for load range i, for axle group type j, from table 33
F_{ijk}	=	fraction of axles in load range i, for axle group type j, and vehicle Class k

TABLE 33
Pavement performance impact factors, W from LTPP PLUG [4]

Load Bin	Single		Tandem		Tridem		Quad	
	Load Range (lb)	Weight	Load Range (lb)	Weight	Load Range (lb)	Weight	Load Range (lb)	Weight
BIN_01	0-999	0.00	0-1999	0.00	0-2999	0.00	0-2999	0.00
BIN_02	1000-1999	0.00	2000-3999	0.00	3000-5999	0.00	3000-5999	0.00
BIN_03	2000-2999	0.00	4000-5999	0.00	6000-8999	0.00	6000-8999	0.00
BIN_04	3000-3999	0.00	6000-7999	0.00	9000-11999	0.00	9000-11999	0.00
BIN_05	4000-4999	0.00	8000-9999	0.00	12000-14999	0.00	12000-14999	0.00
BIN_06	5000-5999	0.00	10000-11999	0.00	15000-17999	0.04	15000-17999	0.00
BIN_07	6000-6999	0.00	12000-13999	0.01	18000-20999	0.09	18000-20999	0.02
BIN_08	7000-7999	0.00	14000-15999	0.04	21000-23999	0.15	21000-23999	0.05
BIN_09	8000-8999	0.02	16000-17999	0.08	24000-26999	0.21	24000-26999	0.09
BIN_10	9000-9999	0.04	18000-19999	0.14	27000-29999	0.28	27000-29999	0.14
BIN_11	10000-10999	0.08	20000-21999	0.22	30000-32999	0.35	30000-32999	0.20
BIN_12	11000-11999	0.12	22000-23999	0.30	33000-35999	0.43	33000-35999	0.27

Load Bin	Single		Tandem		Tridem		Quad	
	Load Range (lb)	Weight	Load Range (lb)	Weight	Load Range (lb)	Weight	Load Range (lb)	Weight
BIN_13	12000-12999	0.18	24000-25999	0.40	36000-38999	0.53	36000-38999	0.34
BIN_14	13000-13999	0.24	26000-27999	0.51	39000-41999	0.64	39000-41999	0.42
BIN_15	14000-14999	0.31	28000-29999	0.62	42000-44999	0.76	42000-44999	0.52
BIN_16	15000-15999	0.40	30000-31999	0.75	45000-47999	0.92	45000-47999	0.62
BIN_17	16000-16999	0.49	32000-33999	0.89	48000-50999	1.10	48000-50999	0.73
BIN_18	17000-17999	0.59	34000-35999	1.04	51000-53999	1.32	51000-53999	0.85
BIN_19	18000-18999	0.71	36000-37999	1.21	54000-56999	1.58	54000-56999	0.99
BIN_20	19000-19999	0.85	38000-39999	1.40	57000-59999	1.90	57000-59999	1.14
BIN_21	20000-20999	1.01	40000-41999	1.63	60000-62999	2.27	60000-62999	1.30
BIN_22	21000-21999	1.19	42000-43999	1.90	63000-65999	2.71	63000-65999	1.47
BIN_23	22000-22999	1.41	44000-45999	2.23	66000-68999	3.22	66000-68999	1.66
BIN_24	23000-23999	1.67	46000-47999	2.63	69000-71999	3.82	69000-71999	1.87
BIN_25	24000-24999	1.99	48000-49999	3.13	72000-74999	4.51	72000-74999	2.10
BIN_26	25000-25999	2.38	50000-51999	3.74	75000-77999	5.30	75000-77999	2.35
BIN_27	26000-26999	2.85	52000-53999	4.49	78000-80999	6.20	78000-80999	2.63
BIN_28	27000-27999	3.43	54000-55999	5.42	81000-83999	7.22	81000-83999	2.93
BIN_29	28000-28999	4.12	56000-57999	6.56	84000-86999	8.37	84000-86999	3.26
BIN_30	29000-29999	4.96	58000-59999	7.95	87000-89999	9.66	87000-89999	3.62
BIN_31	30000-30999	5.97	60000-61999	9.64	90000-92999	11.09	90000-92999	4.02
BIN_32	31000-31999	7.18	62000-63999	11.67	93000-95999	12.68	93000-95999	4.46
BIN_33	32000-32999	8.62	64000-65999	14.11	96000-98999	14.44	96000-98999	4.94
BIN_34	33000-33999	10.33	66000-67999	17.00	99000-101999	16.37	99000-101999	5.47
BIN_35	34000-34999	12.35	68000-69999	20.43	102000-104999	18.48	102000-104999	6.06
BIN_36	35000-35999	14.72	70000-71999	24.47	105000-107999	20.78	105000-107999	6.71
BIN_37	36000-36999	17.48	72000-73999	29.19	108000-110999	23.28	108000-110999	7.42
BIN_38	37000-37999	20.70	74000-75999	34.68	111000-113999	25.98	111000-113999	8.20
BIN_39	38000-38999	24.41	76000-77999	41.04	114000-116999	28.90	114000-116999	9.06
BIN_40	≥ 39000	28.70	≥ 78000	48.37	≥ 117000	32.03	≥ 117000	10.01

T-test procedures were used to check the equality of the means between RPPIF for NALS representing different loading categories or different data sources. To identify appropriate t-test procedure, F-test was conducted first to identify if variances in RPPIF observed within each NALS group were equal or not. Based on t-test results, the following conclusions were formulated:

1. NALS representing different loading conditions (Moderate, Heavy 1, and Heavy 2) were found to be statistically different. This conclusion applies to both LTPP and Georgia NALS and supports the need for multiple NALS defaults representing different loading conditions.

2. When Georgia NALS (based mostly on portable WIM data) were compared to LTPP NALS in the same loading category, statistical differences were observed. On average, Georgia NALS were heavier than LTPP NALS in the same loading category. Based on visual observation of NALS presented earlier in this chapter, this may be attributed to lower accuracy of the portable WIM data, as was evidenced by higher-than-expected percentages of very heavy loads and shifts of peaks for unloaded axles towards heavier loads. Because Georgia data were collected using less precise portable WIM equipment, compared to the LTPP data, the validity of this statistical conclusion is limited. Therefore, it is important for GDOT to install permanent WIM sites to test this conclusion and collect a reliable source of Georgia specific WIM data for pavement design.

6.5 CONCLUSIONS

The following conclusions and recommendations were developed based on comparison of Georgia WIM data to the available defaults:

1. The shape of Georgia moderate NALS distributions (ALL and MEPDG) is similar to the Florida and LTPP moderate default distributions. For a short-term solution, either the Florida urban interstate or the LTPP moderate default axle load spectra can be used to represent Georgia sites in the Moderate loading category.
2. The shape of Georgia Heavy 1 distributions (ALL and MEPDG) falls between the Florida urban interstates default and the LTPP Heavy 1 default. Georgia Heavy 1 distributions have a larger spread of heavy loads but a lower peak compared to the LTPP Heavy 1 default. This can be explained by the lower precision of the portable WIM data used to collect Georgia data. As a short-term solution, LTPP Heavy 1 default axle load spectra can be used to represent Georgia sites in the Heavy 1 loading category until more precise data from Georgia permanent WIM sites become available to verify or update this default.
3. The shape of the Georgia Heavy 2 distributions (ALL and MEPDG) is similar to the Florida rural interstates default and the LTPP Heavy 2 default. As a short-term solution, the LTPP Heavy 2 default axle load spectra can be used to represent Georgia sites in the Heavy 2 loading category until more precise data from Georgia permanent WIM sites become available to verify or update this default.
4. “Very Heavy” loading conditions were observed in only two Georgia WIM samples. This category was observed in the national study but for only one case at an Arizona site with low truck volume serving a specific industrial facility. No Florida defaults represent this loading. It is recommended that GDOT investigate if other instances of very heavy loading of Class 9 tandems can be observed in Georgia, especially for rural interstates with high percentages of throughway truck traffic. If such sites are found, a Georgia-specific default representing this loading category would be needed.
5. Statistical comparison of NALS from different loading categories (Moderate, Heavy 1, and Heavy 2) confirmed that a statistical difference in loading exists between these categories for both Georgia and LTPP sites. It is recommended that an MEPDG sensitivity study using NALS representing these loading categories be used to determine whether these differences have a significant effect on pavement design outcomes. This analysis is described in the next chapter.

6. When Georgia NALS (based mostly on portable WIM data) were statistically compared to LTPP default NALS in the same loading category, statistical differences were observed. This was somewhat expected, as Georgia data were collected using less precise portable WIM equipment. Because the accuracy of the data from these two sources was different, the validity of this statistical conclusion is limited. It is very important for GDOT to install permanent WIM sites to test this conclusion and also to get a reliable source of Georgia-specific WIM data for pavement design and defaults generation.

CHAPTER 7 – MEPDG SENSITIVITY TO AXLE LOADING DISTRIBUTIONS

7.1 ANALYSIS PURPOSE

The purpose of the analysis described in this section is to determine the importance of the NALS for predicting pavement distress and defining NALS groups representing different traffic loading conditions for MEPDG design in Georgia. This is accomplished by comparing the MEPDG outcomes to NALS representing different loading conditions observed in Georgia. The analysis was conducted by comparing calculated distresses, predicted design life, and pavement design thickness.

In addition to NALS representing Georgia loading conditions, NALS defaults developed under the NCHRP 1-37A project, the new national LTPP NALS defaults, and the NALS defaults developed by the Florida DOT were used in the comparative analysis of the MEPDG outcomes. MEPDG analyses were conducted using pavement designs (flexible and rigid) typical for higher volume Georgia roadways, which is their predominant use of the MEPDG.

7.2 ANALYSIS INPUTS

7.2.1 Traffic Inputs

The analysis focused on roads with high volumes of heavy trucks. Pavement structures with slightly thinner surface layers than would be typically observed on Georgia roads were used to magnify the effect of traffic loading on pavement structural performance.

7.2.1.1 Truck Volume

A truck volume typical to high volume Georgia interstate roads was used in the design, with the following parameters:

- Initial two-way AADTT: 7,500.
- Number of lanes in design direction: 2.
- Trucks in the design direction: 50 percent.
- Trucks in the design lane: 95 percent.
- Truck compound growth rate: 2.5 percent.

The vehicle class distribution used in the analysis is listed in table 34.

Class 9 trucks were found to be the major heavy truck type observed on Georgia roads. Typically, the percentage of Class 9 trucks on rural interstates in Georgia is between 70 and 80 percent. For the analysis scenario tested, the percentage of Class 9 trucks was 74 percent.

TABLE 34
AADTT distribution by vehicle class

Vehicle Class	Percentage of Vehicles in Classes 4-13
Class 4	1.3
Class 5	8.5
Class 6	2.8
Class 7	0.3
Class 8	7.6
Class 9	74.0
Class 10	1.2
Class 11	3.4
Class 12	0.6
Class 13	0.3

7.2.1.2 Traffic Loading

Traffic loading scenarios included the following NALS:

- NALS from Georgia permanent WIM. These are the only sites where high-quality site-specific loading data were available for Georgia routes. All these sites are on interstate routes located close to large urban areas.
    - Site 067-2373; Lane 2 in the northbound direction.
    - Site 207-0222; Lane 1 in the northbound direction.
    - Site 207-0222; Lane 2 in the southbound direction.
- NALS based on Georgia portable WIM data for the sites that did not show signs of bias in heavy weight measurements.
    - Georgia Portable Lightest (WIM site #161-189 on SR 19).
    - Georgia Portable Moderate (average of all sites with this loading condition).
    - Georgia Portable Heavy 1 (average of all sites with this loading condition).
    - Georgia Portable Heavy 2 (average of all sites with this loading condition).
    - Georgia Portable Heaviest (WIM site #313-101 on I-75).

  Because of the lower precision of portable WIM devices, these distribution show wider spreads than distributions based on more accurate permanent WIM systems. A wider spread of heavy loaded axles can lead to prediction of faster deterioration rates, leading to reduced pavement life or thicker pavements. These sites cover a wide range of loading conditions observed on Georgia roads, from light to very heavy. Loading conditions were described in Section 4.3. Georgia Portable Lightest and Heaviest sites were chosen to test the range of predicted MEPDG outcomes that could be expected for Georgia.
- NALS representing the new LTPP MEPDG defaults. All NALS based on LTPP data were computed based on averaging of NALS for the sites with the same identified loading condition. These NALS represent the variety of loading conditions observed in the national study.
    - LTPP Tier 1 (Global) – default based on averaging data from all LTPP SPS TPF 5(004) WIM sites.

    - LTPP Tier 2 Moderate – default recommended for roads where up to 30 percent of Class 9 trucks are heavily loaded.
    - LTPP Tier 2 Heavy 1 (Typical) – default recommended for roads where 30 to 40 percent of all Class 9 trucks are heavy loaded.
    - LTPP Tier 2 Heavy 2– default recommended for roads where 40 to 50 percent of all Class 9 trucks are heavy loaded.

  These NALS defaults were selected to investigate if significantly different MEPDG outcomes would be produced using Georgia designs for heavy volume roads and determine if these defaults could be used in the interim for Georgia loading defaults.

- NALS representing Florida MEPDG defaults. Only loading conditions for Florida interstates were considered. Loading on Florida State roads is expected to be different from Georgia State roads due to differences in truck weight regulations between the two States.
    - FL IR – for Florida rural interstates (average of all sites with this road type).
    - FL IU – for Florida urban interstates (average of all sites with this road type).

  These defaults were used in the analysis to see if they could be used in the interim for Georgia loading defaults.

- NALS computed from historical data (1990s) included in the LTPP database for Georgia LTPP General Pavement Studies (GPS) sites:
    - NALS for sites 13-4118 and 13-7028 were based on data from portable WIM and are likely to have limited reliability due to lower accuracy of weight measurements associated with portable WIM data collection.
    - NALS for sites 13-3017 and 13-3020 were based on data from permanent WIM that showed very high variability in axle weights, possibly due to temperature sensitivity of piezo-ceramic sensors or poor calibration, resulting in super-heavy axle weights.

  These NALS are not recommended for use in establishing default NALS for Georgia. These NALS were used in the analysis to evaluate the implications of using low quality WIM data for MEPDG-based designs.

- Florida and Virginia NALS from LTPP TPF 5(004) study. These data are of high quality and considered by LTPP to be “research-quality” data. These data were selected because some of the Georgia, Florida, and Virginia major highway corridors are used by the same trucks, and these data represent wide range of loading conditions. These data were used only in the analysis of pavement distresses.

- MEPDG NALS global default values included in the current version of the MEPDG software. These defaults were developed under NCHRP 1-37A project using the WIM data included in the LTPP database prior to 1998. Because these defaults were developed based on data of unknown quality, these defaults may be replaced in the future by the new LTPP defaults. These defaults were used only in the analysis of pavement distresses.

Examples of single and tandem NALS from the above sources are shown in figures 23 and 24. It should be noted that the NALS for site 13-3017 has over 10 percent of the Class 9 single axles weighing over 38 kips and over 10 percent of the Class 9 tandem axles weighing over 70 kips.

Site 13-7028 also has questionable or anomalous WIM data (see figure 23), with a high percentage of very light single and tandem axle of Class 9 trucks. Other truck classes have single and tandem axles with the heavier loads, as recorded in the WIM data at site 13-7028. The research team does not know of any reason why that would be the case for these two sites and expects that the data are highly biased and/or include many misclassification data. However, both sites were used in the analysis of NALS to demonstrate the impact of ignoring highly biased data on pavement distress predictions and that impact on local calibration. NALS shown in figure 24 are based on data of known acceptable quality, except for the MEPDG defaults that is based on data of known quantity but not quality. NALS shown in figure 24 indicate that loading distributions obtained from different sources vary widely with respect to heavy tandem loads.

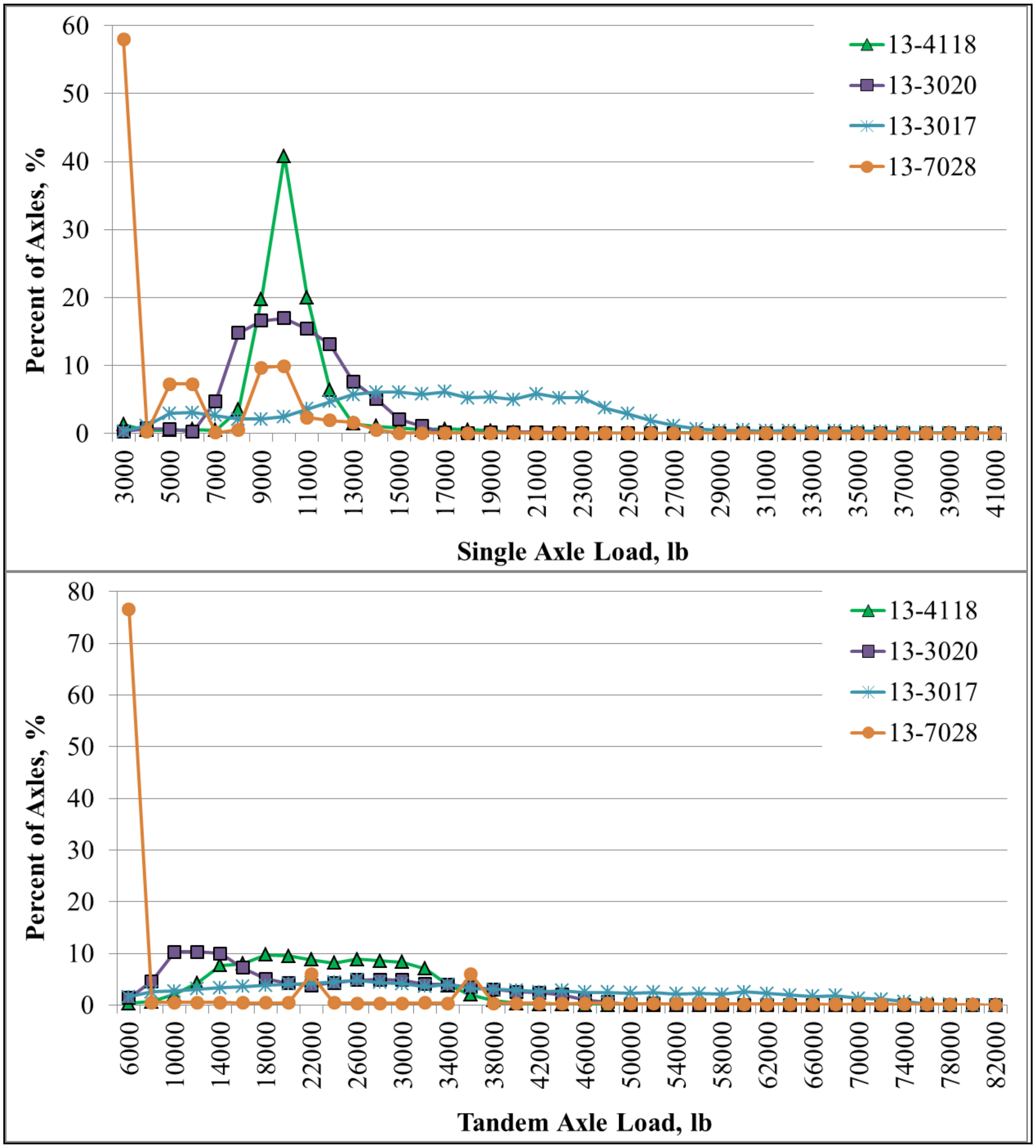


FIGURE 23
NALS for Class 9 vehicles determined for the LTPP sites in Georgia

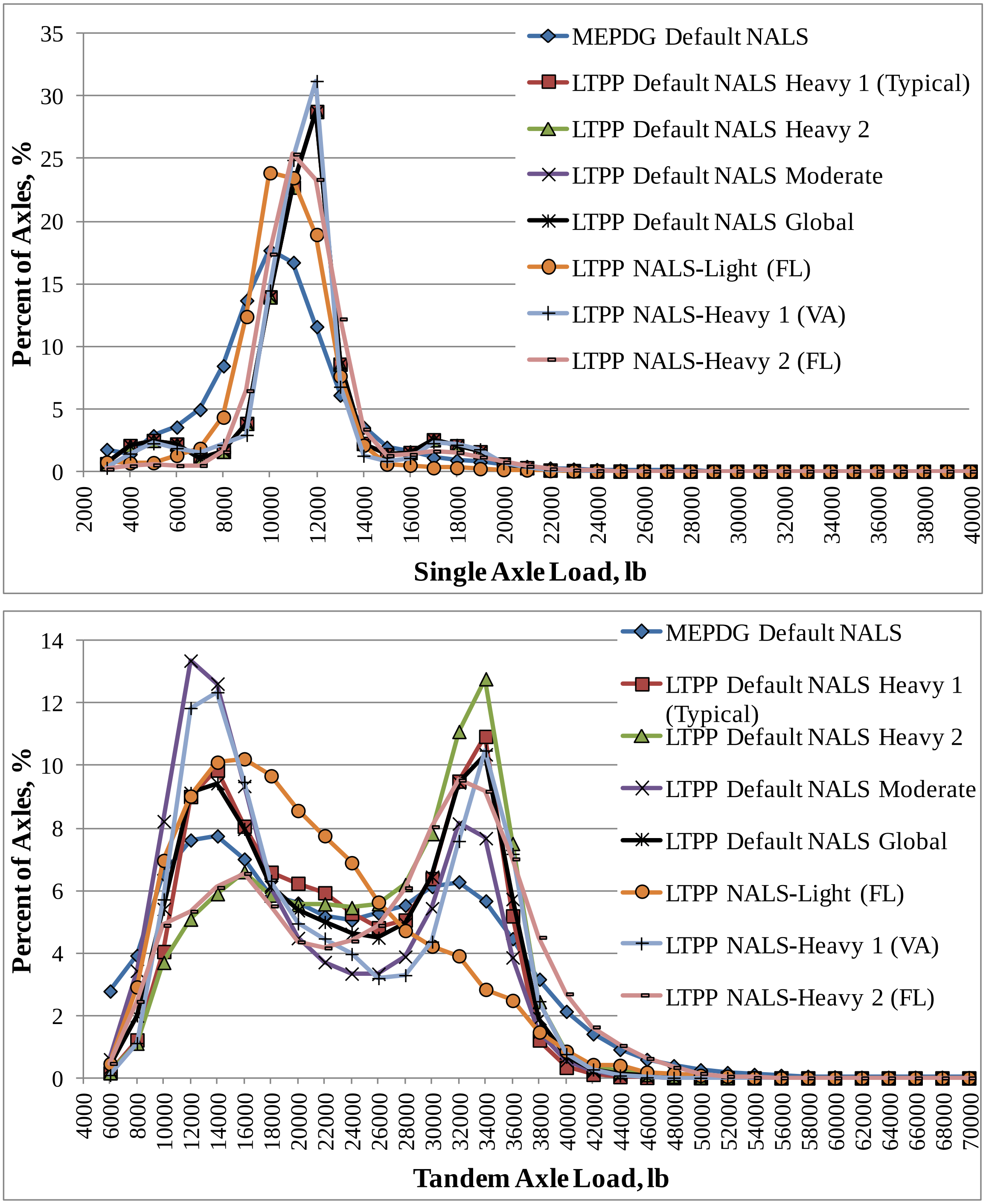


FIGURE 24

NALS for Class 9 vehicles using original MEPDG default and new default values based on the LTPP TPF 5(004) data

7.2.2 Pavement Inputs

Pavement structures used for analysis were based on typical Georgia pavement designs for high truck volume roads. Two types of pavement structures were used in the analysis for each pavement type. This was done to analyze the effect of axle load distribution for different failure modes: rutting or alligator cracking for AC pavements and slab cracking or joint faulting for JPCP.

Pavement structure inputs used for analysis are shown in table 35. Climatic conditions typical to Macon, Georgia, were used in all analyses. Traffic inputs were described in the previous sections of this report. All other inputs were default values in the MEPDG software.

TABLE 35
Summary of pavement design features used for MEPDG analysis

Design Scenario	MEPDG Inputs
Design #1: Alligator Cracking Failure Mode	AC Layer 1: 2.5 in, Binder Grade: 76-22, 7% air voids, 10% effective binder content AC Layer 2: 6 in, Binder Grade: 76-22, 7% air voids, 10% effective binder content Base Type/Thickness: Crushed Stone/12 in, Modulus: 30,000 psi Soil Type (Layer 1): A-2-6, 18 in, Modulus: 20,500 psi Soil Type (Layer 2): A-2-6, Modulus: 20,500 psi
Design #2: Rutting Failure Mode	AC Layer 1: 2 in, Binder Grade: 76-22, 7% air voids, 10% effective binder content AC Layer 2: 6 in, Binder Grade: 70-22, 7% air voids, 10% effective binder content Base Type/Thickness: Crushed Stone/12 in, Modulus: 30,000 psi Soil Type (Layer 1): A-2-6, 18 in, Modulus: 20,500 psi Soil Type (Layer 2): A-2-6, Modulus: 20,500 psi
Design #3: JPCP Slab Cracking Failure Mode	JPCP: 10.5 in, 28-day PCC modulus of rupture: 690 psi Dowels: Yes Erodibility Index: Erosion Resistant (3) Layer 2: HMA, 3 in, Binder Grade: 64-22 Base Type/Thickness: Crushed Stone/12 in, Modulus: 25,000 psi Soil Type (Layer 1): A-6, 18 in, Modulus: 14,500 psi Soil Type (Layer 2): A-6, Modulus: 12,500 psi
Design #4: JPCP Joint Faulting Failure Mode	JPCP: 12 in, 28-day PCC modulus of rupture: 690 psi Dowels: No Erodibility Index: Erosion Resistant (3) Layer 2: HMA, 3 in, Binder Grade: 64-22 Base Type/Thickness: Crushed Stone/12 in, Modulus: 25,000 psi Soil Type (Layer 1): A-6, 24 in, Modulus: 14,500 psi Soil Type (Layer 2): A-6, Modulus: 12,500 psi

7.2.3 Pavement Design Criteria

The design criteria and the terminal values used in the analysis were based on default values included in the MEPDG version 1.1, which are listed in table 36.

TABLE 36
Design criteria used for MEPDG analysis

Design Criteria	Terminal Value
International Roughness Index	160 in/mile
AC bottom-up fatigue cracking (alligator cracking)	10%
Permanent deformation for the total pavement	0.4 in
Rigid pavement transverse slab cracking	10%
Mean joint faulting	0.15 in

In addition, the following criteria, based engineering judgment, were used to identify significant differences between MEPDG design outcomes:

- A thickness difference for the top structural layer of over 0.5 inches for the fixed pavement life designs.
- Pavement life differences of over 20 percent for the fixed pavement thickness designs.

In thickness and pavement life prediction analyses, the thickness of the top structural layer was selected to provide 15 years target design life for asphalt concrete (AC) pavements and 20 years for jointed plain concrete pavements (JPCP). These values were used for the analysis convenience and do not represent current GDOT target pavement service life values. However, it is believed that differences in pavement performance at these pavement age milestones could be used to objectively evaluate whether different NALS are likely to have a significant effect on pavement performance.

Each of the designs was executed for each case of traffic loading by changing the NALS input for the design and observing differences in pavement performance predictions or by adjusting pavement thickness to achieve fixed pavement life. Only the thickness of the surface layer was modified in each of these designs involving different NALS. Therefore, the impact of different NALS on the design could be evaluated by simply comparing the differences in the surface layer design thickness. On the other hand, increasing surface thickness is usually not the parameter to be changed in obtaining a successful design for flexible pavements that exceed the rutting criteria or the faulting criteria for rigid pavements.

7.2.4 MEPDG Models

This analysis was done using MEPDG version 1.1. Globally calibrated MEPDG models were used, with the exception of the rutting model. The AC rutting model coefficient k1 was changed to -2.4, and the coefficient k3 was changed to 0.28. The k2 coefficient was kept the same. For the subgrade rutting model, a βs1 coefficient of 0.3 was used for both granular and fine-grain models. These coefficients were determined through local calibration studies done by other State agencies and believed to provide more accurate rut prediction.

7.3 ANALYSIS OUTCOMES

7.3.1 Differences in Distress Prediction

The calculated distresses were investigated first because of their impact on the standard error of the estimate (SEE) for future calibration and resulting designs. The SEE can have a significant effect on the required thickness at varying reliability values, which would be ignored by simply comparing layer thickness for a specific design life and distress criteria.

The purpose of this effort was to determine the effect on pavement distress from NALS to determine whether there is a significant difference in the calculated distresses for both flexible and rigid pavements. The MEPDG software, version 1.1, was used to calculate pavement distress for the different NALS, everything else being equal. The pavement distresses used in the analysis include the following:

- Flexible Pavements – a conventional type of flexible pavement which includes a thick hot mix asphalt (HMA) layer with an unbound aggregate base over a subgrade soil.
    - Area fatigue or bottom-up alligator cracking – this transfer function has been used in many other flexible pavement studies. This distress is the one typically used to determine the structural thickness requirements for most flexible pavements and HMA overlays.
    - Longitudinal or top-down cracking – this transfer function and the mechanism simulated in the MEPDG for this type of cracking have been debated and questioned. This distress was not recommended for use in altering any design parameter by the American Association of State Highway and Transportation Officials (AASHTO) or the MEPDG Manual of Practice. [6] Thus, it was used primarily for information purposes.
    - Total rutting (includes rutting in the unbound and HMA layers and in the subgrade) – the transfer functions for both HMA and the unbound materials and soils have been used in many other studies and are considered reasonable. It should be noted, however, that the MEPDG software has been found to over predict rutting in the unbound and/or HMA layers. Most agencies that have sponsored local calibration have revised the plastic deformation parameters or determined the local calibration coefficients to be non-unity.
    - International Roughness Index (IRI) values – the regression equations to predict IRI over time have been found to be reasonably accurate.
- Rigid Pavements – jointed plain concrete pavement (JPCP); continuously reinforced concrete pavement (CRCP) was excluded from this analysis because Georgia does not plan to build many more CRCP.
    - Percent cracking or slabs cracked– this transfer function has been used in many other rigid pavement studies. This distress is the one typically used to determine the structural thickness requirements for most JPCP and Portland cement concrete (PCC) overlays.
    - Faulting – this transfer function has been found to be reasonable from many other studies. Faulting was analyzed for undoweled pavements only because doweled pavements did not show significant faulting in MEPDG analyses. A thicker pavement structure was used for faulting sensitivity analysis to prevent excessive faulting, since no dowels were used in this analysis.
    - IRI values – the regression equations to predict IRI over time have been found to be reasonably accurate.

Figures 25 through 30 illustrate the outcomes for the flexible pavement runs, while Figures 31 through 34 present the results for the rigid pavement runs. The following summarizes the maximum difference in the calculated values for each distress type for flexible and rigid pavements, excluding Georgia LTPP sites where highly biased values were expected due to questionable quality of load data.

Flexible Pavements:	Distress Type	Maximum Difference in Predicted Distress (Mean MEPDG values)	SEE
	Rut Depth, inches:	0.14	0.107
	Fatigue Cracking, %:	6.5	5.01
	IRI, in/mi.:	9.7	18.9

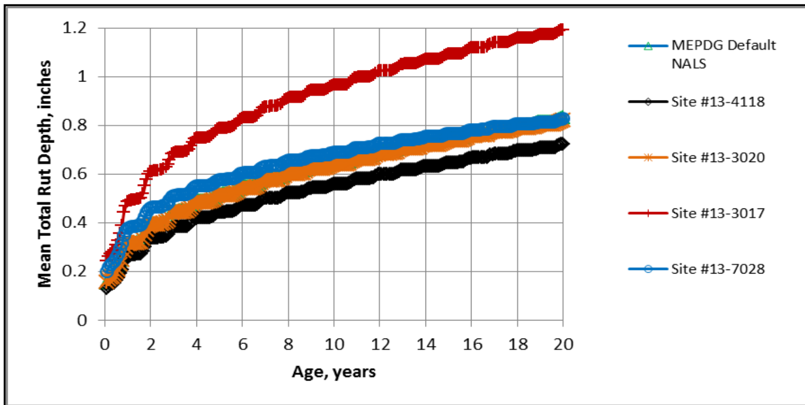
Rigid Pavements:	Distress Type	Maximum Difference in Predicted Distress (Mean MEPDG values)	
	Percent Slabs Cracked, %:	15.3	6.5
	Faulting, inches:	0.029	0.033
	IRI, in/mi.:	19.9	22.3

In summary, the differences in the calculated outcomes for 20 years between the NALS used in the analysis were found to be greater than the SEE for the following MEPDG distress prediction models: the percent slabs cracked for JPCP, fatigue cracking and rutting for flexible pavements. For these models, variations in NALS for the sites considered in the analysis are likely to contribute significantly to the SEE and, thus, could have a significant effect on thickness or material property requirements for the specific design. However, for the JPCP joint faulting and all both flexible and rigid IRI models, calculated maximum MEPDG differences were less than SEE; therefore, variations in NALS is not likely to contribute significantly to the SEE for these models and, thus, will have an insignificant effect on MEPDG predictions.

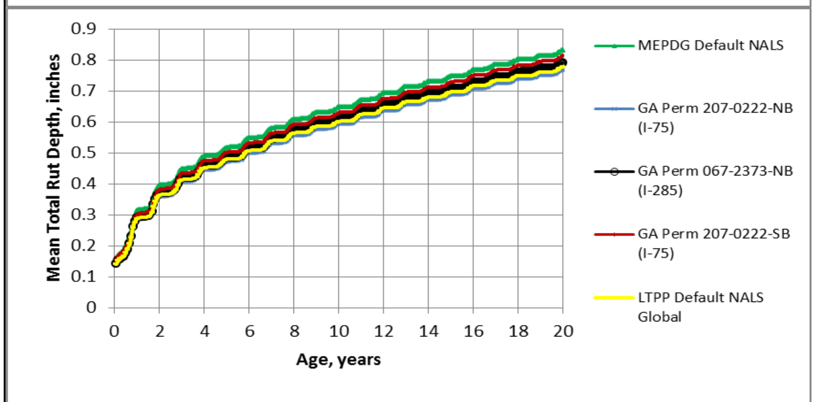
Tables 37 through 39 summarize the predicted distresses (sites sorted by increasing distress magnitudes) at 10 and 20 years for flexible and rigid pavements. All results are reported using mean distress values predicted using the MEPDG software. Some important observations from this summary and analysis of NALS impact on MEPDG outcomes are listed below:

- There is a small difference in predicted distresses between the NALS for Sites 067-2373 on I-285 NB and 207-0222 on I-75 SB from the Georgia permanent WIM sites. There are modest differences between these NALS and NALS for Site 207-0222 on I-75 NB for cracking distress prediction for both flexible and rigid pavements.
- NALS from the portable WIM sites classified as the lightest and the heaviest resulted in significant differences in the MEPDG distress predictions. Modest differences were also observed between NALS pairs classified as Moderate and Heavy 1, and Heavy 1 and Heavy 2.
- The new LTPP default NALS generated from the LTPP TPF 5(004) study produced different levels of distresses. This finding was expected because the LTPP default NALS were developed to represent a variety of loading conditions.
- LTPP NALS default called “Global” produced less distress than the original global default NALS included in the MEPDG software.
- NALS from the LTPP TPF 5(004) study for two Florida sites and one Virginia site represented three different loading conditions: LTPP NALS – Light (FL non-interstate site), LTPP NALS – Heavy 1 (VA site), and LTPP NALS – Heavy 2 (FL interstate site). These sites produced significantly different MEPDG distresses, especially when Light and Heavy 2 loading conditions were compared.

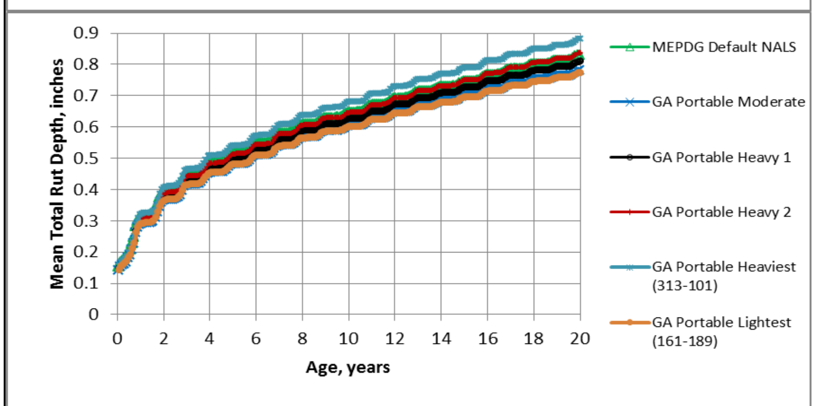
- The MEPDG outcomes for the global default NALS determined initially under NCHRP Project 1-37A produce higher distresses than the majority of NALS tested. This NALS does not have the largest percentage of heavy loads but does have the larger percentage of overloads compared to other NALS developed based on data from the permanent WIM sites. This finding indicates high sensitivity of MEPDG pavement performance prediction models to overloads. The results for the original MEPDG default and the new LTPP Heavy 2 default were close.
- NALS has little effect on the IRI for both flexible and rigid pavements. Load-related cracking is the MEPDG distress that is more affected by variations in the NALS or percentage of overloads.
- The NALS prepared from the historical WIM data collected at LTPP site 13-3017 is believed to be highly biased towards the higher loads based on the higher distresses calculated for this distribution than for all of the other distributions. The LTPP historical data for Georgia sites were used to assess the differences in MEPDG outcomes if data from a poorly calibrated site or a site with temperature-sensitive WIM sensors. These differences were found the most significant among all sites tested. Site 13-3017 is not recommended for use in developing default NALS for use in calibration and design. The other three sites may be used with caution, as the quality of the data is unknown and load distributions deviate from those expected for Class 9 vehicles, unless it can be confirmed that the WIM data represents accurate axle load data.
- A relationship between the percentages of heavy loads in NALS and MEPDG outcomes was investigated, using several definitions of "heavy loads." The highest correlation was found using the statistic representing cumulative percent of loads above 80 percent of the legal load limit. Table 40 shows the percentage of heavy loads for the NALS included in the analysis to cover the range of values. A heavy load for this example is defined as equal to or more than 80 percent of legal limit, which is 16 kips on a single axle and 27 kips on a tandem axle. The percentage of heavy loads was found to be a simple and reasonable discriminator of the effect of NALS on the MEPDG outcomes. This statistic is especially useful if the percentages of loads above legal load limit are similar between different NALS. However, if a given NALS has higher percentage (by 5 percent or more) of overloads compared to the other NALS, this NALS will be more damaging even if the total percentage of heavy loads for this NALS is lower compared to the other NALS.



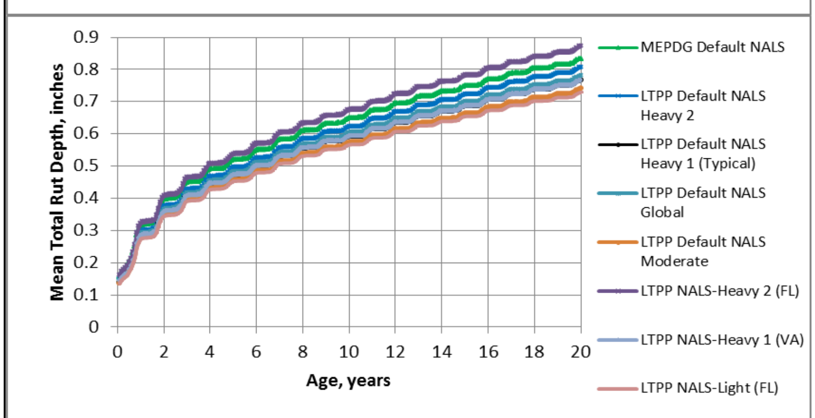
Mean total rut depth predicted using the NALS from selected LTPP sites in Georgia.



Mean total rut depth predicted using NALS from permanent WIM sites in Georgia.

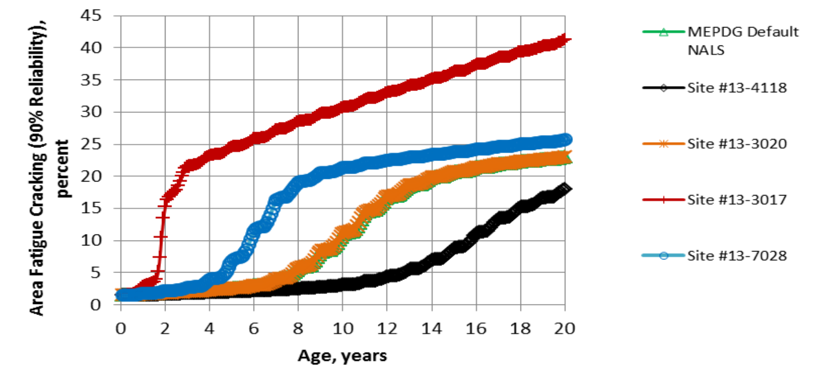


Mean total rut depth predicted using NALS from portable WIM sites in Georgia.

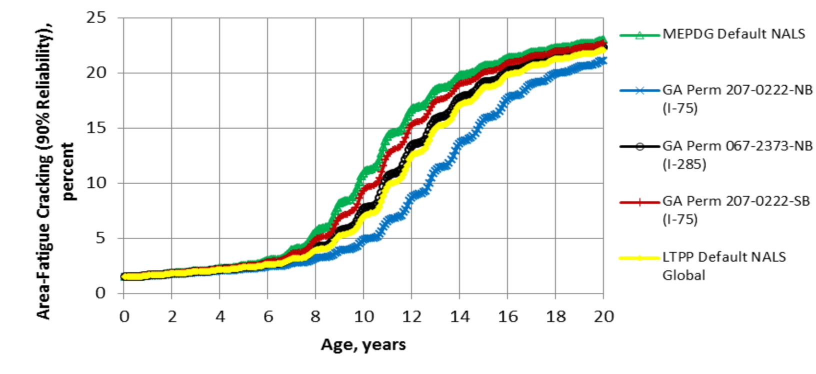


Mean total rut depth predicted using NALS from LTPP WIM traffic pooled study.

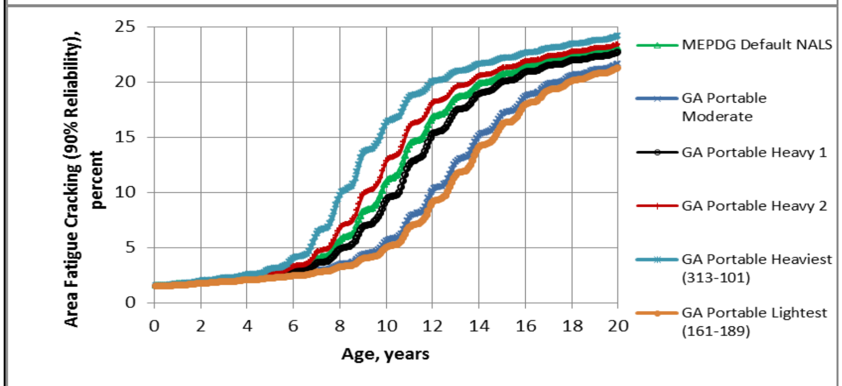
FIGURE 25
Rutting predicted with NALS from different sources



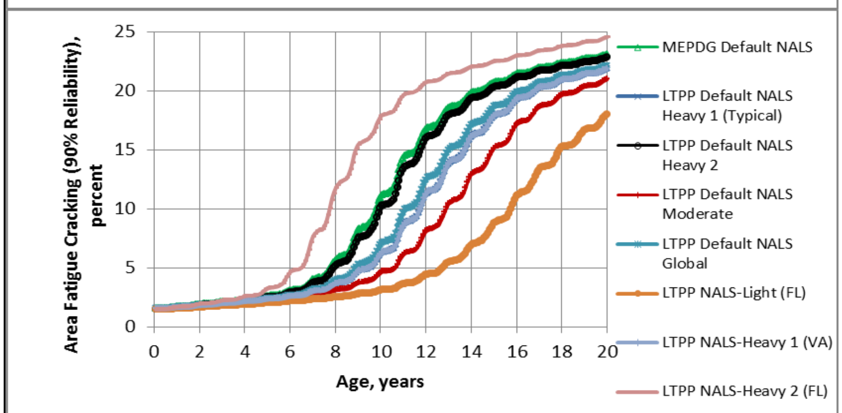
Fatigue cracking predicted for 90% reliability using the NALS from selected LTPP sites in



Fatigue cracking predicted for 90% reliability using NALS from permanent WIM sites in Georgia.

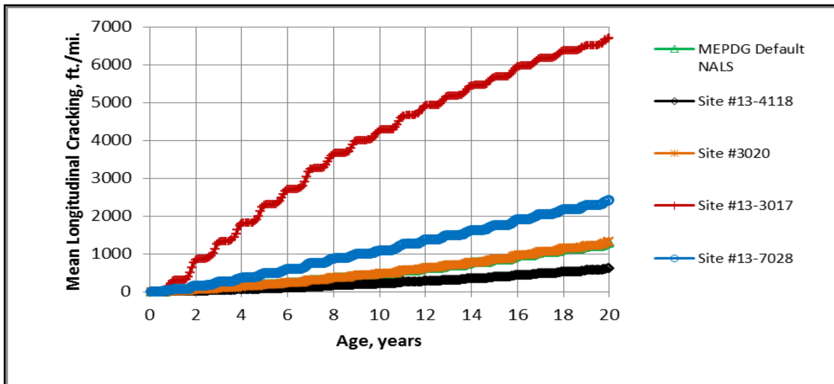


Fatigue cracking predicted for 90% reliability using NALS from portable WIM sites in Georgia.

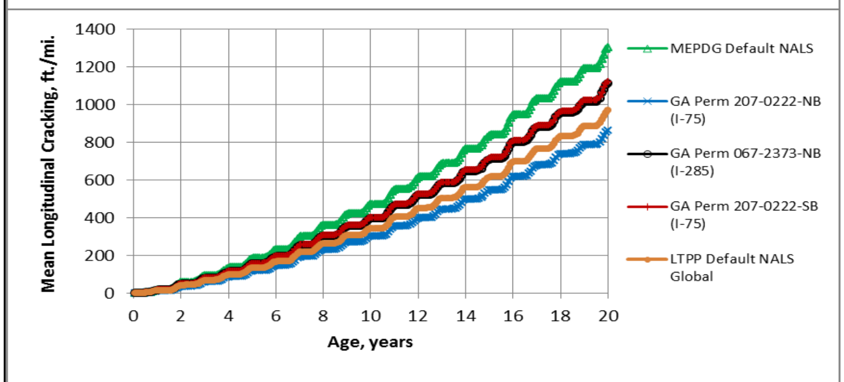


Fatigue cracking predicted for 90% reliability using NALS from LTPP WIM traffic pooled study.

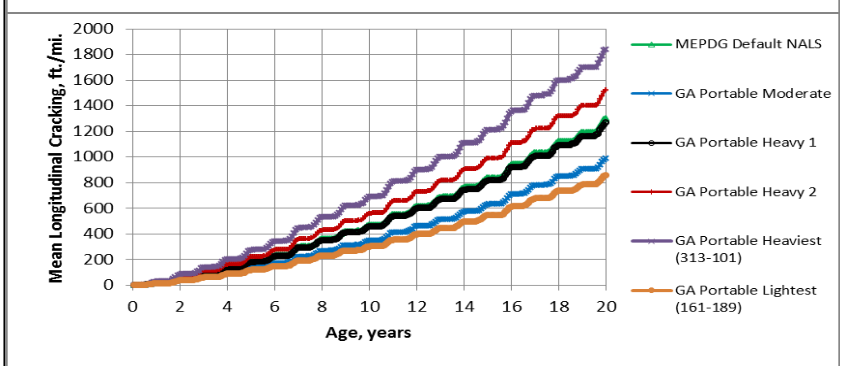
FIGURE 26
Area fatigue (bottom-up) cracking predicted with NALS from different sources



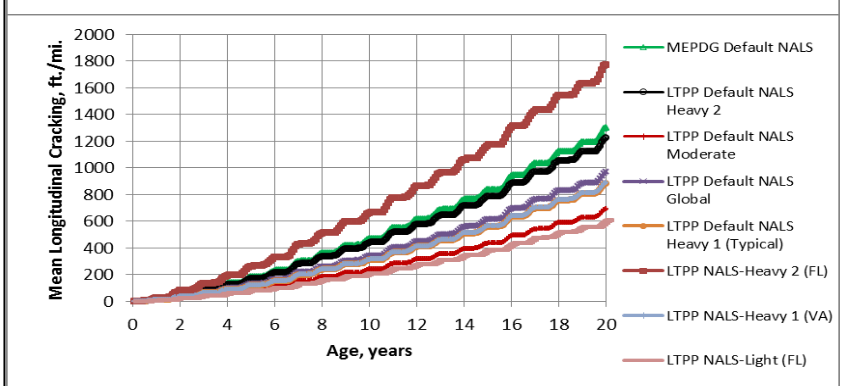
Mean longitudinal cracking predicted using the NALS from selected LTPP sites in Georgia.



Mean longitudinal cracking predicted using NALS from permanent WIM sites in Georgia.



Mean longitudinal cracking predicted using NALS from portable WIM sites in Georgia.



Mean longitudinal cracking predicted using NALS from LTPP WIM traffic pooled study.

FIGURE 27
Longitudinal (top-down) cracking predicted with NALS from different sources

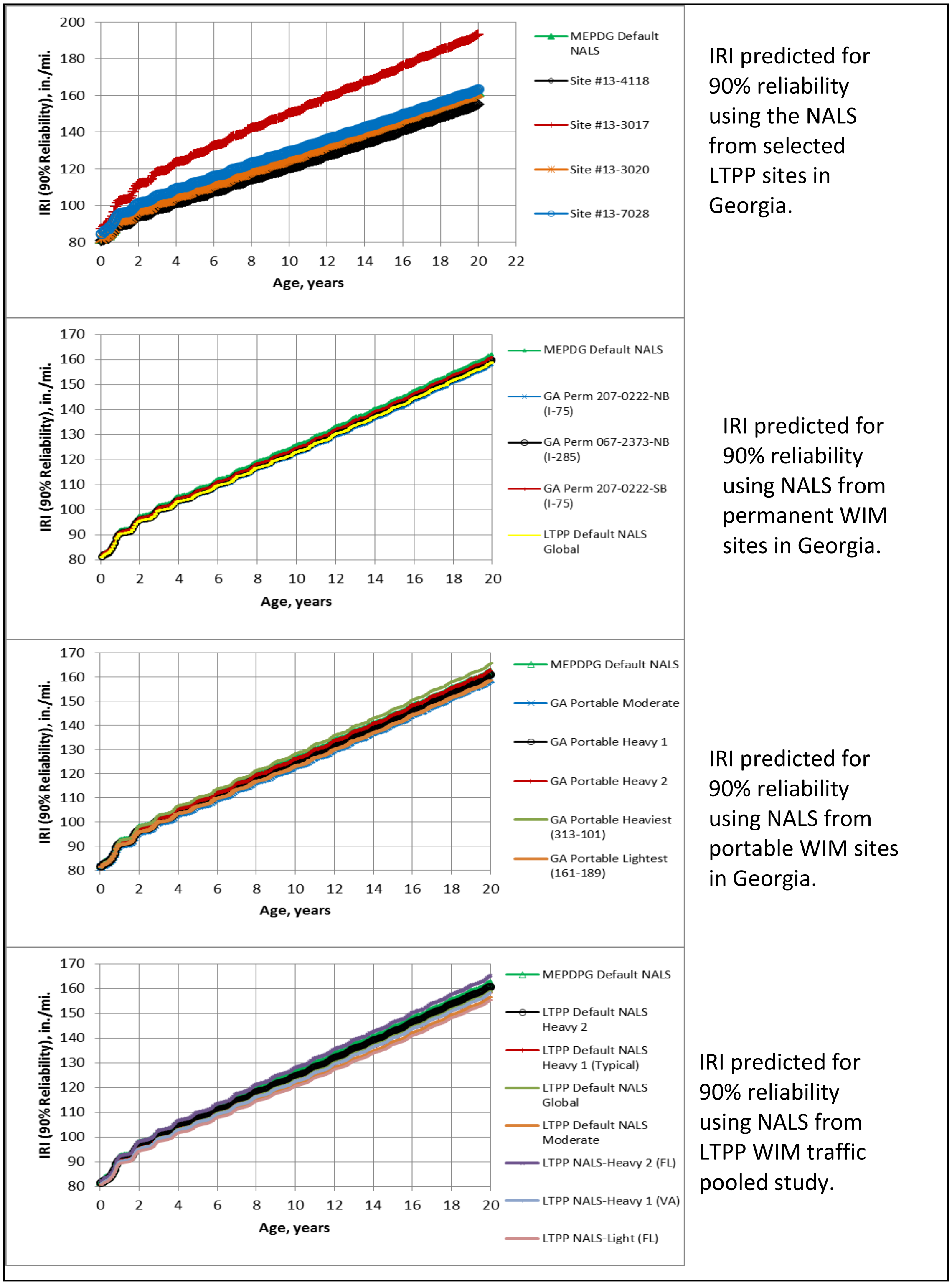
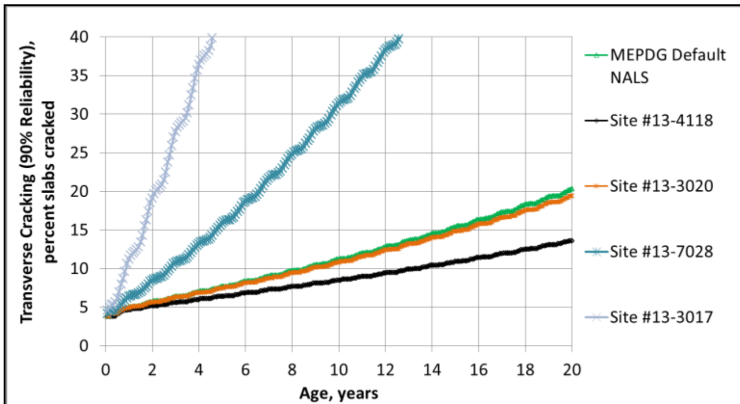
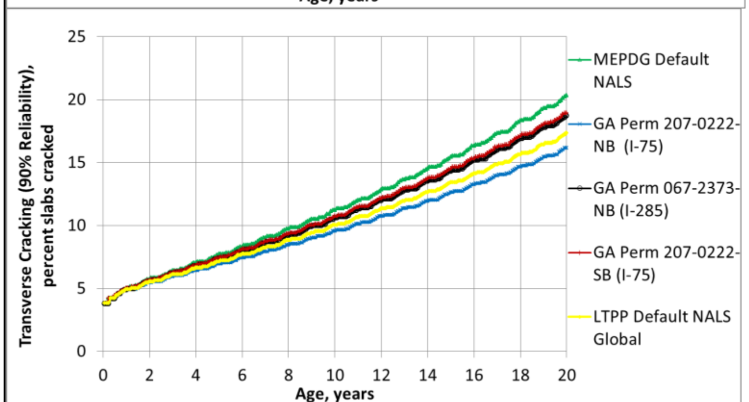


FIGURE 28

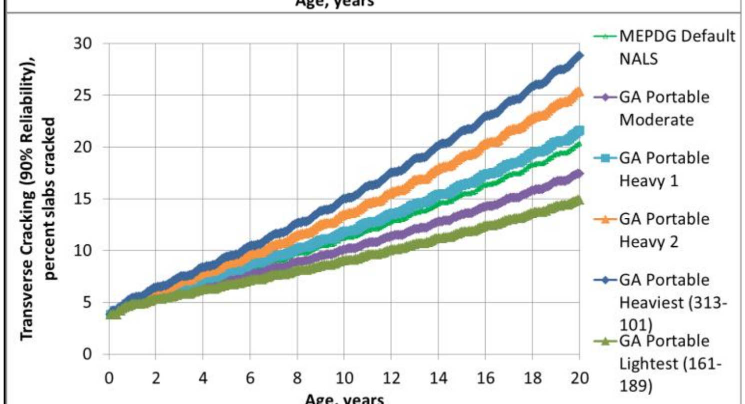
Roughness or IRI (flexible pavement) predicted with NALS from different sources



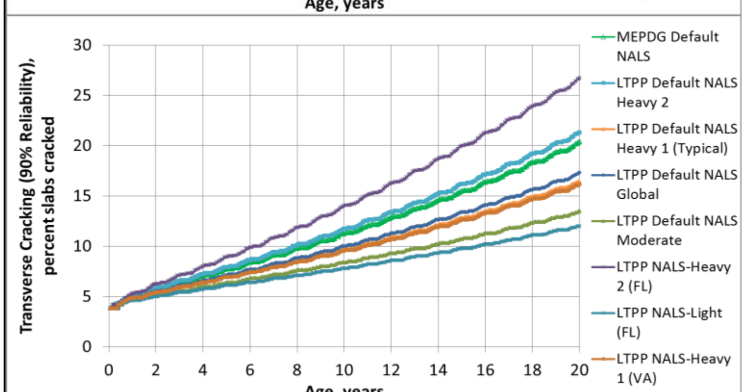
Slab Cracking predicted for 90% reliability using the NALS from selected LTPP sites in Georgia.



Slab Cracking predicted for 90% reliability using NALS from permanent WIM sites in Georgia.

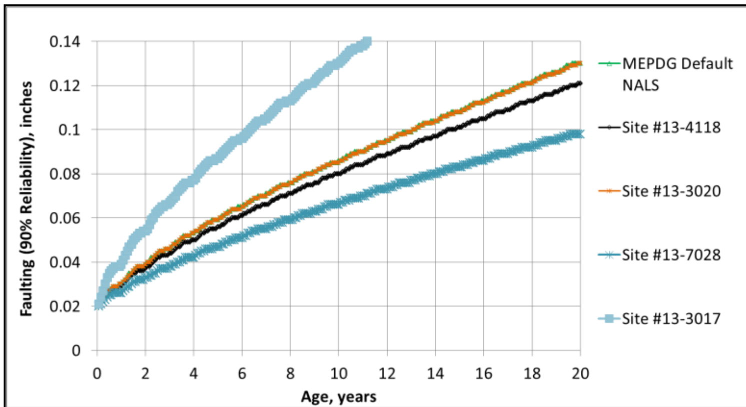


Slab Cracking predicted for 90% reliability using NALS from portable WIM sites in Georgia.

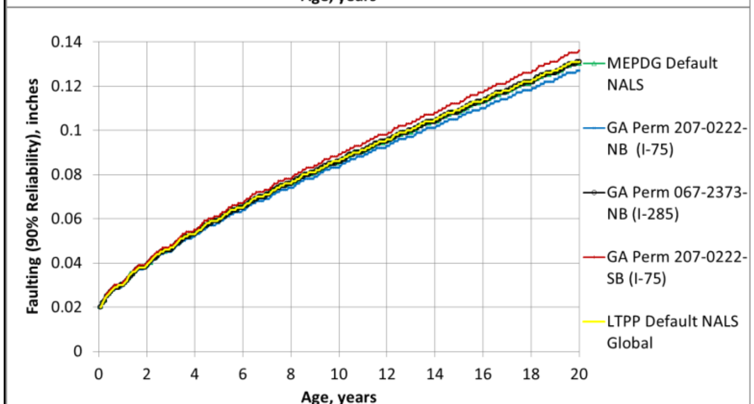


Slab cracking predicted for 90% reliability using NALS from LTPP WIM traffic pooled study.

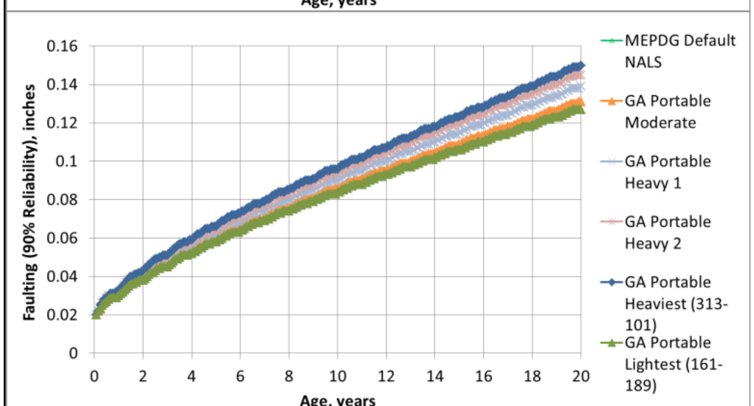
FIGURE 29
Percent cracked slabs (doweled pavement) predicted with NALS from different sources



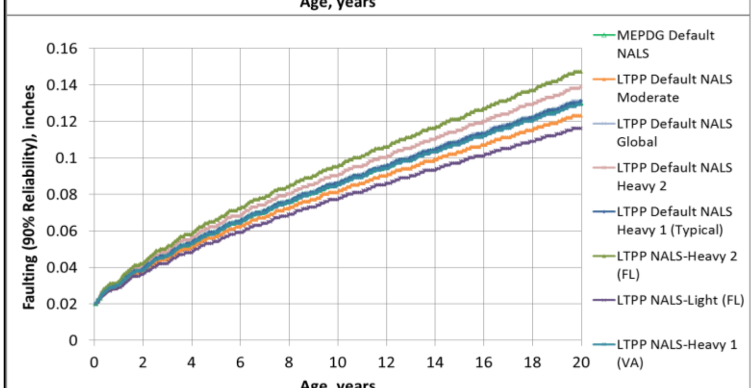
Faulting predicted for 90% reliability using the NALS from selected LTPP sites in Georgia.



Faulting predicted for 90% reliability using NALS from permanent WIM sites in Georgia.

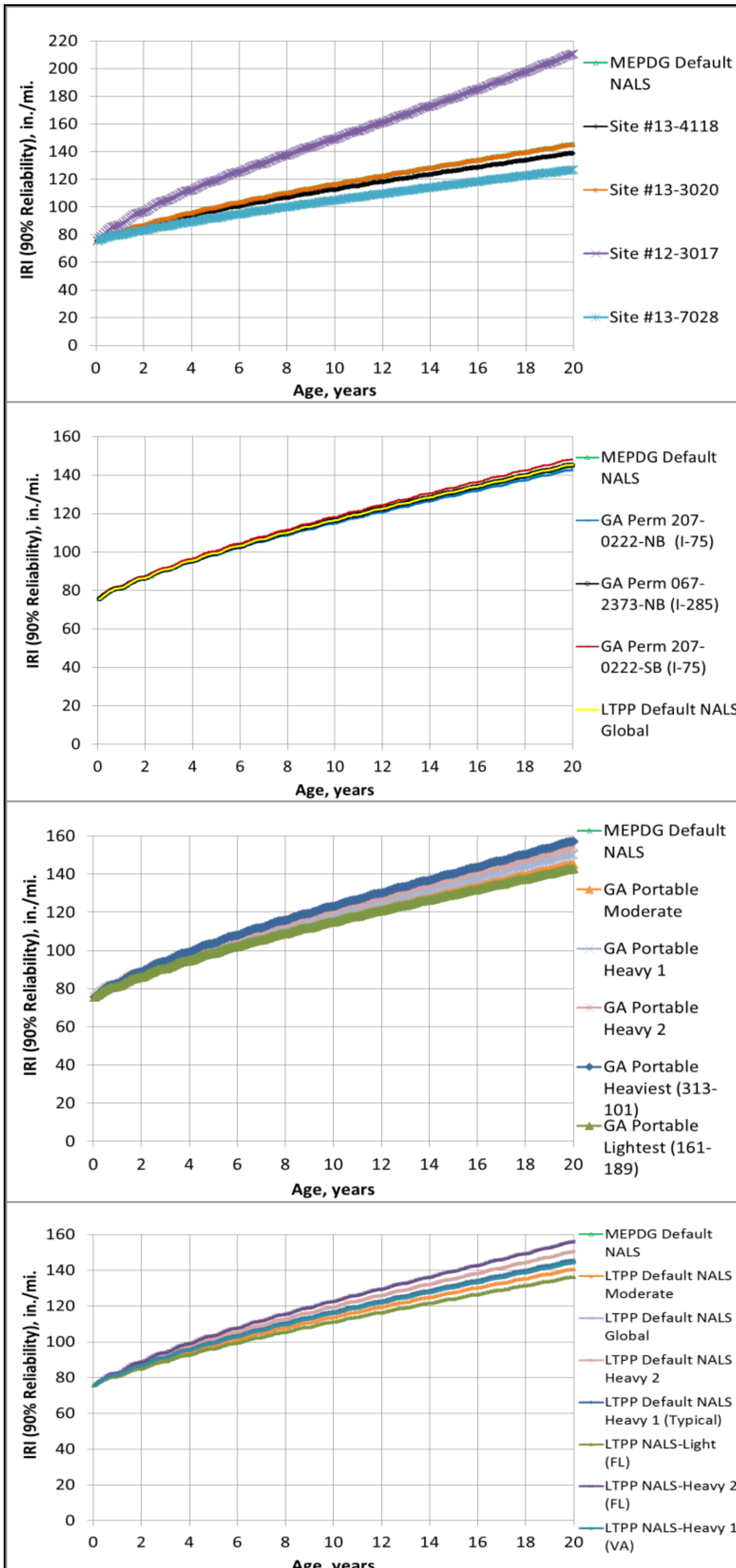


Faulting predicted for 90% reliability using NALS from portable WIM sites in Georgia.



Faulting predicted for 90% reliability using NALS from LTPP WIM traffic pooled study.

FIGURE 30
Faulting (non-doweled JPCP) predicted with NALS from different sources



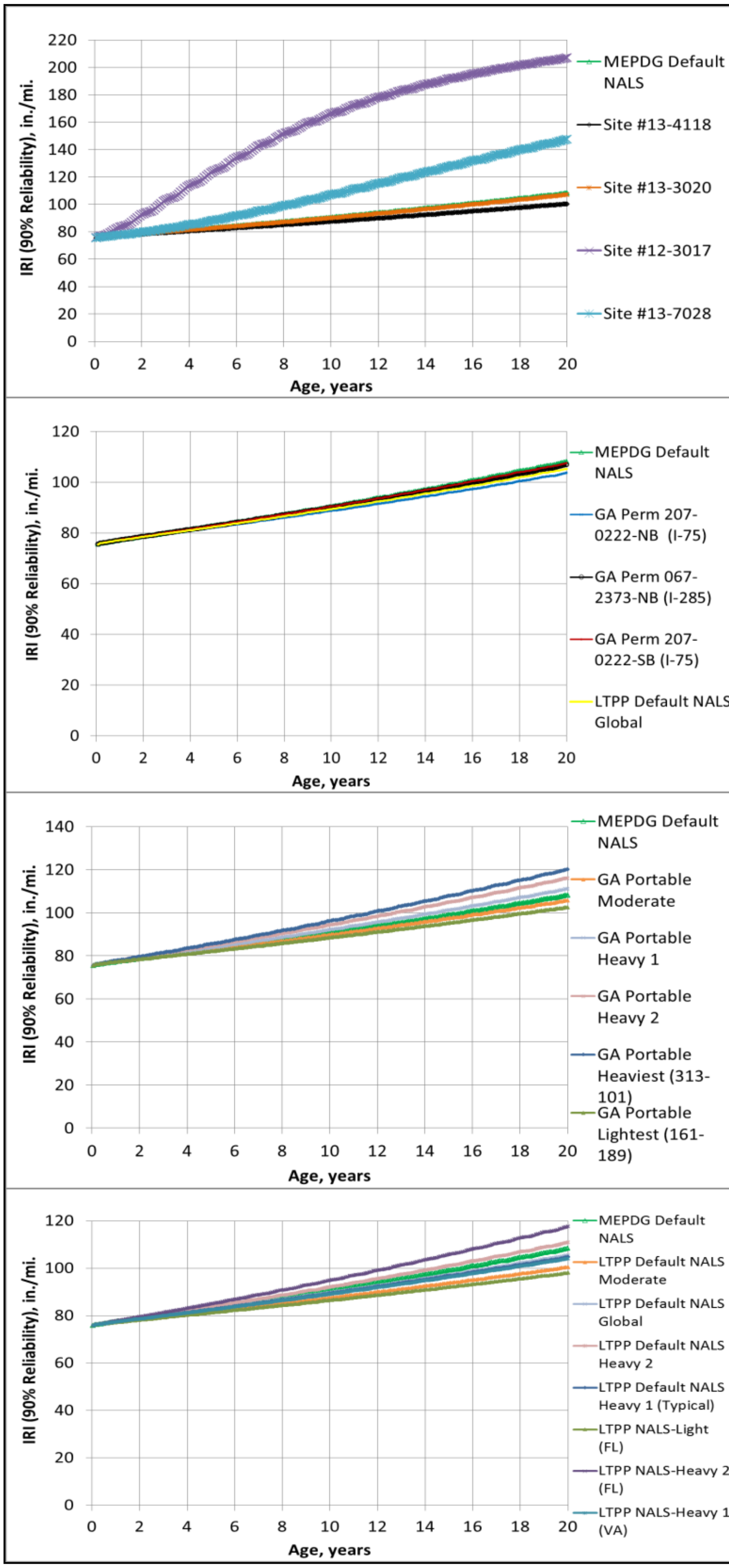
IRI predicted for 90% reliability using the NALS from selected LTPP sites in Georgia.

IRI predicted for 90% reliability using NALS from permanent WIM sites in Georgia.

IRI predicted for 90% reliability using NALS from portable WIM sites in Georgia.

IRI predicted for 90% reliability using NALS from LTPP WIM traffic pooled study.

FIGURE 31
IRI (non-doweled JPCP) predicted with NALS from different sources



IRI predicted for 90% reliability using the NALS from selected LTPP sites in Georgia.

IRI predicted for 90% reliability using NALS from permanent WIM sites in Georgia.

IRI predicted for 90% reliability using NALS from portable WIM sites in Georgia.

IRI predicted for 90% reliability using NALS from LTPP WIM traffic pooled study.

FIGURE 32
IRI (doweled pavement) predicted with NALS from different sources

TABLE 37
Summary of distresses predicted at 10 and 20 years for the flexible pavements

NALS Designation	10 years			20 years		
	Alligator Cracking, %	Rut Depth, inches	IRI, in/mi	Alligator Cracking, %	Rut Depth, inches	IRI, in/mi
13-4118 (GA LTPP portable)	3.1	0.56	120.1	18.0	0.72	155.0
LTPP NALS-Light (FL)	3.1	0.71	120.6	18.0	0.73	155.3
LTPP NALS Default – Moderate	4.5	0.57	121.2	20.9	0.74	156.4
GA Permanent 207-0222-NB (I-75)	4.8	0.59	122.2	21.1	0.77	157.9
GA Portable Lightest (161-189)	5.0	0.60	122.7	21.3	0.77	158.3
GA Portable Moderate	5.6	0.60	123	21.5	0.78	158.8
LTPP NALS Default - Heavy 1 (Typical)	6.12	0.59	122.4	21.8	0.77	158.1
LTPP NALS-Heavy 1 (VA)	6.12	0.74	122.4	21.8	0.77	158.1
LTPP NALS Default – Global	6.9	0.60	123	22.1	0.78	158.9
GA Permanent 067-2373-NB (I-285)	7.6	0.61	123.5	22.3	0.79	159.6
GA Portable Heavy 1	9.3	0.63	124.5	22.7	0.81	160.8
GA Permanent 207-0222-SB (I-75)	9.3	0.63	124.6	22.7	0.81	160.9
LTPP NALS Default - Heavy 2	10.1	0.62	124.3	22.8	0.80	160.6
MEPDG Defaults	**10.9**	**0.65**	**125.7**	**23.0**	**0.83**	**162.0**
13-3020 (GA LTPP permanent)	11.0	0.64	125.3	23.0	0.82	161.4
GA Portable Heavy 2	12.8	0.65	125.8	23.3	0.84	162.5
GA Portable Heaviest (313-101)	16.2	0.68	128.1	24.1	0.88	165.3
LTPP NALS-Heavy 2 (FL)	17.8	0.84	127.9	24.5	0.87	165.0

TABLE 38
Summary of distresses predicted at 10 and 20 years for doweled rigid pavements

NALS Designation	10 years		20 years	
	Percent Slabs Cracked, %	IRI, in/mi	Percent Slabs Cracked, %	IRI, in/mi
LTPP NALS-Light (FL)	7.8	86.2	12	97.8
LTPP NALS Default - Moderate	8.4	87.3	13.5	100.2
13-4118 (GA LTPP portable)	8.5	87.4	13.6	100.3
GA Portable Lightest (161-189)	9	88.3	14.9	102.5
GA Permanent 207-0222-NB (I-75)	9.5	88.7	16.1	103.6
LTPP NALS-Heavy 1 (VA)	9.5	88.8	16.1	103.8
LTPP NALS Default - Heavy 1 (Typical)	9.7	89.2	16.4	104.5
LTPP NALS Default - Global	10	89.5	17.3	105.3
GA Portable Moderate	10.1	89.7	17.4	105.7
GA Permanent 067-2373-NB (I-285)	10.6	90.1	18.7	106.9
GA Permanent 207-0222-SB (I-75)	10.7	90.5	18.9	107.5
13-3020 (GA LTPP permanent)	10.8	90	19.4	107.1
MEPDG Defaults	**11.2**	**90.4**	**20.3**	**108.1**
LTPP NALS Default - Heavy 2	11.7	91.8	21.3	110.7
GA Portable Heavy 1	11.8	92	21.6	111
GA Portable Heavy 2	13.5	94.2	25.4	116
LTPP NALS-Heavy 2 (FL)	14	94.7	26.7	117.4
GA Portable Heaviest (313-101)	15	96.1	28.8	120.1

TABLE 39

Summary of distresses predicted at 10 and 20 years for non-doweled rigid pavements

NALS Designation	10 years		20 years	
	Faulting, in	IRI, in/mi	Faulting, in	IRI, in/mi
LTPP NALS-Light (FL)	0.077	110.8	0.116	135.9
LTPP NALS Default - Moderate	0.081	113.4	0.123	140.2
13-4118 (GA LTPP portable)	0.080	112.4	0.121	138.7
GA Portable Lightest (161-189)	0.084	114.8	0.127	142.8
GA Permanent 207-0222-NB (I-75)	0.083	114.7	0.127	142.5
LTPP NALS-Heavy 1 (VA)	0.085	115.5	0.129	143.9
LTPP NALS Default - Heavy 1 (Typical)	0.086	116.1	0.131	144.9
LTPP NALS Default - Global	0.086	116.4	0.131	145.3
GA Portable Moderate	0.086	116.2	0.131	145
GA Permanent 067-2373-NB (I-285)	0.086	116.3	0.131	145.1
GA Permanent 207-0222-SB (I-75)	0.089	117.9	0.136	148.1
13-3020 (GA LTPP permanent)	0.085	115.9	0.130	144.6
MEPDG Defaults	**0.086**	**116.1**	**0.130**	**145**
LTPP NALS Default - Heavy 2	0.09	119.1	0.139	150
GA Portable Heavy 1	0.09	119.1	0.139	150
GA Portable Heavy 2	0.094	121.4	0.145	154.2
LTPP NALS-Heavy 2 (FL)	0.095	122.2	0.147	155.6
GA Portable Heaviest (313-101)	0.096	123	0.15	157

TABLE 40

Percentage of the NALS with heavy loads on the single and tandem axles

Site or NALS Designation	Percentage of Heavy Loads		Total % of Heavy Single and Tandem
	Single Axle; 16+ kips	Tandem Axle; 27+ kips	
LTPP NALS-Light (FL)	2.9	21.6	13.2
GA Portable Lightest (161-189)	5.9	23.7	15.2
13-4118 (GA LTPP portable)	2.2	29.9	16.6
LTPP NALS Default - Moderate	7.1	30.1	19.1
13-3020 (GA LTPP permanent)	5.3	32.6	19.5
GA Portable Moderate	4.5	33.7	19.7
GA Permanent 207-0222-NB (I-75)	4.4	35.4	20.5
GA Permanent 207-0222-SB (I-75)	4.8	36.8	21.4
LTPP NALS - Heavy 1 (VA)	7.1	35.1	21.6
MEPDG Defaults	**6.2**	**36.2**	**21.8**
GA Permanent 067-2373-NB (I-285)	4.4	38.6	22.2
LTPP NALS Default - Heavy 1 (Typical)	7.2	37.4	22.9
LTPP NALS Default - Global	**7.3**	**38.6**	**23.5**
GA Portable Heavy 1	5.8	43.1	25.2
LTPP NALS Default - Heavy 2	7.2	47.5	28.1
GA Portable Heavy 2	6.5	53	30.7
LTPP NALS - Heavy 2 (FL)	10.1	50.5	31
GA Portable Heaviest (313-0101)	7	57.4	33.2

7.3.2 Differences in Pavement Life Predictions

The results of MEPDG distress prediction sensitivity analysis showed that NALS could have significant effect on MEPDG outcomes for some distress models. Therefore, the availability of defaults representing different loading conditions may lead to more accurate designs compared to using of only one set of defaults for design. To further investigate this, a set of analyses involving pavement life predictions using different NALS was conducted. NALS selected for this analysis included NALS based on GDOT permanent and portable WIM data and NALS defaults from LTPP and Florida studies that represent different loading conditions. All other pavement design inputs were the same as in the analysis of distresses.

For this analysis, pavement life was determined as a length of time that it took for the leading distress to reach its terminal value for the selected level of reliability (90 percent). The results of the pavement life predictions are shown in table 41.

TABLE 41
Pavement life predictions from MEPDG analysis

Loading Condition	AC Pavement		JPCP Pavement	
	Design #1: Failure due to Alligator Cracking	Design #2: Failure due to Rutting	Design #3: Failure due to Slab Cracking	Design #4: Failure due to Joint Faulting
Georgia Portable Lightest (Site 161-189)	16.3	15.8	22.0	25.1
Georgia Portable Moderate	15.8	15.0	18.8	26.3
Georgia Portable Heavy 1	13.8	12.8	14.9	24.2
Georgia Portable Heavy 2	12.3	11.8	12.7	22.2
Georgia Portable Heaviest (Site 313-101)	10.9	9.8	10.8	20.0
Georgia Permanent Site 207-0222; Lane 1, NB	16.7	15.9	20.6	25.3
Georgia Permanent Site 207-0222; Lane 2, southbound	13.8	12.8	16.8	22.9
Georgia Permanent Site 067-2373; Lane 2, northbound	14.7	13.9	17.4	24.1
LTPP Global Default	14.8	14.8	18.9	24.0
LTPP Moderate Default	16.9	17.8	25.6	26.3
LTPP Heavy 1 (Typical) Default	15.6	15.8	20.0	22.2
LTPP Heavy 2 Default	13.0	12.8	14.8	22.1
FL Urban Interstates Default	16.1	15.8	18.9	22.5
FL Rural Interstates Default	15.1	15.8	16.8	22.5

Some important observations from this analysis of NALS impact on MEPDG outcomes are listed below:

- Among the Georgia loading conditions tested, the maximum difference in predicted pavement life was 53 percent for pavements that failed due to alligator cracking, 62 percent for pavements that failed due to rutting, 90 percent for pavements that failed due to JPCP slab cracking, and 26 percent for pavements that failed due to JPCP joint faulting. This finding supports the need for accurate loading characterization and development of multiple defaults representing different loading conditions.

- For the three loading categories identified based on Georgia portable WIM data (Moderate, Heavy 1, and Heavy 2), significant differences (over 20 percent) in pavement life were observed between the Moderate and Heavy 2 loading categories for all modes of failure, except for joint faulting. Significant differences in pavement life between the Moderate and Heavy 1 loading categories were also observed for JPCP slab cracking. No significant differences in pavement life were observed between the Heavy 1 and Heavy 2 loading categories.
- For Georgia permanent WIM sites, significant differences (up to 24 percent) in pavement life were observed for Site 207-0222 between the northbound and southbound directions for all modes of failure, except for joint faulting. This finding supports the need to identify design lane for pavement design based on site-specific loading information, especially for high importance projects.
- The results in table 41 also indicate that Georgia loading conditions captured through portable and permanent WIM data resulted in a difference in pavement life prediction similar to the differences observed for cases where various LTPP defaults were used. Florida defaults for rural and urban interstate roads resulted in smaller differences in pavement life predictions compared to the range of outcomes observed in LTPP or Georgia cases.

7.3.3 Differences in Pavement Thickness Predictions

Similar to the pavement life analysis approach, a set of analyses involving pavement thickness prediction was conducted. NALS selected for this analysis included NALS based on GDOT permanent and portable WIM data and NALS defaults from LTPP and Florida studies that represent different loading conditions. With the exception of the thickness of the top structural layer, all pavement design inputs were the same as in the analysis of distresses.

Differences in the thickness of the top structural layer were used to design pavements for the same fixed pavement life values selected for the analysis (15 years for flexible and 20 years for rigid pavements were used in the analysis for convenience). A reliability level of 90 percent was used in predicting pavement performance. The results of thickness prediction for the top structural layer are shown in table 42.

TABLE 42
Pavement thickness predictions from MEPDG analysis

Loading Condition	AC Pavement		JPCP Pavement	
	Design #1: Failure due to Alligator Cracking	Design #2: Failure due to Rutting	Design #3: Failure due to Slab Cracking	Design #4: Failure due to Joint Faulting
Georgia Portable Lightest (Site 161-189)	8.4	7	10.4	11.6
Georgia Portable Moderate	8.4	7	10.4	11.6
Georgia Portable Heavy 1	8.7	7.3	10.8	11.7
Georgia Portable Heavy 2	8.9	7.6	11	11.9
Georgia Portable Heaviest (Site313-101)	9.1	8.5	11.2	12
Georgia Permanent Site 207-0222; Lane 1, NB	8.3	7	10.5	11.6
Georgia Permanent Site 207-0222; Lane 2, SB	8.7	7.4	10.7	11.7
Georgia Permanent Site 067-2373; Lane 2, NB	8.6	7.2	10.7	11.7
LTPP Global	8.6	7.1	10.6	11.7
LTPP Moderate	8.3	6.1	10.4	11.5
LTPP Heavy 1 (Typical)	8.5	7	10.5	11.7
LTPP Heavy 2	8.8	7.4	10.9	11.8
FL Urban Interstates	8.4	7	10.6	11.7
FL Rural Interstates	8.5	7	10.7	11.7

Some important observations from this analysis of NALS impact on MEPDG outcomes are listed below:

- Among Georgia loading conditions tested, the following maximum differences in the predicted thickness of the pavement's top structural layer were observed: 0.7 inch for pavements that failed due to alligator cracking, 1.5 inches for pavements that failed due to rutting, 0.8 inch for pavements that failed due to JPCP slab cracking, and 0.4 inch for pavements that failed due to JPCP joint faulting. Using a 0.5-inch criterion of significant difference, all distresses except joint faulting showed significant difference in thickness prediction. However, these differences are not as dramatic as the differences observed in pavement life prediction, which was an expected outcome. It is possible that as more accurate loading data become available, the difference in thickness between the different loading categories may become more sensitive to changes in loading conditions.
- For the three loading categories (Moderate, Heavy 1, and Heavy 2) identified based on Georgia portable WIM data, significant differences in top structural layer thickness were observed between Moderate and Heavy 2 loading categories for rutting and JPCP slab cracking failure modes. No significant differences in top layer thickness were observed between Moderate and Heavy 1 or between Heavy 1 and Heavy 2 loading categories.
- For Georgia permanent WIM sites, no significant differences (over 0.5 inch) in top structural layer thickness were observed.
- Using LTPP loading defaults, significant differences in top structural layer thickness were observed between Moderate and Heavy 2 loading defaults for all failure modes, except joint faulting. Significant differences were also observed between Moderate and Heavy 1 loading defaults for AC alligator cracking and rutting modes of failure. No significant differences were observed between outcomes using the two Florida loading defaults.

7.4 CONCLUSIONS AND RECOMMENDATIONS

7.4.1 Sensitivity of MEPDG Outcomes to NALS

- Analysis of traffic loading based on GDOT WIM data indicated that a significant range of traffic loading conditions may be observed on Georgia roads.
- Using globally calibrated MEPDG models subjected to Georgia climatic conditions and typical Georgia pavement designs for high truck volume roads, over 50 percent difference in pavement design life was observed when different NALS observed in Georgia were used, even though the total number and type of trucks was kept the same in all design cases (see table 41).
- At the same time, the predicted difference in pavement thickness was less than 1 inch, and in some cases less than 0.5 inches, for the loading cases tested. Since these differences are not as significant as service life differences, further investigation using locally calibrated MEPDG pavement performance models would be necessary to further understand MEPDG sensitivity to the Georgia NALS and come up with the final recommendation on the number and type of NALS defaults to be used for routine MEPDG-based pavement designs in Georgia.
- Because different NALS inputs could result in significantly different pavement service life, it is recommended that multiple defaults representing different loading conditions observed on Georgia roads be used, especially during the local calibration of the transfer functions.

7.4.2 Applicability of Defaults Developed by Other Agencies

- Given the limited availability of high-quality WIM data in Georgia, data from other sources are recommended to be used as a short-term solution for NALS defaults and local calibration, until GDOT installs a sufficient number of permanent WIM sites and implements quality control and calibration procedures to assure quality of WIM data for pavement design.
- Through comparison of the MEPDG predictions (including distress, pavement service life, and pavement structural thickness) using available Georgia WIM data, LTPP defaults, and Florida defaults, it was found that the range of MEPDG design predictions based on Georgia data can be modeled using various LTPP defaults, while the Florida defaults did not produce significantly different MEPDG predictions. This is likely because LTPP defaults represent both interstate and non-interstate roads while only Florida default NALS interstate defaults were used in the analysis. Therefore, the LTPP defaults result in greater differences and are believed to be more applicable to Georgia loading categories than the Florida defaults.
- Based on loads carried by Class 9 vehicles, loading conditions observed at Georgia WIM sites are similar to those described in the new LTPP NALS defaults:
  - Moderate – about one-third of Class 9 trucks are heavily loaded.
  - Heavy 1 – more than one-third but less than one-half of the Class 9 trucks are heavily loaded.
  - Heavy 2 – about half of Class 9 trucks are heavily loaded.
- Because LTPP loading defaults were developed using high-quality WIM data and represent loading conditions similar to the ones observed on Georgia roads, it is recommended that the new LTPP NALS defaults are to be considered as interim default

NALS for Georgia MEPDG implementation, until sufficient Georgia-specific high quality WIM data are collected to develop State-specific defaults.

- All cases of LTPP NALS defaults produced significantly different MEPDG pavement designs when LTPP Moderate and Heavy 2 defaults were used, except for the design that failed due to joint faulting. The results were mixed when pavement designs using either Moderate and Heavy 1 or Heavy 1 and Heavy 2 defaults were compared.
- For the present, it is recommended that all three LTPP defaults be considered for use during local calibration and MEPDG implementation, in addition to the Georgia-developed NALS, but that GDOT should revisit this subject when Georgia permanent WIM data (for development of the defaults) become available.
- The recommendation for future use of the NALS derived under LTPP or the GDOT study should be based on the local calibration study being conducted under another MEPDG project sponsored by GDOT.

7.4.3 Use of GDOT'S WIM data for MEPDG

WIM data from permanent WIM sites:

- Currently, Georgia has very few permanent WIM sites. However, data analysis indicates that NALS based on WIM data from the Georgia pilot permanent WIM sites show many similarities to the default NALS developed through the LTPP TPF 5(004) study. Both GDOT and the LTPP TPF 5(004) study use similar WIM equipment and similar calibration procedures, so the reliability of these WIM data is expected to be high. Based on the observed similarities in NALS, it is also possible to conclude that traffic loading conditions observed on Georgia interstates are similar to the conditions represented by the new LTPP NALS defaults. NALS based on data collected at Georgia pilot permanent WIM sites were found to be similar to the new LTPP defaults NALS:
    - NALS for site 067-2373-NB (on I-285) results in similar outcomes (distresses) to LTPP Global NALS defaults.
    - NALS for site 207-0222-NB (on I-75) results in similar outcomes (distresses) to LTPP Moderate NALS defaults for flexible pavements and similar to LTPP Heavy 1 NALS for rigid pavements.
    - NALS for site 207-0222-SB (on I-75) results in similar outcomes (distresses) to LTPP Heavy 2 NALS defaults for flexible pavements and similar to LTPP Global NALS for rigid pavements.

WIM data from portable WIM sites:

- Georgia has many portable WIM sites. However, most of these data are believed to have low precision, and over half of all WIM samples analyzed exhibited significant bias. Use of NALS based on such data can result in biased local calibration factors, which will result in over- or under-designed pavements, as illustrated with the use of LTPP site 13-3017 (see Figures 26 through 33). Use of biased or imprecise WIM data will also increase the SEE of the transfer function. A higher SEE and higher reliability levels result in increased pavement thicknesses, so the impact becomes important and can be costly to GDOT.
- Historical LTPP data and portable WIM data for Georgia sites, therefore, are not recommended for development of the default values or be used to define the range of values in loading. However, this recommendation should be checked and confirmed

through the local calibration study currently being completed under a different project. In other words, the local calibration study should consider use of these different NALS to provide definitive data regarding the use of permanent versus portable WIM data in terms of the standard error for the different transfer functions.

- Load spectra constructed based on portable WIM samples that did not have apparent calibration issues regarding heavy axles (37 sites) may be used as a short-term solution for Level 2 MEPDG inputs. However, it should be understood that the low precision of Type II WIM systems, as well as auto-calibration procedures that involved only light steering axles, may have resulted in higher errors for the heavy tandem loads and possible overestimation of heavy loads, as was evidenced by higher-than-expected percentages of very heavy loads and shifts of peaks for unloaded axles towards heavier loads.
- There is a difference in the accuracy and reliability of the NALS developed from the WIM data collected with the permanent and portable equipment. These data should be kept separate.
- Where possible, it is recommended that GDOT use historical WIM data or project-specific portable WIM data samples to identify loading conditions at a particular project location. Once the loading condition is established, an MEPDG loading default representing this condition could be selected for pavement design. In addition, any available information about loads (freight type) carried by the dominant (most frequent) trucks at a site should be used as additional supporting information in selecting the loading condition for design. Project-specific loading information should be accumulated in the GDOT's traffic loading data library database.
- It is recommended that GDOT use the percentage of heavy loads as a qualifier which default NALS should be used in design and/or calibration based on the percentages of heavy axles observed in portable WIM data (using the procedure described in section 4.3). This recommendation assumes that no bias is present in portable WIM data and that the precision of the WIM equipment does not lead to overestimation of heavy loads (spread distributions), or distributions with unusually heavy percentages of Class 9 tandems over the legal load limit – over 20 percent). It should be understood, however, that it is still necessary to evaluate the shape characteristics and where the peaks occur in the NALS to judge whether the WIM data collected at a specific site are reasonable or biased.

CHAPTER 8 – SELECTING MEPDG TRAFFIC LOADING INPUTS AND DEFAULTS USING PAVEMENT LOADING USER GUIDE (PLUG) DATABASE APPLICATION

8.1 OVERVIEW

This chapter presents recommendations for the intermediate traffic loading defaults, introduces the traffic loading library database software application, and provides guidelines and decision trees for selecting MEPDG truck traffic inputs for new pavement designs and rehabilitation or reconstruction projects.

Most of the guidelines are provided in the form of decision trees and include steps to help engineers decide when to use the axle loading default values developed for different road types (MEPDG Level 2 traffic loading inputs for routine designs) or to determine segment- or project-specific inputs (MEPDG Level 1 traffic loading inputs) for individual high importance projects. The decision trees are grouped into pavement designs for new alignments and rehabilitation or reconstruction of existing roadways. In addition to the decision trees, the GDOT Pavement Loading User Guide (PLUG) database software application, a customized version of the LTPP PLUG software, is introduced. This software application and traffic loading library database was designed to aid GDOT's pavement designers in selecting the NALS for MEPDG pavement design and generating axle load distribution files.

8.2 RECOMMENDATIONS FOR INTERMEDIATE MEPDG LOADING DEFAULTS FOR GEORGIA

Due to the limited availability of site-specific truck loading weight data in Georgia, default NALS will be used for the majority of MEPDG-based designs in Georgia. The use of default loading is also the current method used by GDOT in ESAL-based pavement design procedures. The following recommendations for intermediate MEPDG loading defaults for Georgia were developed based on the analyses presented earlier in this report:

- Until more Georgia permanent WIM data become available to compute Georgia-specific MEPDG loading defaults, use the NALS defaults developed by the LTPP program based on SPS TPF 5(004) data. This recommendation is based on similarities in loading characteristics and MEPDG outcomes using Georgia WIM data and LTPP defaults.
- To achieve higher accuracy in design, instead of one statewide default, select values from multiple loading defaults that best represent loading condition at the design location. Base selection of loading defaults on the expected or observed loading condition of Class 9 trucks because these trucks carry the majority of heavy loads on Georgia roads. LTPP provides three loading defaults for Class 9 trucks, as shown in table 43. These LTPP defaults NALS are included in the Georgia PLUG software application and also are available as standalone files that could be uploaded to an AASHTO Pavement ME Design software database. Guidelines for selecting defaults are provided later in this chapter.

TABLE 43
LTPP loading defaults and recommendations for Class 9 vehicles.
(from Long-Term Pavement Performance Pavement Loading User Guide[(4)])

Default Name	% of Heavy Tandem Axles	Description	Recommended to be used for
Moderate	31	This loading condition has more lightly loaded tandem axles (axles between 12,000 and 16,000 pounds) than heavily loaded axles (30,000 and 34,000 pounds). In this NALS, 40 percent of axles carry loads greater than 20,000 pounds.	For use in urban areas and other roads where 70 percent or more of trucks are not fully loaded.
Heavy 1 (Typical)	39	This loading condition NALS has more loaded axles (between 30,000 and 34,000 pounds) than unloaded axles (between 12,000 and 16,000 pounds). This is a balanced distribution with similar total percentages of light and heavy loads. In this NALS, 55 percent of axles carry loads greater than 20,000 pounds.	For use on highways that serve a mix of urban delivery and long haul truck movements.
Heavy 2	49	This heavy loading NALS is representative of roads where a sizeable majority of tandem axles are heavily loaded. It is commonly found on rural highways that serve significant long haul truck movements.	For use on rural highways that serve significant long haul truck movements.

RPPIF =Relative Pavement Performance Factor

- In addition to the LTPP recommendations for road use provided in table 43, the following observations and recommendations for selecting default NALS were developed based on the analysis of the available Georgia loading data:
  - Moderate loading condition is most likely to be observed on Georgia roads with AADTT less than 1,000 trucks and less than 50 percent Class 9 trucks for the design lane. In Georgia, most of these roads are likely to be urban non-interstates, as well as some rural principal and minor arterials. This condition is likely to be applicable to routes that primarily used for local movements of goods (local distribution), away from major industrial and multi-modal transportation facilities and warehouses. This default should not be used for the routes designated as Georgia State freight routes.
  - Heavy 1 loading condition is observed on Georgia roads with a wide range of AADTT and percentages of Class 9 trucks for the design lane. It is likely that over half of Georgia urban interstates and about half of rural interstates will have this loading condition, especially roads with design lane AADTT from 1,000 to 3,000 trucks and 50 to 80 percent Class 9 trucks. This condition could also be observed on both rural and urban non-interstate principal arterials (FC 2 and FC 14) in Georgia. This condition is likely to be applicable to routes that combine local distribution and state-to-state freight movements. Use this distribution for all non-interstate roads designated as Georgia State freight routes and also for urban interstates designated as Georgia State freight routes.

  - Heavy 2 loading condition is most likely to be observed on Georgia roads with AADTT over 2,000 trucks and more than 80 percent Class 9 trucks for the design lane. Most of these roads are likely to be Georgia rural interstate roads, as well as some urban interstates and rural principal arterial non-interstate roads. This condition is likely to be applicable to major freight routes serving multiple States. Use this distribution for interstates designated freight routes located in rural areas. This distribution may also be applicable for routes serving major industrial and multi-modal transportation facilities and warehouses.
- In addition to the analysis of NALS for Class 9 vehicles, it is recommended to select load-specific LTPP defaults for vehicles in any other classes carrying over 20 percent of the total pavement load (not total volume). Defaults should be selected based on the expected loading category for these dominant classes. Otherwise, in the interim, the LTPP "typical" default is recommended for all other vehicle classes. These defaults are included in the Georgia PLUG software application.
- NALS developed from the Georgia axle weight data should be used whenever applicable. If site-specific WIM data quality is questionable for use as source of Level 1 design inputs (such as NALS based on portable WIM data), use site–specific NALS at least to establish loading category and select appropriate default NALS.
- Recommended interim MEPDG NALS defaults are available in the form of MEPDG input files in *.ALF and *.XML format, as well as database tables included in the GDOT Pavement Loading User Guide software application.

8.3 PAVEMENT LOADING USER GUIDE (PLUG) DATABASE SOFTWARE APPLICATION

The LTPP Pavement Loading User Guide database software application (LTPP PLUG software), was customized to better serve GDOT pavement engineers in selection of the NALS for MEPDG pavement design and generation of axle load distribution files. This customized version of the LTPP PLUG software is referenced as GDOT PLUG in the following sections.

GDOT PLUG could be used for developing MEPDG Level 1, 2, or 3 axle load distribution input files. It is especially beneficial for selecting loading inputs for projects that have site-specific vehicle classification and/or truck volume data but no axle load information, or if the accuracy of the loading information is questionable due to limited data availability or traffic monitoring equipment type. GDOT PLUG could be used to accomplish the following tasks:

- Develop axle load distribution input files for AASHTOWare Pavement ME Design software (formerly DARWin-ME) using site-specific or default NALS for each vehicle Class and axle type from the GDOT PLUG database library.
- Develop MEPDG axle load distribution input files for a specific project by averaging NALS from user-selected individual sites or by using software guidance and user-interactive decision process to identify site-related or default NALS for the design project location.
- Search, select, and review graphs and statistical description of NALS included in the GDOT PLUG database library, including NALS based on GDOT WIM data, NALS and defaults from the LTPP SPS TPF 5(004) study, and Florida NALS defaults for rural and urban interstate roads.
- Select traffic loading inputs for corridor studies and for forensic investigations by reviewing and analyzing NALS from available WIM data collected along selected roads and uploaded to the GDOT PLUG loading library database.

- Identify design lane or design direction by comparing traffic loading conditions for different lanes and directions using NALS uploaded to the GDOT PLUG loading library database.
- Identify different loading scenarios for pavement sensitivity studies and for testing of design alternatives using NALS uploaded to the GDOT PLUG library database.
- Upload NALS, normalized vehicle Class distributions (NVCD), and axle-per-class coefficients (APC) computed by GDOT OTD based on Georgia WIM and vehicle classification data to the GDOT PLUG traffic loading library database.

GDOT PLUG could also be used as a tool for development and updates of MEPDG NALS defaults for Georgia.

- Use site-specific NALS from Georgia WIM sites to identify loading conditions observed within the State and group WIM sites in clusters that are likely to produce significant differences in pavement designs using the MEPDG.
- Average selected site-specific NALS and save results as new or alternative defaults or user-defined NALS.
- Compare new default or user-defined NALS with the existing defaults available in GDOT PLUG traffic loading library database (LTPP, FL or existing Georgia defaults).

The GDOT PLUG user's manual contains detailed instructions for selecting pavement loading inputs and/or defaults from the PLUG database library and for developing user-defined NALS and default NALS.

8.4 GUIDELINES AND DECISION TREES FOR SELECTING TRUCK LOADING INPUTS FOR MEPDG-BASED DESIGN OF NEW ALIGNMENTS – NO EXISTING TRUCK TRAFFIC

For new alignments, existing traffic data are unavailable. The NALS should be selected based on the type of traffic loading conditions expected for the new alignment roadway. Truck loading conditions should be determined by the pavement design engineer in cooperation with the planning department (freight specialist) or traffic engineer. Factors to consider include what type of industries and commodity producers the route will serve and the percentages of throughway versus local truck traffic. The decision tree is provided in figure 33.

1. Determine AADTT and the default or expected normalized vehicle Class distribution that is applicable to the new alignment using information provided in table 44. If no information exists on types of trucks expected to use a new road, use default truck traffic classification (TTC) assignment for given road functional Class developed based on Georgia historical vehicle classification data (see table 45).

TABLE 44
TTC criteria

TTC Group	TTC Description	Percent of AADTT			
		Class 9	Class 5	Class 13	Class 4
1	Major single-trailer truck route (Type I)	> 70	< 15	< 3	-
2	Major single-trailer truck route (Type II)	60 - 70	< 25	< 3	-
3	Major single- and multi- trailer Truck route (Type I)	60 - 70	5 - 30	3 - 12	-
4	Major single-trailer truck route (Type III)	50 - 60	8 - 30	0 - 7.5	-
5	Major single- and multi- trailer Truck route (Type II)	50 - 60	8 - 30	> 7.5	-
6	Intermediate light and single-trailer Truck route (I)	40 - 50	15 – 40	< 6	-
7	Major mixed truck route (Type I)	40 - 50	15 – 35	6 - 11	-
8	Major multi-trailer truck route (Type I)	40 - 50	9 - 25	> 11	-
9	Intermediate light and single-trailer Truck route (II)	30 - 40	20 - 45	< 3	-
10	Major mixed truck route (Type II)	30 - 40	25 - 40	3 - 8	-
11	Major multi-trailer truck route (Type II)	30 - 40	20 - 45	> 8	-
12	Intermediate light and single-trailer Truck route (III)	20 - 30	25 - 50	0 - 8	-
13	Major mixed truck route (Type III)	20 - 30	30 - 40	> 8	-
14	Major light truck route (Type I)	< 20	40 - 70	< 3	-
15	Major light truck route (Type II)	< 20	45 - 65	3 - 7	-
16	Major light and multi-trailer truck route	< 20	50 - 55	> 7	-
17	Major bus route	-	-	-	< 35

TABLE 45
Recommended TTC default assignments by road functional class

Functional Class	TTC						
	1	2	4	6	9	12	14
1	Y						
2		Y*			Y**		
6				Y			Y**
7							Y
11			Y				
12						Y	
14							Y
16							Y
17			Y				

*Note: * For roads with predominantly throughway traffic. ** For roads with predominantly local traffic.*

2. Identify the major truck classes that will be using the route, the commodities that those trucks will be carrying (or likely loading condition of selected trucks), and whether these trucks are urban/local delivery or long haul trucks. Use this information to estimate

percentage of heavy loaded trucks for significant truck classes. If no information is available, assume a "typical" condition based on available historical loading data for similar roads.

3. Using information from enforcement program regarding the local area or trucks, estimate the percentage of overloaded trucks/axles for significant truck classes using the roadway, if any. Truck classes with expected low volumes (less than 15 percent of total truck volume) can be ignored. If over 15 percent of overloaded trucks in any of significant truck classes are identified, use the GDOT PLUG traffic library to identify available sites-specific or default NALS with similar percentages of overloads, as described in the next step. If no knowledge exists, assume a "typical" condition with respect to overloads.
4. Review the default NALS and other truck weight input values stored in the AASHTO Pavement ME Design or the GDOT PLUG traffic library database. Focus on the heavier portion of the NALS (75 percent or more of the legal weight limit), especially for truck classes with higher truck volumes in the normalized truck volume distribution, in determining whether one of the default or site-specific NALS should be similar to the expected truck traffic. This step may need to be revised after the local calibration study has been completed, but two outcomes from this decision are possible at the present:
    - 4.1. A site-specific NALS from one or more similar routes is available that fits the expected weights of dominant heavy truck classes—routes that are believed to be similar in terms of truck traffic or axle weights. This NALS should be entered into the MEPDG for each truck Class and axle type. Currently, 3 site-specific NALS from permanent WIM sites and 37 site-specific NALS from portable WIM sites (that did not exhibit significant measurement bias) are included in the GDOT PLUG.
    - 4.2. None of the existing site-specific NALS are believed to fit the expected truck traffic along the new alignment, and/or the pavement engineer and planning personnel are unsure about the future truck traffic along the new alignment. For this option, use the heaviest NALS from the following two options:
        - 4.2.1. Default or site-specific NALS from the PLUG database that has the closest fit for the heavier load percentages.
        - 4.2.2. Default NALS from the GDOT PLUG database for a given road functional type, expected truck volume, and percentage of Class 9 trucks. Currently, three defaults NALS are available in the GDOT PLUG database based on most frequently loading conditions observed in Georgia:
            - GDOT Moderate Default NALS – This default is computed based on the LTPP Moderate NALS default for Class 9 trucks and "typical" NALS default for all other vehicle classes. It is applicable for Georgia urban and rural minor arterials, collectors, and local roads. Also applicable for non-interstate principal arterial roads with design lane AADTT less than 1,000 trucks and Class 9 trucks less than 50 percent (roads in TTC 9, 12, and 14). This default is applicable for routes that primarily used for local movements of goods (local distribution). This default should not be used for routes designated as Georgia State freight routes or routes primarily serving major industrial and multi-modal transportation facilities and warehouses.
            - GDOT Heavy 1 (Typical) Default NALS – This default is computed based on the LTPP Heavy 1 (typical) default NALS for Class 9 and "typical" default NALS for all other vehicle classes. It is applicable for Georgia

rural and urban interstates and other principal arterial roads with design lane AADTT from 1,000 to 3,000 trucks and Class 9 trucks between 50 and 80 percent (TTC 1, 2, 4, and 6). This default also applicable for non-interstate primary arterials designated as Georgia State freight routes and also for urban interstates designated as Georgia State freight routes. This default should not be used for routes primarily serving major industrial and multi-modal transportation facilities and warehouses.

- GDOT Heavy 2 Default NALS – This default is computed based on the LTPP Heavy 2 default loading condition for Class 9 trucks and "typical" default loading condition for all other vehicle classes. It is applicable for Georgia rural and urban interstates and rural major arterial roads with design lane AADTT over 2,000 trucks and Class 9 trucks over 80 percent (TTC 1). This default also applicable for interstates located in rural areas and designated as Georgia State freight routes. This default is also applicable for routes primarily serving major industrial and multi-modal transportation facilities and warehouses.

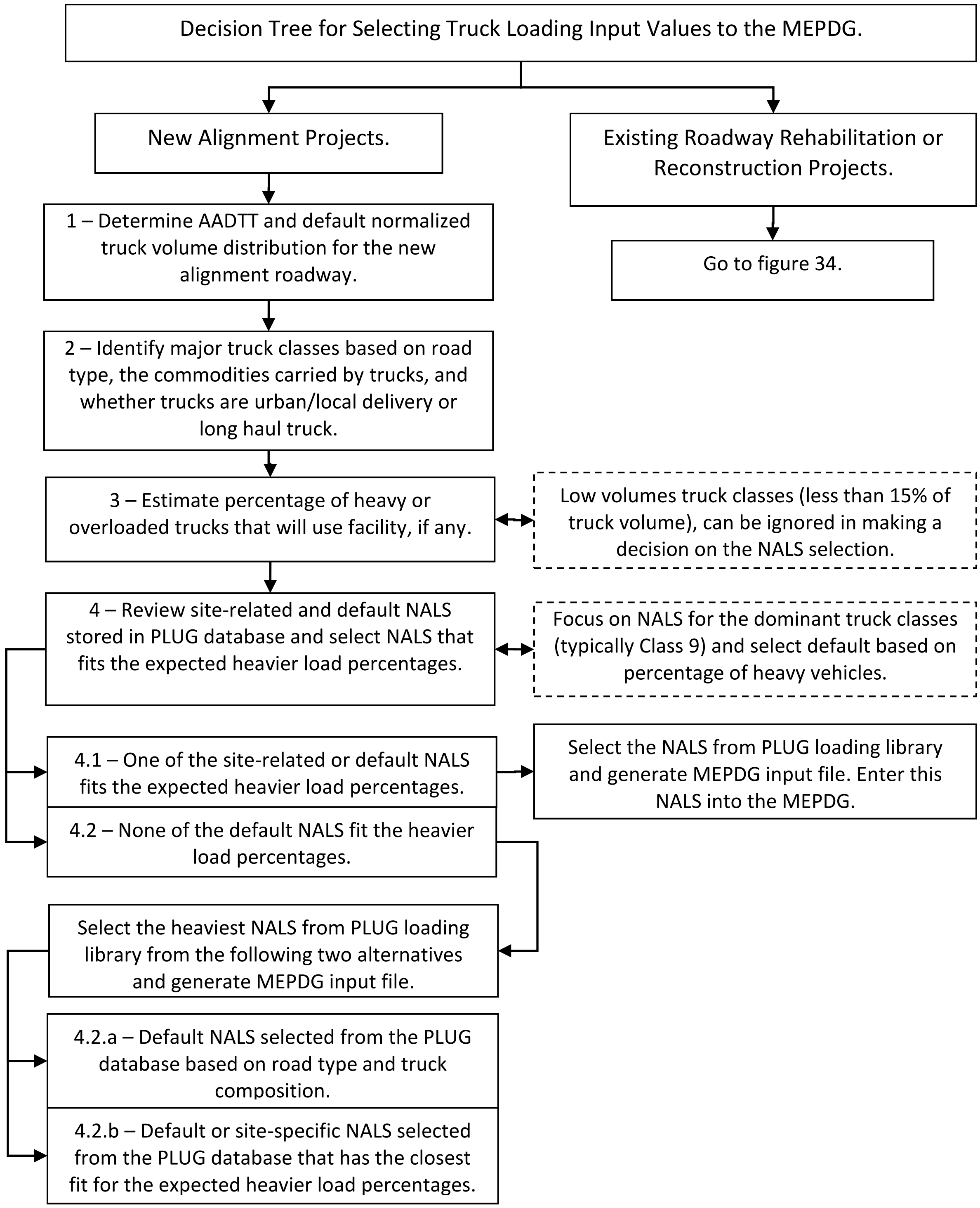


FIGURE 33
Decision tree for selecting the NALS and other truck weight input parameters to the MEPDG

8.5 GUIDELINES AND DECISION TREES FOR SELECTING TRUCK LOADING INPUTS FOR MEPDG-BASED DESIGN OF EXISTING ROADWAYS

For existing roadways, GDOT collects project-specific truck volumes and vehicle Class distributions for the design, but project-specific WIM data may or may not be available. The NALS should be selected based on as much historical loading information as possible. The decision tree is provided in figure 34. The decision on the traffic loading inputs should be made during the concept phase of project development using the following steps:

1. Establish the limits for the design or rehabilitation project and request vehicle classification, truck volume (AADTT), truck volume seasonal adjustment factors, and truck growth values from the Office of Planning. In addition, for the high importance projects, request project-specific WIM sample from the Office of Transportation Data.
2. Use information about project route name and county to sort through the GDOT PLUG traffic library database to determine whether there are any WIM sites located on the same roadway close to the design project location.
3. If a WIM site is found, establish whether data from the WIM site would likely represent the distribution of loads at the project location (consider major intersections or other truck traffic generators between the project location and WIM site), as well as inputs from freight personnel from the planning office on percentages of throughway and local trucks or whether the road is part of major freight corridor.
   3.1. If there are no significant local truck traffic generators, the data from the identified WIM site can be considered representative of loading conditions for the design project. Check with the GDOT Office of Transportation Data if this WIM site produces quality data acceptable for direct MEPDG use. The WIM site should be a Type I WIM system, calibrated annually based on ASTM 1318 using heavily loaded Class 9 trucks, and should have at least 1 week of acceptable quality data for each of 12 calendar months (Recommendation to GDOT: add WIM data quality identifier to traffic database to identify WIM sites that satisfy these criteria).
      - If yes, use site-specific NALS for the project. This is considered MEPDG input Level 1. Use GDOT PLUG to generate MEPDG NALS input files for identified WIM site.
      - If no, use site-specific NALS to identify loading condition (see procedure in section 4.4) and select default NALS (MEPDG Level 2 inputs) or NALS from other similar sites representing identified loading condition from the GDOT PLUG library. This is considered MEPDG input Level 2. Go to step 4.2.

   3.2. If there are significant traffic generators located between the WIM site and project location, go to step 4.
4. If there are no WIM locations along any segment of that roadway, the NALS should be determined based on either defaults for given road type, truck volume, and percentage of Class 9 trucks or based on averaging NALS, included in the GDOT PLUG traffic library, using high- for similar roads (MEPDG Level 2 inputs). If the latter approach is used, make sure that the NALS being averaged are based on good quality WIM data from permanent WIM sites.
   4.1. If site-specific portable WIM data were collected at or near the project location (recommended for high importance projects), establish traffic loading condition for the design project by analyzing data from the portable WIM data sample. Otherwise, issue a request to collect a 1-week sample of WIM data using a portable WIM device along or near the project location. Portable WIM should be set to

assure accurate measurement of heavy axle weights (over 26,000 lb for tandem axles).

4.2. Using collected portable WIM data, compute the NALS for each vehicle Class (FHWA Classes 4-13) and axle type. Use the procedures from section 4.4 to determine a generic loading condition based on loading observed for Class 9 tandems or other dominant heavy vehicle classes. If NALS for Class 9 tandems based on portable WIM data do not show bias in measurement or atypical distribution, upload NALS to GDOT PLUG; otherwise, note general loading condition but do not use this NALS and go to step 7.

5. Use GDOT PLUG's "View, compare, and combine NALS" option to identify Georgia permanent WIM sites on roadways that are likely to have similar traffic loading condition (based on similarities in road use or truck traffic composition and volume) to the subject roadway segment. To narrow site selection, applying any of the following filters in GDOT PLUG: county, road functional class, AADTT level, and percentage of combination unit trucks.

6. Use GDOT PLUG to compare the NALS based on site-specific WIM data to NALS determined from other permanent WIM sites on roadways with similar truck flow characteristics or loading conditions. This comparison is accomplished by reviewing NALS plots and assessing similarities in percentages of heavy and overloaded axles and/or RPPIF values. Two outcomes from this decision are possible:

   6.1. The NALS from the portable WIM location is similar to one of the other permanent WIM sites on a similar roadway. Use the NALS from that permanent WIM location to generate the MEPDG input file for use in design. These inputs are considered MEPDG Level 2.

   6.2. The NALS from the portable WIM location is different from the NALS from the other permanent WIM sites. For this condition, compare NALS from the portable WIM with the default NALS available in GDOT PLUG. Two outcomes from this decision are possible:

      6.2.1. The NALS generated from the portable WIM location is similar to one of the default NALS stored in the GDOT PLUG database. The default NALS found similar should be entered in the MEPDG. These inputs are considered MEPDG Level 2.

      6.2.2. The NALS from the portable WIM location is different from all the defaults. For this condition, the pavement designer should select NALS default that has the closest match for the percentages and distribution of heavy loads.

7. If portable WIM data can't be provided or found of limited quality/usability, and no loading information about the site is available, use the heaviest NALS from the following two options:

   7.1. A site-specific NALS from one or more similar routes could be identified—routes that are believed to be similar in terms of truck traffic or axle weights. This NALS should be entered into the MEPDG for each truck Class and axle type. Currently, 3 site-specific NALS from permanent WIM sites and 37 site-specific NALS from portable WIM sites (that did not exhibit significant measurement bias) are included in the GDOT PLUG.

   7.2. None of the existing site-specific NALS are believed to fit the expected truck traffic along the design project, and/or truck traffic conditions are unclear. For this option, use the heaviest NALS from the following two options:

7.2.1. Default or site-specific NALS from the GDOT PLUG database that has the closest fit for the expected percentages of heavy loads.

7.2.2. Default NALS from the GDOT PLUG database for a given road functional type, expected truck volume, and percentage of Class 9 trucks. Currently, three defaults NALS are available in the GDOT PLUG database based on most frequently loading conditions observed in Georgia:

- GDOT Moderate Default NALS – This default is computed based on the LTPP Moderate NALS default for Class 9 trucks and "typical" NALS default for all other vehicle classes. It is applicable for Georgia urban and rural minor arterials, collectors, and local roads. Also applicable for non-interstate principal arterial roads with design lane AADTT less than 1,000 trucks and Class 9 trucks less than 50 percent (roads in TTC 9, 12, and 14). This default is applicable for routes that primarily used for local movements of goods (local distribution). This default should not be used for routes designated as Georgia State freight routes or routes primarily serving major industrial and multi-modal transportation facilities and warehouses.
- GDOT Heavy 1 (Typical) Default NALS – This default is computed based on the LTPP Heavy 1 (typical) default NALS for Class 9 and "typical" default NALS for all other vehicle classes. It is applicable for Georgia rural and urban interstates and other principal arterial roads with design lane AADTT from 1,000 to 3,000 trucks and Class 9 trucks between 50 and 80 percent (TTC 1, 2, 4, and 6). This default also applicable for non-interstate primary arterials designated as Georgia State freight routes and also for urban interstates designated as Georgia State freight routes. This default should not be used for routes primarily serving major industrial and multi-modal transportation facilities and warehouses.
- GDOT Heavy 2 Default NALS – This default is computed based on the LTPP Heavy 2 default loading condition for Class 9 trucks and "typical" default loading condition for all other vehicle classes. It is applicable for Georgia rural and urban interstates and rural major arterial roads with design lane AADTT over 2,000 trucks and Class 9 trucks over 80 percent (TTC 1). This default also applicable for interstates located in rural areas and designated as Georgia State freight routes. This default is also applicable for routes primarily serving major industrial and multi-modal transportation facilities and warehouses.

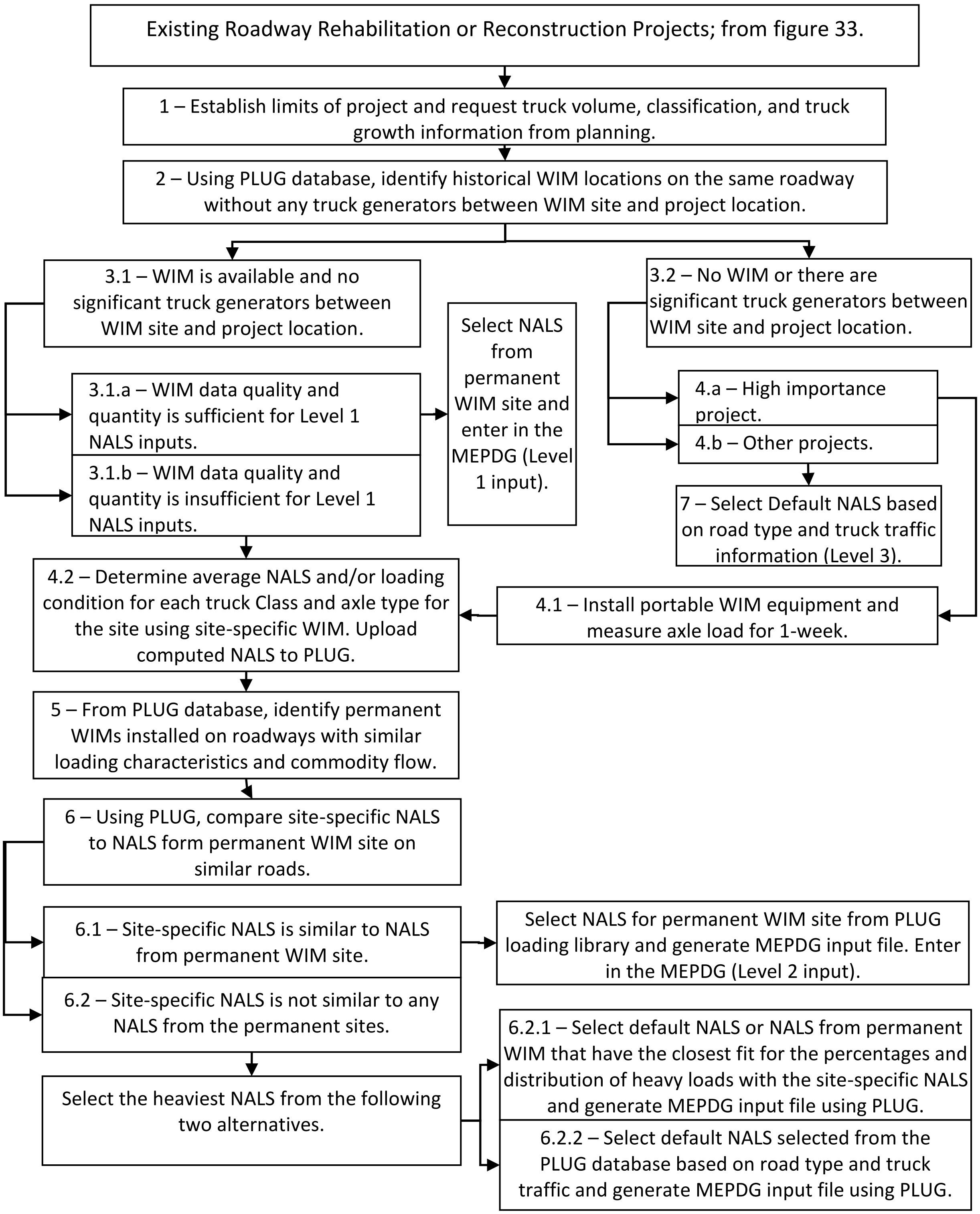


FIGURE 34

Decision tree for selecting the NALS and other truck weight input parameters to the MEPDG for existing roadway rehabilitation or reconstruction projects

CHAPTER 9 – RECOMMENDATIONS FOR WIM DATA COLLECTION PROGRAM TO SUPPORT MEPDG IMPLEMENTATION AND USE

9.1 INTRODUCTION

The MEPDG design procedures require detailed traffic loading characterization. One of the main traffic loading inputs is the NALS. NALS are constructed based on data collected by WIM devices. Due to the significant costs associated with collecting project-specific axle loading data using WIM, most future GDOT pavement designs will require Level 2 (regional or local defaults) or Level 3 (state-wide or national defaults) traffic loading inputs.

The following sections summarize recommendations for WIM data collection to support the implementation of the MEPDG pavement design method and calibration of the MEPDG transfer functions. These recommendations should be considered in the overall GDOT WIM program that will serve multiple GDOT WIM data users.

The following sections provide recommendations regarding collecting, processing, and distributing axle load spectra data to MEPDG users. In addition, the WIM Data Collection Plan (presented in appendix A) addresses in detail the number, location, and type of WIM sites necessary to support MEPDG implementation in Georgia, including a phased implementation plan.

9.2 WIM DATA NEEDS TO SUPPORT MEPDG IMPLEMENTATION

9.2.1 Use of WIM data for MEPDG Pavement Design

In the MEPDG software, NALS are used to characterize axle loading conditions for pavement design. NALS is a percentile distribution of axle loads by predetermined load bins. NALS are developed for each truck Class (FHWA vehicle classes 4-13) and axle type (single, tandem, tridem, and quad). Site-specific NALS are developed to represent distribution of axle loads for typical day of the month, while default NALS usually are developed to represent a typical day of the year. In the pavement design process, NALS are combined with site-specific information regarding expected truck volumes for different vehicle classes and truck growth rates to obtain total estimate of traffic loading over the pavement's design life.

Default NALS are developed and used when actual and reasonably accurate site-specific NALS are unavailable—which will be the case for most designs in Georgia, at least in the near future. Thus, the default NALS need to be representative of the actual truck traffic throughout Georgia. Defaults should be computed using representative site-specific NALS collected throughout Georgia. To assure accuracy of the defaults, representative site-specific NALS should be computed using data from permanent WIM sites that satisfy ASTM 1318 WIM requirements for Type I systems.

Portable WIM data could be used to make a qualitative determination of axle loading conditions for the dominant truck types, such as classifying loading condition in terms of light, moderate, or heavy distribution of Class 9 axle weights. This information could be used to select default NALS best representing identified loading condition for a specific project location.

We recommend that emphasis of WIM program to support MEPDG implementation will be placed on development of permanent and portable WIM program components that would support the development of Level 2 and Level 3 MEPDG traffic loading inputs.

To develop traffic loading inputs for Level 2 or 3 pavement designs, pavement design engineers need to have knowledge of the following:

- The expected loading category for the road being designed, overall or by vehicle Class and axle type. In the interim, loading categories developed for LTPP defaults are recommended.
- Default axle load distribution for each identified loading category for each truck Class (FHWA classes 4-13) and axle type (single, tandem, tridem, and quad).

9.2.1.1 Identification of Loading Category for The Road Being Designed Based on Data from Portable WIM Sites

The expected loading category for the road being designed can be established relatively inexpensively using several options:

1. Short-term portable WIM samples.
2. Information on expected freight road use.
3. Historical information of traffic loading patterns for different roads and truck types in Georgia.

Portable WIM, while not accurate enough to produce loading distributions for design, could be used successfully to establish descriptive loading patterns that could be used to select the appropriate default axle loading distribution.

The primary effort in identifying loading categories should be placed on dominant heavy truck classes. For GDOT, vehicle Class 9 was found to be the most significant truck type by truck volume and by percentage of heavy axles relative to other heavy truck classes. Therefore, we recommend that Class 9 be the focus for identifying loading category for the road and for development of default load group definitions. In addition to Class 9, analysis of GDOT classification data shows that other potential classes to be evaluated are classes 4, 6, and 8. These are potentially significant for secondary roads.

9.2.1.2 Development of The Default Axle Load Distributions Based on Data from Permanent WIM Sites

To develop default axle load distributions representing different loading patterns, a number of permanent WIM sites will be necessary. These sites will monitor truck axle weights continuously and provide accurate measures of axle weight distribution frequency for different roads, truck, and axle types, as well as expected seasonal changes in truck weights. To assure accuracy of the defaults, these permanent WIM sites should satisfy ASTM1318 WIM requirements for Type I systems. A minimum of 1 year of continuous WIM data collection is needed to develop representative site-specific annual NALS for a WIM site, while 2 to 3 year of WIM data per site is preferred.

Because different truck loading patterns are observed on different types of roads in Georgia, permanent WIM sites need to be positioned strategically on the State road network to produce a sample of truck load distributions typical for different Georgia State road types.

In the absence of these permanent WIM sites, default axle load distributions developed through the LTPP SPS TPF study could be used as an interim measure.

Analysis of the data obtained from permanent WIM sites also will provide a means of comparing GDOT traffic loading distributions with distributions developed by neighboring States and by national studies. From this comparison, it will be possible to establish if GDOT could benefit from data sharing with other States or from national loading defaults. This could have an effect on the size and the extent of GDOT's WIM Data Collection Program coverage.

9.2.1.3 Emphasis on Accurate Characterization of Heavy Loads

The accuracy of pavement design will be affected by the accuracy of WIM data used to compute traffic loading design inputs, especially the accuracy of heavy axle load measurements. Systematic calibration of WIM devices using heavily loaded test trucks is of paramount importance for use of WIM data for pavement design.

In addition to WIM data collection, extensive post-processing of the data is required to develop traffic loading inputs for pavement design. Data collected from permanent WIM sites will need to be downloaded, quality checked, summarized, archived, and reported to the GDOT Office of Materials and Testing, Pavement Design Branch.

9.2.2 WIM Program Activities to Serve MEPDG Needs

The following WIM program activities will be needed to support MEPDG-based pavement design at GDOT:

- Short-term sampling of traffic loading using portable WIM conducted on either a cyclic (annual) basis or through special studies for specific future pavement design project locations.
- Continuous WIM data collection using permanently installed WIM devises strategically located throughout GDOT road network.
- WIM data processing and quality assurance program or process to develop necessary traffic loading inputs and defaults for use in MEPDG.

In summary, the permanent WIM program component will provide high-accuracy data for developing a library of representative axle load distributions and traffic loading defaults. This library will reflect a variety of axle loading conditions observed on Georgia State routes. The portable WIM program component will be used to aid in selecting traffic loading inputs and defaults from the traffic load library for specific pavement design projects. WIM data processing and quality assurance program component will assure that WIM data used to develop traffic loading inputs and defaults are of sufficient quality for pavement design use.

9.3 SOURCES OF DATA TO DEVELOP MEPDG TRAFFIC INPUTS

The following are recommendations on the sources of data to develop MEPDG traffic inputs. Please note that not all inputs require WIM data collection.

- Normalized Axle Load Spectra:
    - If data from a permanently installed WIM site is available for the design project location, these data should be used to develop Level 1 NALS inputs; otherwise, see next bullet.
    - If data from portable WIM data collection is available for the design project location, use these data to compute NALS and evaluate traffic loading category

based on NALS shape and percentages of heavy loads. Using this information, identify default NALS that best describes loading category identified based on portable WIM; otherwise, see next bullet.
    - If no portable WIM data are available for the design project location and the design project is qualified as "high importance," request a special study that includes WIM data sampling near the project location. Use collected WIM sample to compute NALS and evaluate traffic loading category based on NALS shape and percentages of heavy loads. Using this information, identify default NALS that best describes loading category identified based on portable WIM; otherwise, see next bullet.
    - Use default NALS that best represents the expected loading condition or use NALS recommended for given road type, AADTT level, and percentage of Class 9 vehicles.
    - As more permanent WIM data are collected and added to the database, periodically update the default values (every 3 years recommended).
- Number of Axles Per Truck Class:
    - In the short term, use the existing two permanent WIM sites to establish default values for initial use of the MEPDG or use values developed for the new LTPP defaults.
    - As more permanent WIM data are collected and added to the database, periodically update the default values (every 3 years recommended).
- Axle Spacing – Same as for number of axles per truck class.
- Normalized Truck Class Distributions:
    - For new alignments, use current vehicle classification data to establish the default normalized truck volume distribution factors for GDOT based on road type and road use.
    - For existing roadways, set this parameter to be site-specific, Level 1 MEPDG input based on current GDOT practice for special traffic studies to support highway design projects.
- Average Annual Daily Truck Traffic:
    - For new alignments, use current truck traffic volume data to establish the default AADTT value based on road type and road use.
    - For existing roadways, set this parameter to be site-specific, Level 1 MEPDG input based on current GDOT practice for special traffic studies to support highway design projects.
- Truck Traffic growth factor:
    - Use inputs provided by GDOT's Office of Planning.
- Monthly and Seasonal Truck Volume Distribution Factors:
    - Use current AVC data to establish these factors.

9.4 WIM SYSTEM REQUIREMENTS TO SUPPORT DATA USE FOR MEPDG

9.4.1 WIM System Requirements

NALS typically are computed based on WIM data. Because pavement design models are highly sensitive to heavy axle loads, the equipment and procedures used to collect axle weight data should provide accurate estimates of heavy loads.

This typically would require the use of permanently installed WIM systems conforming to ASTM 1318[5] Type I WIM system requirements, shown in the table below. These requirements were evaluated by the LTPP TPF 5(004) study and concluded that WIM systems installed and annually calibrated based on ASTM 1318 Type I WIM system requirements are capable of producing high-quality WIM data suitable for development of MEPDG defaults.

TABLE 46
Type I WIM System Requirements

Parameter	95% Confidence Limit of Error*
Steering Axles	+/-20 percent
Tandem Axles	+/-15 percent
GVW	+/-10 percent
Vehicle Length	+/-3.0 percent (1.9 ft)
Axle Length	+/- 0.5 ft

** In addition to +/- range, mean error should be approximately zero, to minimize measurement bias.*

9.5 RECOMMENDED WIM SYSTEM TECHNOLOGIES

9.5.1 WIM Technology Assessment

Based on the review of available WIM technologies, three types of WIM systems are currently available on the market that consistently satisfy ASTM 1318 Type I WIM system requirements:

- WIM systems with Kistler Quartz piezoelectric sensors
- Bending plate WIM systems
- Load cell WIM systems

In addition to the above three technologies, WIM systems with piezo-ceramic sensors could also satisfy ASTM 1318 Type I WIM system requirements when used under constant temperature conditions. This limitation is attributed to high temperature sensitivity of piezo-ceramic sensors. Because pavements located in Georgia are subject to high temperature differentials, both time-of-day and seasonally, this technology is not recommended for collecting continuous WIM data at permanent WIM sites for MEPDG use. This technology currently is being used to collect portable WIM data in Georgia.

Load cell technology is more expensive than bending plate and Kistler Quartz sensors while producing similar quality data. Based on cost/benefit and budgetary considerations, this technology was not investigated further.

In addition to sensors, each WIM system requires a recorder box with a computer that process signal outputs from multiple sensors and assigns axle weights based on sensor output. The recorder is also capable of capturing a wide range of vehicle information, including volume, class, and speed. These WIM recorders are available in permanent and portable models with solar and wireless capabilities. Typically, new recorders cost from $8,000 to $16,000.

Review and comparison of bending plate WIM systems and WIM systems with Kistler Quartz sensors is provided in the following sections.

9.5.1.1 Bending Plate WIM (ASTM 1318-09 Type I WIM)

The Bending Plate WIM system consists of two steel frames (per lane) which are installed into existing or new asphalt (with concrete vault) or concrete pavement with weigh pads bolted to the installation frame. This sensor technology utilizes strain gauges.

FIGURE 35
Bending Plate WIM System Installation

Life cycle:

- Life expectancy is 5 to 10 years.

Pros:

- Accuracy +/- 5% of gross vehicle weight (GVW) at highway speeds.
- Speed ranges are 10 to 100 mph.
- Accurate enough for weight enforcement screening.
- Calibration frequency: once every 1 to 2 years, subject to site-specific conditions.

Cons:

- Installation is labor intensive (not quite as bad as load cells).
- Sensor initial costs ~ $20,000 per lane.
- Should not be used in asphalt pavements without installation of concrete vault to provide a solid foundation (as pavement wears, the risk of sensors becoming dislodged increases).

9.5.1.2 Kistler Quartz WIM (ASTM 1318-09 Type I WIM)

The Kistler Quartz sensor utilizes quartz crystal force sensing technology. It consists of an aluminum alloy profile in the middle of which quartz disks are fitted under pre-load. The sensor is isolated from side forces by a special elastic material. These sensors are easily installed flush with the surface of any existing or new asphalt or concrete pavement surface with epoxy adhesive. The sensors are available in 0.75-meter and 1.00-meter sensor lengths and various cable lead lengths. Four sensing elements are used per 12-foot travel lane. The surfaces of these sensors are ground to conform to the pavement profile. Quartz sensors are used for medium and high-speed WIM and/or vehicle classification applications.

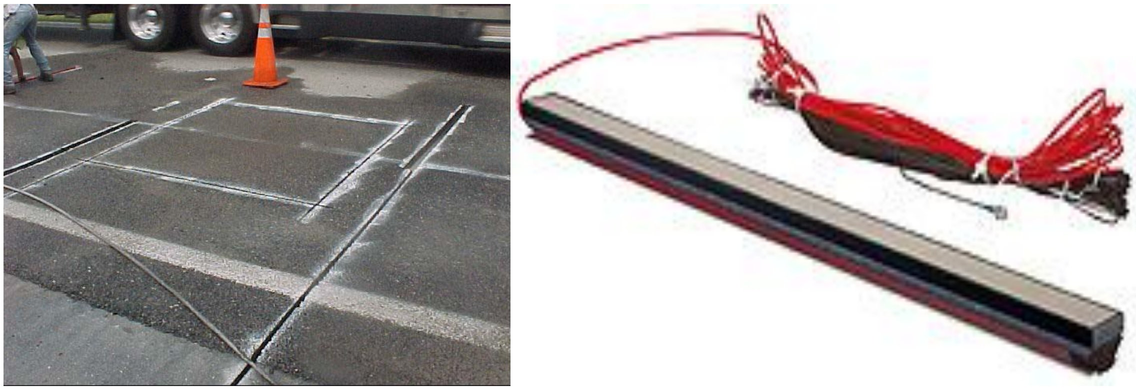


FIGURE 36
Kistler Quartz Sensor Installation

Life cycle:

- Life expectancy is 2 to 5 years.

Pros:

- Accuracy +/- 6% of GVW at highway speeds.
- Speed ranges are 10 to 100 mph.
- Installation is not labor intensive.
- Sensor initial costs ~ $12,500 per lane.
- Can be used in asphalt (4 inch or thicker) or concrete pavements.
- Calibration frequency: once a year.

Cons:

- Slightly less accurate than bending plate and load cells but still within Type I WIM system requirements.
- Not used for strict weight enforcement, but can be used for targeting.
- May require slightly higher calibration frequency compared to bending plate WIM, subject to site-specific conditions.

9.5.2 WIM Technology Recommendation

A WIM system utilizing the Kistler Quartz sensors is recommended for collecting WIM data to support MEPDG needs because it is capable of providing sufficient accuracy at a moderate cost. Another advantage of the quartz piezoelectric sensors is that they could be installed both in rigid pavements and in relatively stiff flexible pavements. The thickness of the asphalt layer where the devices are installed in flexible pavements should exceed 4 inches.

Multiple vendors are available who offer WIM systems with Kistler Quartz sensors. However, WIM hardware and software capabilities differ vendor-to-vendor. Therefore, use of performance-based specification is recommended in procuring WIM systems and services.

Performance parameters should satisfy those outlined in ASTM 1318 for Type I systems. In addition, we recommend that GDOT use the LTPP performance specification outlined in "LTPP Weigh-in-Motion (WIM) System: Model Performance Specifications and Application Requirements for Equipment – Hardware and Software, Version 2.0."

For MEPDG purposes, WIM data collected for the "truck lane" should be used. The truck lane is the lane that has the heaviest volume of heavy trucks or the highest ESAL value. Portable WIM data sampling could be used to identify the truck lane. If WIM sensors are installed in all or several lanes, use the data from the truck lane in each direction of traffic for MEPDG traffic loading data library. For WIM sites installed exclusively to support pavement design needs, such as locations off the statewide freight road network, WIM data collection could be limited to the truck lane only.

9.6 WIM SITE CONDITIONS AFFECTING WIM ACCURACY

When selecting WIM site locations along the road segment, it is important that all site conditions conform to ASTM 1318 requirements [5] to assure accuracy of WIM data. Some additional recommendations are summarized below:

- Pavement surface deflections should be measured prior to installing any permanent WIM device to ensure that the pavement has sufficient stiffness in the area with the device. In other words, the deflection basins are used to identify the specific segment where the permanent device is to be installed. The thickness of the asphalt layer where the devices are installed in flexible pavements should exceed 4 inches.
- The smoothness of a WIM site can affect its ability to produce high-quality data. An assessment will include checking the pavement smoothness using either the output from a high-speed profiler or a straightedge. The LTPP WIM Smoothness Index software could be used to evaluate if the selected location is favorable for WIM data collection.
- A pavement distress survey is recommended to assure that the selected site is free of surface anomalies that may affect truck motions across the sensors. This survey includes such items as potholes, patches, rutting, cracking, joint and crack faulting, and asphalt-concrete transition.
- Vehicle-pavement interaction should be observed near proposed WIM site using 30 or more heavy trucks (in FHWA vehicle classes 6-13). Truck movement should be free of any of the following adverse characteristics: bouncing, swerving, and leaning to one side, braking, accelerating, or lane changing within 135 feet of the sensors.

9.7 WIM MAINTENANCE RECOMMENDATIONS

We recommend that GDOT implement a semiannual preventive maintenance schedule and have a mechanism in place for on-call (or as-needed) repairs to correct WIM system deficiencies or failures. The following paragraphs list the minimum recommended semiannual preventive maintenance tasks.

9.8.1 Bending Plate Scale

- Conduct a visual inspection on the clamp or hold down bars; bolts, nuts, frost plugs, and applicable hardware; and seal between the frame and the platform.
- Measure resistance of signal and excitation cabling.
- Check baselines and thresholds.

- View vehicle records in manufacturer diagnostic mode to ensure the software is processing the signal properly.
- View signals with oscilloscope style software to ensure the signal is proper.

9.8.2 Quartz Piezo Sensors

- Conduct a visual inspection on the grout, sealant, and connectors.
- Check voltage deflection as vehicles pass.
- Check baselines and thresholds.
- View vehicle records in manufacturer diagnostic mode to ensure the software is processing the signal properly.
- View signals with oscilloscope style software to ensure the signal is proper.

9.8.3 WIM Electronics Controller

- Conduct a visual inspection of the equipment layout; cabling; and interconnects.
- Clean and dust all surfaces within cabinet.
- Maintain WIM cables, connectors, terminal strips, and back-up batteries by ensuring that the connector screws of the WIM cables, terminal strips, and all other accessory components are tight.

9.8 WIM CALIBRATION RECOMMENDATIONS

Systematic field WIM calibration is very important for collecting high-quality WIM data for MEPDG use. Use of the auto-calibration mode is not recommended because it forces the equipment to use a compensation factor (or multiple factors) based on expected weight values from industry standards rather than actual weight measurements from the site, which may be quite different.

Calibration shall be performed in accordance with the ASTM 1318 and methods recommended by the equipment manufacturer. In addition, we recommended using the LTPP Field Operations Guide for SPS WIM Sites [4] for detailed guidance on calibration procedures. When performing WIM calibration, special attention should be paid to minimizing weight measurement bias by keeping the mean error between the measured and static axle weights of the calibration truck as close to zero as possible.

For the permanent WIM sites, calibration should be planned on an annual basis, unless WIM data for the site suggests some other interval. Potential calibration drift between field calibration sessions should be checked monthly or bi-weekly (by comparing current NALS against reference NALS computed using 2 weeks of data after calibration), and calibration activities should be scheduled or data flagged if data analysis indicates likely measurement bias over 5 percent. See the section 9.9.4 “Data Reasonableness QC Checks” for more details.

For the portable WIM sites, calibration should be done after equipment is set at the monitoring site. A fully loaded Class 9 truck or other similar heavy truck of a known weight should be used as a calibration vehicle.

[4] http://www.tfhrc.gov/pavement/ltpp/spstraffic/index.htm

9.8.1 Calibration Trucks

Loaded Class 9 trucks are recommended as calibration trucks for Georgia WIM sites because this type of truck is the dominant heavy truck observed on Georgia roads. Using two trucks is preferred: one fully loaded and another partially loaded. If only one truck is being used due to budgetary constraints, use a fully loaded truck to assure accurate measurement of heavy loads.

Calibration test trucks should be in good operating condition, with loads that are not susceptible to shifting, harmonics, moisture gain or loss, and are securely anchored.

9.8.2 WIM Performance Evaluation and Calibration

Initial calibration is recommended after the new WIM site has been installed. After initial calibration, annual calibration is recommended. Following are recommendations for calibration procedures:

1. Making no adjustments to the system, conduct 10 to 20 runs per calibration truck at the various operating speeds (typical to the site location) and temperatures and compute differences between static and WIM-based GVW and axle weights. Weight measurement accuracy evaluation should focus on satisfying the following two parameters:
    a. The mean error (or measurement bias) in weight measurements, considering all calibration truck runs, should be less than +/-2% of the true static weight value.
    b. The range of error, as measured by 2 standard deviation (or 95 percent confidence, using student t-distribution for small samples), should be within performance parameters provided in the ASTM 1318 for Type I WIM systems.

    If the initial performance evaluation shows the site to be functioning with sufficient accuracy and without systematic bias, per ASTM 1318 requirements for Type I WIM systems, then go to step 5. Otherwise go to step 2.
2. Analyze test truck data from the initial performance evaluation to determine the system's calibration adjustment factors. Make necessary changes to calibration adjustment factors.
3. Perform a second performance evaluation using the procedures detailed in step 1. If the second performance evaluation shows the site to be functioning with sufficient accuracy, then go to step 5. Otherwise, go to step 4.
4. If analysis of the data obtained from the second performance evaluation does not meet the ASTM 1318 performance requirements for Type I WIM systems, then the system has failed performance requirements. In this case, further troubleshoot reasons for WIM system failure, including but not limited to the following actions:
    a. Recalibrate the system using different test trucks.
    b. Assess pavement condition before and immediately after WIM site and investigate any truck bouncing in the vicinity of WIM site.
    c. Make WIM software adjustments.
    d. Reinstall or replace and install pavement sensors.
    e. Replace or make adjustments to electronics components.

5. Report calibration results, including WIM system performance parameters (precision and bias). For a report template, we recommend using the LTPP WIM System Field Calibration and Validation Summary Report format.

9.9 WIM DATA PROCESSING AND QUALITY CHECKS FOR MEPDG USE

Development of traffic loading inputs for MEPDG use is a multi-step process. The accuracy of traffic loading inputs is dependent on data quality and data quantity. Therefore, it is recommended that data processing should include checking the data on a daily (rudimentary checks) and monthly (comprehensive checks) basis, to identify and fix any potential problem without a substantial loss of data. QC should be viewed as an essential part of WIM data processing.

The WIM data processing and QC/QA program implemented under the LTPP TPF 5(004) study[1, 2] is recommended for GDOT as an example of a systematic, comprehensive, and well-documented process. An additional resource for developing a WIM data QC/QA program is FHWA's WIM Data Analyst's Manual.

We recommend that GDOT consider implementing the LTPP LTAS software for traffic data QC and processing, along with LTPP procedures for systematic WIM scale validation and calibration. LTAS is free upon request from LTPP and requires an Oracle database to house the data, which is GDOT's corporate database platform. In addition to LTAS, WIM vendor-provided data processing software should be implemented to auto poll the data and to develop W-files for further processing using LTAS or another similar system.

WIM data processing and QC recommendations are provided in the following sections:

- Daily data downloads and rudimentary QC checks
- Data summarization for MEPDG use
- Data validity QC checks
- Data reasonableness QC checks

WIM data storage and distribution for MEPDG use is described in section 9.10.

9.9.1 Daily Data Downloads and Rudimentary Checks

The primary goal of daily data downloads and rudimentary QC checks is to identify any missing or invalid data. The following activities are recommended to provide systematic data management and timely identification of operational issues with WIM equipment:

- Download (auto poll) the WIM system's binary data file(s) containing WIM data on a daily basis to a designated space on a local area network (Monday through Friday). Data files downloaded on the Monday of each week should also include downloads of the previous Friday through Sunday.
- If the first attempt to download data is unsuccessful, make two additional attempts to download the data from the site. If the site cannot be connected to, or rings busy after three attempts, notify the WIM program manager so that corrective action can be initiated.
- Using WIM vendor software, generate Traffic Monitoring Guide (TMG) W-files in ASCII format. These files should be saved to a designated folder on an OTD office computer or to a mass storage device.

- Using WIM vendor software, screen downloaded files for missing or invalid data and print error report. When procuring WIM vendor software, we recommend specifying software capabilities for screening information included in W-files to identify missing or corrupt (unexpected) data and provide error summary reports. Rudimentary checks performed by WIM vendor software should include the following, as a minimum:
    a. Identify, count, and report records with missing values in any required column of W-file.
    b. Identify, count, and report records with characters other than specified data type for a given column.
    c. Identify, count, and report unclassified and partial vehicles missing or having additional axles for a given vehicle class.
    d. Identify, count, and report records with axle spacing out of range for a given vehicle class.
    e. Identify, count, and report records with axle weights out of range for a given vehicle class.
    f. Identify, count, and report records with the left and right wheel weights of any axle having a difference of 40 percent or more.
    g. Identify, count, and report records where total weight is different from sum of axle weights.
    h. Identify and remove empty lines in PVR records.
    i. Identify and remove extra characters (other than specified for W-file format) at the end of the rows in PVR records.
    j. Report total count of vehicles in FHWA vehicle classes 4-13.
    k. Report percentage of Class 9 vehicles among vehicle classes 4-13.
    l. Report average GVW of Class 9 vehicles.
    m. Report average steering axle weight of Class 9 vehicles.
    n. Report average axle spacing between 2rd and 3rd axles of Class 9 vehicles.

  Note: Additional data validity and reasonableness QC checks should be conducted on a monthly basis using processed data (see sections covering WIM data validity and reasonableness checks below).
- Review error reports, compare summary statistics from items j-n in the list above with the historical average values for a given site. Identify WIM sites that have excessive number of records with errors or changes in summary statistics over 5 percent. Report findings to WIM program manager.
- Remove from further processing records, where problems (error flags) were identified through rudimentary checks. WIM vendor software should have capability of removing records, where problems were identified and reported, based on user's action request.
- Organize all downloaded files in folders by WIM site ID. Filing system should reflect the time period for which data were collected.
- It is also recommended to compute on the daily basis the Daily Key Summary Parameters described in the following section.

9.9.2 WIM Data Summarization for MEPDG Use

To aid in data processing, we recommend developing a set of database tables (to be maintained by GDOT OTD) to store intermediate computed traffic loading parameters and other statistics for MEPDG use. This includes WIM data summaries aggregated on daily, monthly, and annual basis.

Using these aggregated data, representative MEPDG traffic loading input parameters could be computed for each WIM site. These parameters then would be used as MEPDG Level 1 inputs.

Representative site-specific traffic loading input parameters computed for each WIM site will also be used to develop GDOT's traffic loading defaults (MEPDG Level 2 and 3 inputs).

Necessary traffic loading parameters are described in the following paragraphs. Given the extensive number of these parameters, it is recommended that GDOT develops an automated database application for computation of these parameters or implements third party software such as LTPP LTAS. It is also possible that FHWA TMAS will have future capabilities to compute these parameters but detailed plans are unknown at this time.

9.9.2.1 Daily Key Summary Parameters

Daily traffic volume and loading summary statistics are used to compute monthly summary statistics. In addition, daily statistics could be used to troubleshoot the issues identified in the daily rudimentary QC reports. These computations could be conducted on daily, weekly, bi-weekly, or monthly basis. For each WIM site, compute the following parameters for each day of WIM data and store these computed parameters in the database tables:

- Day, month and year being analyzed
- Daily total truck volume for classes 4-13
- Normalized (percentile) vehicle Class distribution (classes 4-13)
- Daily count of unclassified vehicles
- Average weight of unclassified vehicles for the day being analyzed
- Axle load spectrum for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad) for the day being analyzed
- Average GVW of Class 9 vehicles for the day being analyzed
- Average tandem axle weight of Class 9 vehicles for the day being analyzed
- Average single axle weight of Class 9 vehicles for the day being analyzed
- Average percentage of Class 9 tandem axles weighting more than 26 kips for the day being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 34 kips for the day being analyzed.
- Hourly truck volume by vehicle Class (for vehicle classes 4-13)
- Average axle-to-axle spacing for tandem, tridem, and quad axle groupings.

9.9.2.2 Monthly Key Summary Parameters

Monthly summary statistics are used to conduct data reasonableness checks and to compute annual summary statistics. These computations should be conducted on a monthly basis to assure prompt identification of WIM system calibration drift. For each WIM site, compute the following summary statistics for each month of data and store these computed parameters in database tables:

- Month and year being analyzed
- Number of days with WIM data in the month being analyzed
- Average total daily truck volume for classes 4-13 for the month being analyzed
- Normalized (percentile) vehicle Class distribution (classes 4-13) for the month being analyzed
- Average daily count of unclassified vehicles for the month being analyzed

- Average weight of unclassified vehicles for the month being analyzed
- Normalized (percentile) axle load spectrum and total number of axles for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) for a typical day of the month being analyzed
- Average GVW of Class 9 Vehicles for the month being analyzed
- Average tandem axle weight of Class 9 vehicles for the month being analyzed
- Average single axle weight of Class 9 vehicles for the month being analyzed
- Average percentage of Class 9 tandem axles weighting more than 26 kips for the month being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 34 kips for the month being analyzed.
- Average axle-to-axle spacing for tandem, tridem, and quad axle groupings.

9.9.2.3 Annual Key Summary Parameters for Each WIM Site

Annual summary statistics are used to compute representative traffic loading statistics for each WIM site and MEPDG Level 1 traffic loading inputs. These computations should be conducted on an annual basis. For each WIM site, compute the following summary statistics for each year of WIM data and store these computed parameters in database tables:

- Year being analyzed
- Number of days with WIM data in the year being analyzed
- Average Annual Daily Truck Volume for classes 4-13 for the year being analyzed
- Normalized (percentile) vehicle Class distribution (classes 4-13) for the year being analyzed
- Normalized (percentile) truck volume distribution by calendar month for classes 4-13 for the year being analyzed.
- Normalized (percentile) hourly vehicle Class distribution (classes 4-13) for the year being analyzed
- Normalized (percentile) axle load spectrum and average annual daily total number of axles for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad) for the average day of the year being analyzed
- Axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) for the year being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 26 kips for the year being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 34 kips for the year being analyzed.

9.9.2.4 Representative Traffic Loading Summary Parameters for Each Permanent WIM Site

Representative traffic loading statistics are used to compute site-specific MEPDG Level 1 traffic loading inputs using WIM data from permanent WIM sites. These statistics are also used in computation of traffic defaults. Computation of representative traffic loading statistics is accomplished by averaging annual summary loading statistics from all or selected years with WIM data. Representative site-specific traffic loading statistics should be updated every year.

For each WIM site, the following representative traffic loading summary statistics should be computed and stored in database tables:

- WIM site ID and site information (road name, location, type of WIM).
- Average Annual Daily Truck Volume for classes 4-13.
- Normalized (percentile) vehicle Class distribution (classes 4-13).
- Normalized (percentile) monthly truck volume distribution for classes 4-13.
- Normalized (percentile) hourly vehicle Class distribution (classes 4-13).
- Normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) representing the average day of the year.
- Normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) representing the average day for each of 12 calendar months.
- Axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad).
- Average percentage of Class 9 tandem axles weighting more than 26 kips.
- Average percentage of Class 9 tandem axles weighting more than 34 kips.

9.9.2.5 Representative Traffic Loading Summary Parameters for Each Portable WIM Site

Representative traffic loading statistics are computed for each portable WIM site for a lane with the highest truck traffic volume (classes 4-13). These computations are done separately for each direction of traffic. These summary statistics are computed for each site using all portable WIM data collected (2-7 day samples). These statistics are used to identify and describe traffic loading conditions observed at portable WIM sites. For each portable WIM site, compute the following representative traffic loading summary statistics and store these computed parameters in database tables:

- WIM site ID and WIM site information (road name, location, type of WIM).
- Dates when portable WIM sample was collected.
- Duration of portable WIM data collection in days.
- Average Daily Truck Traffic Volume for classes 4-13.
- Normalized (percentile) vehicle Class distribution (classes 4-13).
- Representative Normalized Axle Load Spectra based on portable WIM sample, for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad).
- Axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad).
- Percentage of Class 9 tandem axles weighting more than 26 kips.
- Percentage of Class 9 tandem axles weighting more than 34 kips.
- Assigned traffic loading category.

9.9.2.6 GDOT's Axle Loading Defaults

GDOT's axle loading defaults (Level 2 and 3 MEPDG inputs) are computed by averaging selected site-specific representative traffic loading summary statistics from permanent WIM sites. We recommend that GDOT's axle loading defaults should be updated every 1-3 years at the beginning of the program and every 3-5 years once the program matures. The following representative traffic loading summary statistics should be computed and stored in database tables:

- Traffic Loading Default ID.
- Default Description.
- Recommended road type applicability for the default.
- Default normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) representing the average day of the year. Multiple defaults representing different loading conditions are recommended.
- Default axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad). A single set of default values is recommended.

9.9.3 Data Validity QC Checks

The following QC checks are recommended to assess validity of collected WIM data. Most of these checks were developed by LTPP for LTAS software to assure that research-quality WIM data are collected and summarized for the LTPP program. LTAS is considered benchmark software for WIM data QA. These checks are conducted using daily and monthly summary tables described in the previous sections:

- Using Hourly truck volume distribution (for vehicle classes 4-13), conduct the following checks:
    a. 1:00 a.m. traffic volume > 1:00 p.m. traffic volume.
    b. 8 or more Hours of Consecutive Zero volume Check.
    c. 4 or more Hours of Static Non-Zero volume Volumes.
    d. Traffic volume (classes 1-15) of 2500 or greater for any specific hour for any lane.

    Note any observations that did not pass the checks and investigate possible reasons. If differences are caused by WIM malfunction, remove data from further summarization.
- Using daily or monthly NALS tables, conduct the following checks:
    a. Class 9 Tandem NALS graph or table – evaluate stability/repeatability of distribution shape and location of peak loads for normalized distribution.
    b. Class 9 Steering NALS graph or table – evaluate stability/repeatability of distribution shape and location of peak loads for normalized distribution.

    Note any significant differences (5 percent or more) from historical averages over time and investigate possible reasons. If differences are caused by WIM malfunction or calibration drift, remove data from further summarization.
- Using monthly axle load summary tables, conduct the following checks:
    a. Steering axle weight average (SAWA) check for Class 9 vehicles
    b. ESAL per vehicle variance over multiple months and/or years.
    c. Average tandem axle spacing for Class 9 vehicles – evaluate variance or stability/repeatability over multiple months and/or years.

    Note any significant differences (5 percent or more) from historical averages over time and investigate possible reasons. If differences are caused by WIM malfunction or calibration drift, remove data from further summarization.
- If the same WIM site uses different algorithms for classifying data based on AVC and WIM site functionality, additional checks are recommended:
    a. Atypical pattern in vehicle Class distribution.

b. Average traffic volume match.
c. Match of weight and classification volumes by type of vehicle.

Note any significant differences (5 percent or more) and investigate possible reasons. If differences are caused by WIM malfunction, classification algorithm error, or calibration drift, remove data from further summarization.

9.9.4 Data Reasonableness QC Checks

The purpose of data reasonableness checks is to identify anomalies or changes in truck load distributions that may result from possible WIM calibration drift. These checks are recommended to assure accuracy of WIM data for pavement design. These checks are conducted using the reference data set defined below. Results of WIM data reasonableness checks could be used in prioritizing and scheduling WIM calibration activities.

9.9.4.1 Reference Data Set

- The first two weeks of data following a successful WIM calibration and validation activity should be considered the reference data set for each WIM site. Data for days when the truck volumes and/or operating characteristics may not be typical, such as a major holiday, should not be included in the reference data set. In this case, substitute the same day(s) of the week from the following week in the reference data set sample.
- These data, converted to TMG W-file format, should be clearly marked as the reference data set and saved to a designated folder on the network. Include time period when these data were collected in the file or folder name.
- Using the reference data set, the following summary statistics should be developed and stored in the database tables for each WIM site:
    - WIM Site ID
    - Time period covering collection of the reference data set
    - Average total daily truck volume for classes 4-13
    - Normalized (percentile) vehicle Class distribution for classes 4-13
    - Average daily count of unclassified vehicles
    - Average weight of unclassified vehicles
    - Axle load spectrum for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad)
    - Normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad)
    - Average GVW of Class 9 Vehicles
    - Average tandem axle weight of Class 9 vehicles
    - Average single axle weight of Class 9 vehicles
    - Average percentage of Class 9 tandem axles weighting more than 26 kips
    - Average percentage of Class 9 tandem axles weighting more than 34 kips
- A data analyst or traffic engineer should review the reference data set to confirm and/or establish the expectations of data quality and traffic characteristics for the site. This review should include, as a minimum, analysis of loading distribution for Class 9 vehicles, including identification of load bins with peak single axle load, load bins with unloaded and loaded peak tandem axle loads, percentage of single axles over 20 kips, percentage of tandem axles over 26 kips, percentage of tandem axles over 34 kips, and identification of vehicle classes representing over 20 percent of total truck load (over 20 percent of total ESAL).

- A data analyst or traffic engineer should identify and explain any unique, site-specific loading conditions (such as significant differences between NALS from the reference data set and the default NALS used for a particular road type). These explanations should be saved in a format that could be easily accessed in the future (such as a comment field in the NALS database table for the reference data set). After the review is successfully completed, the statistics computed based on the reference data set should be used as the baseline for comparison until the next field calibration/validation is performed on the WIM system.
- If review of the reference data set indicates any anomalies that may be attributed to malfunctioning of the WIM system, the WIM program manager should be notified.
- The following reasonableness checks based on the reference data set are recommended. These checks should be performed monthly using monthly summary statistics (see section 9.9.2.2 Monthly Key Summary Parameters) computed for each permanent WIM site.
    - Use statistics computed based on the Reference Data Set and monthly summary statistics, compare values for the month being analyzed with the values based on the reference data set.
    - Note any deviations over 3 percent over reference set values. Monitor these deviations on a monthly basis.
    - Report deviations over 5 percent to WIM program manager for scheduling WIM field evaluation for possible calibration drift.
- If significant differences (5 percent or more) are observed between current monthly summary statistics and the statistics based on the reference data set, investigate possible reasons. While WIM malfunction or calibration drift may be some of possible reasons, other events could contribute to these changes, such as seasonal changes in average truck loads or changes in loading triggered by construction or other special events. These causes and explanations should be documented and should be made available to data users when data from the WIM site are requested. If differences are caused by WIM malfunction, classification algorithm error, or calibration drift, remove data from further summarization.

9.10 WIM DATA STORAGE AND DISTRIBUTION FOR MEPDG USE

Due to extensive data processing required to confirm data quality and to develop MEPDG inputs, a number of files and database tables based on WIM should be developed and maintained. These data could be segregated in three categories:

1. Raw and minimally processed data obtained from WIM devices and WIM vendor software.
2. Intermediate summary statistics needed to check data quality and to compute MEPDG inputs.
3. Summary statistics that could be used as Level 1 MEPDG traffic loading inputs and as a source of data to develop GDOT’s traffic loading defaults.

Recommendations for data storage are provided in the following sections.

9.10.1 Storing Raw and Minimally Processed WIM Data

The following WIM data should be stored on OTD's dedicated computer, removable mass storage device, or network space for the future reference:

- Binary WIM files from daily data downloads.
- TMG W-files (ASCII format) containing PVR generated based on daily data downloads.

These records should be kept as long as the MEPDG inputs based on these data are being used by GDOT OMR.

9.10.2 Storing Intermediate Summary Statistics for MEPDG Use and Data QC

To develop MEPDG traffic loading inputs and defaults, summary statistics described in the section 9.9.2 "WIM Data Summarization for MEPDG Use" should be computed for each WIM site and stored in the intermediate database tables. Only WIM data that passed QC checks should be used for computations of these statistics.

We recommend using the following database tables for storing intermediate traffic summary statistics:

- **SITE_INFO** – This table contains information from GDOT's road inventory and traffic databases about each traffic site with AVC and WIM data. See GDOT PLUG Operator's Manual for table format.
- **SITE_SPECIFIC_DAY_ALS** – This table contains daily axle load spectra (ALS) for each GDOT permanent WIM site. NALS are computed for each vehicle Class and axle type and stored in load bins compatible with MEPDG.
- **SITE_SPECIFIC_MONTH_NALS** – This table contains NALS computed for each month that has data for at least one instance of each day of the week (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday) for each GDOT permanent WIM site. NALS are computed for each vehicle Class and axle type and stored in load bins compatible with MEPDG. Include in this table total number of axles for each month, vehicle class, and axle type.
- **SITE_SPECIFIC_PORTABLE_NALS** – This table contains NALS computed for each GDOT portable WIM site using all data from a given data collection period (typically 48-hour sample). NALS are computed for each vehicle Class and axle type and stored in load bins compatible with MEPDG. Also, include in this table total number of axles for each vehicle class, and axle type.
- **SITE_SPECIFIC_MONTH_NVCD** – This table contains normalized vehicle Class distributions (NVCD) for FHWA vehicle classes 4-13 for each permanent WIM site computed for each month of data. Include in this table total number of trucks for each month.
- **SITE_SPECIFIC_AXLESPERTRUCK** – This table contains representative APCs for each site. APC are computed by dividing total number of axles by total number of vehicles for each WIM site, vehicle class, and axle type.
- **SITE_SPECIFIC_ MONTHLY_SUMMARY** – This table contains the following summary statistics computed for each month with WIM data:
  - WIM Site ID
  - Month and year

- Average total daily truck volume for classes 4-13
    - Average daily count of unclassified vehicles
    - Average weight of unclassified vehicles
    - Average GVW of Class 9 Vehicles
    - Average tandem axle weight of Class 9 vehicles
    - Average single axle weight of Class 9 vehicles
    - Average percentage of Class 9 tandem axles weighting more than 26 kips.
    - Average percentage of Class 9 tandem axles weighting more than 34 kips.
- **SITE_SPECIFIC_PORTABLE_ SUMMARY** – This table contains the following summary statistics computed for each sampling period for each portable WIM site:
    - Average percentage of Class 9 tandem axles weighting more than 26 kips.
    - Average percentage of Class 9 tandem axles weighting more than 34 kips.
    - Average percentage of Class 9 single axles over 20 kip.
    - Assigned traffic loading category.
    - Comment field describing method for loading category assignment and other loading pattern observations.

In addition, to aid in data QC, the following tables are recommended to store summary statistics computed based on the reference data set. We recommend using the following database tables to store summary statistics for the reference data set:

- **SITE_SPECIFIC_REFERENCE_NALS** – This table contains NALS for each GDOT permanent WIM site computed based on the latest reference data set. NALS are computed for each vehicle Class and axle type and stored in load bins compatible with MEPDG.
- **SITE_SPECIFIC_ REFERENCE_NVCD** – This table contains normalized vehicle Class distributions (NVCD) for FHWA vehicle classes 4-13 for each permanent WIM site computed based on the latest reference data set.
- **SITE_SPECIFIC_ REFERENCE_SUMMARY** – This table contains the following summary statistics computed based on the latest reference data set:
    - WIM Site ID
    - Time period covering collection of the reference data set
    - Average total daily truck volume for classes 4-13
    - Average daily count of unclassified vehicles
    - Average weight of unclassified vehicles
    - Average GVW of Class 9 Vehicles
    - Average tandem axle weight of Class 9 vehicles
    - Average single axle weight of Class 9 vehicles
    - Average percentage of Class 9 tandem axles weighting more than 26 kips
    - Average percentage of Class 9 tandem axles weighting more than 34 kips

9.10.3 Storing and Distributing Traffic Loading Summary Statistics for MEPDG Use

The main WIM-based MEPDG traffic inputs and defaults are:

1. Normalized axle load spectra for atypical day of a year or a typical day of each calendar month
2. Axle per Class coefficients for each vehicle Class and axle type

When these site-specific inputs are not available, WIM-based MEPDG traffic inputs and defaults could be generated by the GDOT PLUG database application. In this case, use of additional traffic summary statistics is recommended to aid in selection of traffic loading defaults or site-related inputs (using GDOT PLUG), including the following:

1. Representative normalized vehicle Class distribution for FHWA vehicle classes 4-13 for the design lane.
2. AADTT for the design lane.
3. NALS and/or loading category assignment based on portable WIM data.

To provide data needed for MEPDG traffic loading inputs and defaults, OTD should maintain the following database tables. These tables should be updated on periodic basis with new WIM information and provided to OMR on an annual basis (or based on GDOT OMR request) for upload to the GDOT PLUG database.

- **SITE_INFO** – This table contains information from GDOT's road inventory and traffic databases about each traffic site with AVC and WIM data.
- **SITE_SPECIFIC_NALS** – This table contains representative annual NALS for each GDOT permanent site and NALS from portable WIM sites that passed QC checks. This table should be updated on an annual basis with site-specific NALS values.
- **SITE_SPECIFIC_MONTHLY_NALS** – This table contains representative NALS by calendar months (for 12 months) for each GDOT permanent WIM site that passed QC and data completeness checks. This table should be updated on an annual basis with site-specific NALS values.
- **SITE_SPECIFIC_NVCD** – This table contains representative normalized vehicle Class distributions (NVCD) for FHWA vehicle classes 4-13 for each traffic site where GDOT collects vehicle classification data. Representative NVCD could be based on the most recent year or based on a five year average or based on any other methods employed by the State. This table should be updated on an annual basis with site-specific NALS values.
- **SITE_SPECIFIC_AXLESPERTRUCK** – This table contains representative APCs for each site. It is recommended to periodically update this table with up-to-date site-specific APC values.
- **DEFAULT_NALS** (if generated outside of PLUG) – this table contains GDOT NALS defaults. Most likely these defaults will be generated using GDOT PLUG application. However, it is also possible to upload default NALS generated outside GDOT PLUG. It is recommended to periodically update this table with up-to-date NALS defaults.
- **DEFAULT_AXLESPERTRUCK** – this table contains default axle-per-truck coefficients (APC). Because these values are dependent on truck configuration, these values are not likely to change much over time, unless changes to truck configuration or use of different fleet of vehicles is observed in Georgia. It is recommended to periodically review these values and update on as needed basis using averages computed from site-specific APC.

A data dictionary for these tables is available in the GDOT PLUG Operator's Manual. Once data tables are uploaded to the GDOT PLUG database application, MEPDG traffic loading input files can be generated by GDOT PLUG.

There is also a possibility that an AASHTO Pavement ME Design software database would be set up during GDOT's MEPDG implementation project to directly accept tables containing these statistics. Therefore, it is recommended that the above recommendations are reviewed and revised, if needed, once local calibration of AASHTO Pavement ME Design models is completed and GDOT's MEPDG pavement design manual is finalized.

9.10.4 WIM Data Quality Identifier

For the WIM data stored in the GDOT traffic database, it is highly recommended to add a WIM data quality identifier field to identify WIM sites that provide data acceptable for direct MEPDG use. These are the WIM sites that satisfy ASTM 1318 Type I WIM system requirements, calibrated annually based on ASTM 1318 using heavily loaded Class 9 trucks, and should have at least 1 week of acceptable quality data for each of 12 calendar months.

9.11 RECOMMENDED FUNCTIONALITY OF SOFTWARE TOOLS TO SUPPORT WIM DATA PROCESSING

This section contains recommendations for the minimum software functionality requirements to support WIM data use for MEPDG. These recommendations cover all stages of data processing from the data acquisition in the field to development of traffic loading inputs for AASHTOWare Pavement ME Design. Based on the survey of the available software products, it is likely that more than one software application will be needed to prepare WIM-based MEPDG traffic loading inputs. Discussion of available software products was provided in chapter 5.

The following functionality, as a minimum, should be available in the software tools selected by GDOT to support development of MEPDG inputs and defaults based on WIM data:

1. Auto poll data from permanent WIM sites and save data in binary format on a local server or a desktop. Most likely, this task will be accomplished by WIM vendor software.
2. Using raw (binary) WIM data from permanent or portable sites, generate TMG W-file (in ASCII format) in the latest TMG format for each WIM site. This creates a text file containing per vehicle records documenting axle spacing and axle weight of each vehicle in FHWA classes 4-13 that passes over the WIM sensor. Most likely, this task will be accomplished by WIM vendor software.
3. Perform rudimentary QC checks using PVR records. This should be done as a part of daily data download and processing. This task could be accomplished either by WIM vendor software or third party software like LTAS or TMAS.
4. For permanent WIM sites, use PVR data to develop traffic summary statistics (see sections on Daily, Monthly, Annual, and Representative Key Summary Parameters for details) and save them to the database tables. This task could be accomplished by LTAS software, future versions of TMAS software, or using queries developed in-house.
5. Use daily or monthly GVW and axle weight summary statistics to run data reasonableness checks to identify WIM system performance issues (calibration drifts, sensor failure, etc.). This task could be accomplished by WIM vendor software (IRD WIM vendor has developed these tools for LTPP project) or using queries developed in-house.
6. For portable WIM sites, use PVR data to develop axle load distribution summaries and corresponding normalized axle load spectra for the total monitoring period and save these results to a database table. This task could be accomplished by LTAS software, future versions of TMAS software, or using queries developed in-house.

7. Develop database tables for annual upload to the GDOT PLUG traffic library database. This task could be accomplished using queries developed in-house.
8. Use normalized axle load spectra to determine changes or in load distribution by comparing axle load distributions month-to-month and for the same month year-to-year. Note observations in the comment field of the normalized monthly axle load distribution table, accept or reject data from further summarization and analysis. This task could be accomplished using queries developed in-house.
9. Assign loading categories to NALS for MEPDG use. This task could be accomplished using the GDOT PLUG software or using queries developed in-house.
10. Develop new or update existing default axle loading distributions using data from Georgia permanent WIM sites. This task could be accomplished using the GDOT PLUG software.
11. Develop axle load distribution input files for MEPDG Level 1, 2, and 3 inputs. This task could be accomplished using the GDOT PLUG software.

Items 1-3 listed above are not unique to MEPDG use and are likely to be included in WIM vendor software. Items 4-11 serve unique MEPDG needs and are not likely to be available in the WIM vendor software. Items 9-11 could be accomplished using the GDOT PLUG database application. The LTPP LTAS software has capabilities of computing most of these summary statistics because this software was designed to process WIM data and prepare MEPDG traffic loading inputs for the FHWA LTPP program. We recommend that GDOT consider implementing LTAS for traffic data QC and summarization to develop traffic summary statistics for MEPDG use. This software is free upon request from LTPP and requires an Oracle database to house the data, which is GDOT's corporate database platform.

Alternatively, TMAS software could be considered. It is expected that FHWA TMAS software will have capabilities to produce most of these statistics and NALS input files in the future. However, this capability is not currently implemented in TMAS.

Some other alternatives were discussed in section 2.5 of chapter 2. It is also feasible that GDOT may decide to develop in-house data processing tools, such as custom SQL queries or an automated database application. Using in-house tools will provide flexibility in making necessary adjustments in the future.

9.12 PERSONNEL RECOMMENDATIONS

The following recommendations are made for the qualifications and "level of effort" requirements to support the fully implemented the GDOT WIM Data Collection Program. Many of the field operations and data related functions could be conducted using GDOT staff or contracted out.

9.12.1 Program Management (Estimated 0.5 full-time equivalent [FTE], once fully implemented)

Major responsibilities of the WIM Program Manager:

1. Support procurement of WIM systems and services.
2. Management and oversight for portable WIM data collection.
3. Management and oversight for installation and maintenance of permanent WIM sites.
4. Management of WIM data processing and reporting.

9.12.2 Field Operations (Estimated 2 FTE: WIM specialist/supervisor and electronics technician, once fully implemented):

Major responsibilities of the WIM specialist/supervisor and electronics technician:

1. Schedule WIM site visits for semi-annual preventive maintenance and annual WIM calibration.
2. Assess road conditions and recommends best locations of future WIM site within the identified road segment to maximize WIM data accuracy.
3. Install or oversee installation of permanent WIM sites, including WIM system infrastructure components (additional resources may be needed for traffic control and construction related activities).
4. Place portable WIM equipment for 2-7 day data collection, including in-place WIM calibration and rudimentary WIM data QC using Class 9 GVW, steering axle, and tandem axle weight checks.
5. Conduct annual calibration of permanent WIM sites and develops calibration report.
6. Conduct semi-annual inspection and preventive maintenance of permanent WIM sites and develops inspection report.

9.12.3 Data Processing, QC/QA, and Analysis (Estimated 1 FTE, data analyst, once fully implemented):

Major responsibilities of the WIM data analyst:

1. Daily auto poll WIM data from permanent WIM sites, review WIM records and QC summary reports using WIM vendor software and/or in-house tools.
2. Upload W-files from permanent and portable WIM sites into FHWA TMAS software or other data processing tools.
3. Process portable and permanent WIM data to develop daily, monthly, annual and representative summary loading statistics, and determines axle loading category using specialty software or in-house tools.
4. Conduct weekly, bi-weekly or monthly QC checks for WIM calibration drifts using reference data set and specialty software or in-house tools.
5. Develop ad-hoc WIM reports and statistics based on management requests using database queries.
6. Develop or updates database tables for annual upload to GDOT PLUG database for use by pavement engineers (Site-specific and default NALS, APC, NVCD, and WIM site information tables) using specialty software or in-house tools.
7. Update axle load spectra defaults (once every 1-3 years) specialty software or in-house tools.
8. Submit data QC reports to WIM Program manager (daily, by-weekly, or monthly, based on report type).
9. Keep inventory of the available WIM data.

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APPENDIX A WIM DATA COLLECTION PLAN TO SUPPORT GDOT'S MEPDG IMPLEMENTATION

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

AADTT	Average Annual Daily Truck Traffic
AASHTO	American Association of State Highway and Transportation Officials
AVC	Automated Vehicle Classification
DOT	Department of Transportation
ESAL	Equivalent Single Axle Load
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
JPCP	Jointed Plain Concrete Pavement
LTPP	Long Term Pavement Performance
MEPDG	Mechanistic-Empirical Pavement Design Guide
NALS	Normalized Axle Load Spectra
NCHRP	National Cooperative Highway Research Program
PLUG	Pavement Loading User Guide
QA	Quality Assurance
QC	Quality Control
RPPIF	Relative Pavement Performance Impact Factor
SPS	Specific Pavement Studies
TMG	Traffic Monitoring Guide
TPF	Transportation Pooled-Fund (study)
TWRG	Truck Weight Road Group
WIM	Weigh-in-Motion

A.1 INTRODUCTION

A.1.1 Traffic Loading Data Requirements for Mechanistic-Empirical Pavement Design Guide

The Mechanistic-Empirical Pavement Design Guide (MEPDG) uses axle load distributions obtained from weighing heavy vehicles as the main vehicle loading input for pavement design. Axle load distributions are entered in the MEPDG design software in the form of normalized axle load spectra (NALS). NALS are percentile distributions of axle counts by load range. Individual NALS are computed for each axle type and truck class. The axle types included in the MEPDG design procedure are single, tandem, tridem, and quad, and the truck classes are vehicle classes 4 through 13 from the Federal Highway Administration (FHWA) classification scheme. Other major traffic inputs include average annual daily truck traffic volume (AADTT), percentile distribution of vehicles by FHWA vehicle class, monthly and hourly truck volume adjustment factors, and truck traffic growth factors.

In the MEPDG, NALS representative of a "typical day of the month" are used. For roads that do not show significant seasonal variations in percentages of heavy and light loads, the same NALS are used for all calendar months. In addition to NALS, other major MEPDG traffic inputs are number of axles per truck for each truck class, percentile truck classification volume distribution, truck volumes (by month or annual), and truck growth rates.

MEPDG accepts several levels of truck loading data, depending on the relative importance of the road and the design input level desired:

- Level 1 design input: site-specific traffic data.
- Level 2 design input: defaults developed regionally or by road grouping or averages based on data from similar sites or roadway segments.
- Level 3 design inputs: global or statewide averages; best-guessed input values.

Due to the significant costs associated with collecting project-specific axle loading data, it is anticipated that most future pavement designs in Georgia will rely on Level 2 defaults.

To collect data for developing default axle load distributions for MEPDG design, a number of permanent weigh-in-motion (WIM) sites should be constructed at selected locations. These sites should be strategically located to produce a sample of truck load distributions representing truck loads that are characteristic of different road groups in Georgia.

Because traffic loading conditions may vary even within an identified group of roads, short-duration (2 to 7 days) portable WIM data should be collected at the project location (primarily for high-importance pavement rehabilitation or reconstruction projects) to aid in selecting the default normalized axle load spectra (NALS) that best matches the loading conditions observed.

A.1.2 Current State of WIM Data Collection by Office of Transportation Data (OTD)

Currently, GDOT conducts two types of WIM data collection: short-duration WIM sampling using portable WIM sites and continuous monitoring using permanent WIM sites.

A.1.2.1 Portable WIM Data Collection

Portable WIM data are collected annually and submitted to the FHWA, as part of HPMS data submission. Historically, these portable WIM data were used primarily to support the FHWA Truck Weight Study. GDOT did not have in-house use of these portable WIM data or data processing tools.

There are 88 sites for which portable WIM data were collected prior to 2013. About one-third of these sites were surveyed each year. The majority of these sites are on the interstate and State routes, as summarized in table 47.

TABLE 47
Distribution of Portable WIM Sites by Route Type

Route Type	Number of WIM sites
I– Interstate	29
US – US Route	1
SR – State Route	49
CR – County route	9

In 2013, GDOT's Office of Planning selected a different set of roads for portable WIM data collection. All of these locations are non-interstate roads. Many of these roads are near urban centers. Locations for 2013 portable WIM data collection are shown in table 48.

TABLE 48
List of Portable WIM Sites for 2013 Data Collection

TC Station #	Priority	Functional Class	Location
District 1			
219-0258	1	2	SR 316 just west of US 78/SR 10 Interchange near Caterpillar Plant (Oconee County)
059-0125	2	14	US 129 (SR-15 Alternate) just north of the Athens Perimeter between Homewood Dr and Trinity Place (Clarke County)
157-0245	3	2	US 129 (SR-11) just east of I-85 Interchange (Jackson County)
241-0052	4	2	US 441 (SR-15) south of SR 246 near the State line (Rabun County)
297-0018	5	6	SR 10 btwn Youth Monroe Rd & SR10BU Alcovy River
District 2			
319-0125	1	2	US 441 (SR-29) just east of SR 112 near Thompson-Denson Road (Wilkinson County)
303-0001	2	6	SR 15 south of Sandersville between Montgomery Road and Harrison-Riddleville Road (Washington County)
107-0022	3	2	US 1/SR 4 north of Swainsboro near Hawhammock Church Road (Emanuel County)
189-0003	4	2	US 78/SR 10 just north of SR 43/Lincolnton Road (McDuffie County)
245-0132	5	16	SR 56/Mike Padgett Highway north of Hephzibah-McBean Road (Richmond County)
District 3			
285-0047	1	2	SR 1/US 27 just south of SR 54 north of LaGrange (Troup County)
199-0212	2	6	SR 109 west of Greenville between Highpoint Road and Fire Tower Road (Meriwether County)
269-0138	3	2	SR 96 west of Butler between McCall Road (CR 239) and Back Road (CR 63) (Taylor County)
151-0103	4	6	SR 155 just north of Bill Georgiardner Parkway/Hampton Locust Grove Rd (Henry County)
171-0127	5	16	SR 7/US 41, 2.3 mi north of town

TC Station #	Priority	Functional Class	Location
255-0373	6	6	SR 16 btwn South McDonough Rd and High Falls Rd
District 4			
065-0107	1	2	SR 38/US 84 east of SR 11/US 129 near Buck Creek (Clinch County) just east of the Lanier-Clinch County Line
027-0138	2	2	SR 38/US 84 east of Boston near Pidcock Road (CR 91) (Brooks County)
071-0006	3	14	SR 133 Southeast of Moultrie near Culbertson Road (Colquitt County)
099-0047	4	2	SR 38/US 84 west of Donalsonville and east of Jakin near Harrell Moye Road (Early County)
321-0145	5	2	US 82/SR 520 near Summer between of W Road and College St (Worth County)
District 5			
051-0350	1	14	SR 307 just outside Georgiarden City Terminal main Georgiate (Chatham County)
179-0041	2	14	SR 38/US 84 in Walthourville just east of SR 119 (Liberty County)
229-0123	3	2	SR 38/US 84 southwest of Patterson near Aaron's Way (Pierce County)
305-0041	4	2	SR 27/US 341 near River Road southeast of Jesup (Wayne County)
031-0187	5		SR 73/US 301 towards town just north of SR 46
District 6			
057-0239	1	11	I-575 just south of Sixes Road interchange (exit 11) (Cherokee County)
223-0103	2	2	SR 6 west of Dallas near Gold Mine Road (Paulding County)
115-0087	3	6	US 411/SR-53 west of Cave Springs near Buttermilk Road (Floyd County)
227-0237	4	2	SR 5/515, 0.3 mi north of SR 108 @ mp 12.85
District 7			
121-5716	1	14	SR 6 just west of I-285 near Welcome All Road
097-0045	2	14	SR 6 north of I-20 near Oak Ridge Road (Douglas County)
089-3112	3	16	SR 42/Moreland Avenue just north of I-285 (Dekalb County)
089-3205	4	16	SR 155 just southeast of I-285 near Columbia Drive (Dekalb County)
097-0323	5	14	SR 6 south of I-20 near Factory Shoals Road (Douglas County)

A.1.2.2 Advantages and Limitations of Portable WIM Data for MEPDG Use

Once collected, this information (in addition to historical portable WIM data) will be useful for understanding loading patterns on different GDOT roads. However, the direct usability of the data in the MEPDG may be limited due to data quality concerns—specifically, the ability of the portable WIM systems to accurately measure heavy axle loads.

There are some limitations with the accuracy of portable WIM data due to the type of equipment and procedure used for data collection. GDOT’s portable WIM data collection consists of 2-day WIM data samples collected using PEEK ADR 1000 equipment with piezoelectric Brass Linguini (BL) sensors. All portable WIM data are collected by GDOT’s contractor. No calibration of the portable WIM equipment is conducted to assure accuracy of heavy axle weight measurement (ASTM 1318), especially for load bearing axles in multi-axle groups (tandems, tridems, quad). The contractor uses in-situ calibration without a calibration truck, by using the steering (not load-bearing) axle weight of passing Class 9 vehicles. There is no clause or requirement in the current contract with GDOT about calibrating WIM equipment using heavily loaded test trucks or for QC-ing the accuracy of axle weight data.

A.1.2.2 Existing Permanent WIM Sites

At the time of the study, GDOT had two functioning pilot permanent WIM sites with equipment supplied by two different vendors: IRD and PEEK.

- Site 067-2373 is located on I-285 at Orchard Road in Cobb County. This site utilizes the IRD iSync data collection system with the iAnalyze software. Kistler WIM sensors are installed in the outside three northbound lanes, and Class I BL sensors are installed in inside northbound passing lane. There are no WIM sensors in the southbound lanes.
- Site 207-0222 is located on I-75 between Pate Road and I-475 in Monroe County. This site utilizes the PEEK ADR WIM device with the TOPS software. Kistler WIM sensors are installed in all northbound and southbound lanes.

Based on assessment of the 2010 WIM data sample, both sites provide (or have the capability of providing) good quality data usable for MEPDG applications. However, there are no QC/QA procedures or tools in place to systematically assess the quality of collected WIM data by GDOT OTD personnel.

A.1.2.3 WIM-Ready ATR Sites

In addition to the two pilot permanent WIM sites, seven of the existing ATR sites have WIM Type I Kistler piezoelectric sensors or Class I BL piezoelectric sensors installed and are WIM-ready. All sites are on the interstates. The following list identifies ATR IDs and location of WIM-ready sites:

1. 021-0334 - I-75 between I-475 & SR-247 Pio Nono (Jennifer Overpass 6-PCC) – Kistler WIM sensors in outside lanes in each direction.
2. 089-3354 - I-285 between Memorial Dr. & Church St. MP 44.4 – Class I BL piezo sensors in two (2) outside lanes in each direction.
3. 089-3363 – I-285 between Chamblee Tucker & North lake Pkwy MP 34.9 at the Henderson overpass - Class I BL piezo sensors in two (2) outside lanes in each direction.
4. 143-0126 – I-20 between Alabama State line & SR100 Veterans Mem. Hwy – Kistler WIM sensors in the outside lanes.
5. 127-0312 - I-95 between SR-27 & Golden Isles Parkway SR-25 Spur MP 36.6 – Kistler WIM sensors in outside lanes.
6. 301-0196 – I-20 between SR-12 and East Cadley Road - Class I BL piezo sensors in two (2) outside lanes in each direction.
7. 245-0218 – I-20 between SR-104 RR and Georgia/South Carolina State Line - Kistler WIM sensors in outside lanes.

Note: Class I BL piezo sensors have a known temperature sensitivity issues, resulting in decrease in weight data accuracy (positive or negative bias) as temperature changes. Unless GDOT has resourced to perform seasonal calibration of WIM sites, this type of technology is not recommended for collecting of weight data for pavement design or for other studies where accurate measurement of heavy axle weights is required. This recommendation is based on findings from WIM technology testing performed by the FHWA LTPP program in early 2000s.

A.1.2.4 Proposed Future Permanent WIM Sites from OTD

In 2013, OTD has made available a new list of 20 proposed permanent WIM sites. All but one of these sites are located on interstate routes. This distribution of sites was developed primarily to support freight studies. However, upon close examination it was determined that these locations would also provide adequate coverage for computation of MEPDG default NALS for Georgia urban and rural interstates. Table 49 provides a list of OTD's proposed permanent WIM sites. This list was updated in February 2014 to show the current installation status of the WIM sites.

TABLE 49
OTD's List of Proposed Permanent WIM Sites

Traffic Site ID	County	Location	WIM TYPE	Installation Status (February 2014)
0021-0334	Bibb	I-75 btwn I-475 & SR-247 Pio Nono (Jennifer Overpass 6-PCC)	KISTLER WIM	Installed
0039-0218	Camden	I-95 btwn Florida Line & St Marys Rd CR-61 North of welcome ctr	BL CLASS I WIM	Installed
0051-0368	Chatham	I-16, 0.6 mi. East of SR-307 Dean Forest Rd	KISTLER WIM	Installed
0051-0387	Chatham	I-95, 2 mi N. of SR-21 @ SC State line SB	KISTLER WIM	
0067-2373	Cobb	I-285 @ Orchard Road	KISTLER WIM	Installed
0081-0101	Crisp	I-75 1.5 M So SR-33 connector(Rock House Rd)	KISTLER WIM	
0081-0347	Crisp	SR-300 btwn SR-300CO Old Albany & SR-7 Bridge MP 9.3	KISTLER WIM	Installed
0089-3354A,B	DeKalb	I-285 Btwn Memorial Dr. & Church St. MP 44.4	KISTLER WIM	
0089-3363A,B	DeKalb	I-285 btwn Chamblee Tucker & North lake Pkwy MP 34.9 @ Henderson overpass	KISTLER WIM	
0127-0312	Glynn	I-95 btwn SR-27 & Golden Isles Parkway SR-25 Spur MP 36.6	KISTLER WIM	Installed
0143-0126	Haralson	I-20 btwn Alabama State line & SR100 Veterans Mem Hwy	KISTLER WIM	Installed
0147-0287	Hart	I-85 btwn Hart/Franklin Co line & SR77 Whitworth Rd	BL CLASS I WIM	
0185-0227	Lowndes	I-75 at the Georgia-Florida State Line	BL CLASS I WIM	Installed
0207-0222	Monroe	I-75 between Pate Road and I-475	KISTLER WIM	Installed
0245-0218	Richmond	I-20 btwn SR-104 RR and Georgia/South Carolina State Line	KISTLER WIM	Installed
0265-0163	Taliaferro	I-20 btwn SR-22 & Warren Co Line MP 148.8	KISTLER WIM	
0277-0256	Tift	I-75 btwn Willis Still Rd & Turner Co line	KISTLER WIM	
0285-0234	Troup	I-85 btwn SR-219 & SR-1	KISTLER WIM	
0289-0183	Twiggs	I-16 (SR-404) btwn SR-96 & SR-358 Homer Change Hghwy	KISTLER WIM	
0301-0196	Warren	I-20WB btwn SR-12 & E Cadley Rd CR-185	KISTLER WIM	

A.1.2.5 Advantages and Limitations of OTD's Permanent WIM Plan

Once installed and properly calibrated (per ASTM 1318 for Type I WIM systems), it is expected that the WIM data from the sites identified on the OTD's Permanent WIM List will be directly usable as MEPDG Level 1 inputs for covered interstate routes and as a source for development of MEPDG Level 2 defaults for interstate roads.

Because few of the proposed sites will use BL sensors that are known for temperature sensitivity (calibration drift due to temperature fluctuations), we recommend that GDOT develop proactive QC/QA procedures for these sites for timely mitigation of temperature-induced calibration drifts.

One limitation of the current OTD list for permanent WIM sites is that it does not support development of the defaults for non-interstate groups of roads. Based on analysis of GDOT's portable WIM data, it is expected that NALS for non-interstate roads will be different than for interstate roads. Therefore, additional permanent WIM sites will be needed to support future MEPDG designs for Georgia non-interstate roads.

A.1.3 Objective of MEPDG WIM Data Collection Plan

The goal of this data collection plan is to identify candidate locations for future permanent WIM sites to support development of MEPDG axle loading defaults for GDOT MEPDG implementation. Using the approach, "collect data once and use it many times," WIM site locations were identified to provide adequate road coverage for development of the MEPDG NALS defaults while maximizing the use of WIM sites proposed by the other GDOT users.

This statewide traffic loading data collection plan identifies short-term, medium-term, and long-term goals in support of GDOT's MEPDG implementation. This plan also provides recommendations for portable WIM data collection in support of MEPDG activities. In the short-term, this plan focuses on satisfying the needs of the GDOT's pavement designers for the truck axle loading data necessary for implementation of the MEPDG design method in Georgia. However, it is anticipated that over time the additional WIM data users will come forward. Therefore, it is recommended for this plan to be reviewed and revised at the beginning of the mid- and-long-term activities outlined in this plan.

A.2 WIM PROGRAM ROAD COVERAGE

A.2.1 Roads Types Requiring WIM Data for MEPDG Use

Based on the NCHRP 1-37A report, traffic loading data collection should cover roads with average annual daily truck traffic (AADTT) of heavy vehicles (vehicle classes 4, 6-13 per Federal Highway Administration [FHWA] vehicle classification scheme F-13) for the roadway with over 70 heavy vehicles per day. Pavement thickness for roads with lower truck volumes is based not as much on traffic loads as on the minimum thickness required by construction practices or to account for environmental impacts on pavement performance. Also, installation of permanent piezo-electric WIM sensors requires minimum pavement thickness, so that pavement structural capacity would not be adversely affected by the cut (typically 2 inches deep) necessary to install WIM sensors. This makes very thin asphalt pavement structures poor candidates for WIM installation. Georgia's minimum pavement thickness requirements, however, generally exceed the definition of thin-surfaced pavements.

Analysis of Georgia vehicle classification data shows that Georgia roads with FHWA Functional Class (FC) codes 01, 02, 04, 06, 11, 12, 14, and 16 have AADTT over 70 heavy vehicles per day. These roads are recommended for WIM coverage to support MEPDG. Roads with functional Class codes 07, 08, 09, 17, and 19, on average, have an AADTT of fewer than 70 heavy vehicles per day. Therefore, these roads are not recommended for the WIM program coverage.

The functional classes used in the report are provided in table 50 for the readers' convenience.

TABLE 50
Road Functional Class Descriptions used in this Report

Road Functional Class Code	Road Description
01	Rural Interstate Principal Arterial
02	Rural Principal Arterial
06	Rural Minor Arterial
07	Rural Major Collector
08	Rural NFA Minor Collector
09	Rural Local
11	Urban Interstate Principal Arterial
12	Urban Freeway and Expressway
14	Urban Principal Arterial
16	Urban Minor Arterial
17	Urban Collector
19	Urban Local

In 2010, the FHWA issued guidance to remove rural and urban differentiation from the functional classification and consolidate functional classes for HPMS reporting. However, we recommend keeping rural and urban differentiation for the purpose of monitoring truck traffic patterns and development of truck loading defaults for pavement design.

A.2.2 Georgia Roads Recommended for Installation of Permanent WIM Sites

To assure that WIM data are collected using a geographically diverse sample of GDOT roads that carry a significant volume of heavy truck traffic, a list of potential roads for permanent WIM installation was developed, as was documented in Interim Report #2 for this project. This list is presented in table 51. The three columns in the table provide recommended road coverage to support short-, mid-, and long-term WIM program options. (This list was subsequently revised based on GDOT's inputs and considering Georgia's new statewide designated freight corridor map, and a list of proposed WIM sites to support MEPDG implementation was developed, as presented later in table 52 of this report.)

TABLE 51
Preliminary List of Roadways for Permanent WIM Installation

Short-Term	Mid-Term	Long-Term
I-95	I-75 (2)*	I-75
I-16	I-85	I-285
I-75 (2)	I-20	I-16
I-85	US-441	I-85
I-20 (2)	US-80	US-441 (2)
I-285	US-41	US-76
US-84	US-341	US-280
US-280	SR-15	US-1
US-78	SR-15	US-27
US-76	SR-133	US-82 (2)
SR-32	SR-38	US-41 (2)
SR-61	Maintain all sites from short-term list	SR-10
SR-96		SR-16
SR-316		SR-18
		SR-20
		SR-22
		SR-24
		SR-35B
		SR-44
		Maintain all sites from short- and mid-term lists

* Number in brackets shows the number of sites to be installed for a listed roadway.

A.2.3 Initial Georgia Default Road Grouping by Loading Condition

This section is provided to introduce the concept of road grouping for the purpose of developing and applying traffic loading defaults in MEPDG-based pavement design procedures. A number of WIM sites are needed to support development of the defaults for each road group.

Level 2 MEPDG traffic loading defaults are computed based on averaging of NALS within the group of roads representing a similar loading condition. Multiple defaults are useful when more than one loading condition is observed in the State and the differences in loading conditions are large enough to produce significant differences in pavement design outcomes.

Based on the analysis of available traffic loading distributions observed in GDOT historical WIM data collected over 2005-2012 time period for over 100 directional sites (if WIM data were collected for both directions of travel, it was counted as 2 sites), it was determined that 70 to 90 percent of total pavement load comes from Class 9 trucks. These trucks are the most frequent heavy loaded trucks in Georgia. A Class 9 truck has a tractor-semitrailer configuration. It typically has 18 wheels with a single axle in the front, followed by two tandem axles (one on a tractor and one on the semi-trailer).

The following loading conditions were frequently observed on Georgia roads, based primarily on the loading observed for Class 9 trucks (the naming of loading conditions/defaults is consistent with the new LTPP MEPDG loading default names):

- Moderate Loading Condition – this loading condition represents roads where about one-third of Class 9 trucks are heavily loaded (although one third is defined as 33 percent, this could range between 25 and 40 percent, subject to engineering judgment of other road attributes). This loading condition is observed on Georgia urban and rural minor arterials, collectors, and local roads and all other low volume roads with unknown loading. Also it is observed on non-interstate principal arterial roads with design lane AADTT less than 1,000 trucks and percentage of Class 9 trucks less than 50 percent (MEPDG Truck Traffic Classification [TTC] 9, 12, 14). Currently, GDOT's default for this loading condition is based on the Long Term Pavement Performance (LTPP) program's "Moderate" default for Class 9 trucks and "typical" default for all other vehicle classes.
- Heavy 1 Loading Condition – this loading condition represents roads where more than one-third but less than one-half (over 33 but less than 50 percent; these boundaries may be slightly adjusted based on engineering judgment of other road attributes) of the Class 9 trucks are heavily loaded. This loading condition is observed on Georgia rural and urban interstates and other principal arterial roads with design lane AADTT from 1,000 to 3,000 trucks and percentage of Class 9 trucks between 50 and 80 percent (MEPDG TTC 1, 2, 4, 6). Currently, GDOT's default for this loading condition is based on the LTPP "Heavy 1" default for Class 9 trucks and "typical" default for all other vehicle classes.
- Heavy 2 Condition – this loading condition represents roads where about one-half of Class 9 trucks are heavily loaded (although one half is defined as 50 percent, NALS in this category could have heavy loads ranging between 45 and 60 percent, subject to engineering judgment of other road attributes). This loading condition is observed on Georgia rural and urban interstates and other principal arterial roads with design lane AADTT over 2,000 trucks and percentage of Class 9 trucks over 80 percent (MEPDG TTC 1). Currently, GDOT's default for this loading condition is based on the LTPP "Heavy 2" default loading condition for Class 9 trucks and "typical" default loading condition for all other vehicle classes.

In this context, "heavily loaded" means trucks with loads exceeding 75 percent of the federal legal load limit. The loading conditions were first identified by the FHWA study to develop new MEPDG traffic loading defaults based on the LTPP WIM data from the Transportation Pooled Fund Study 5(004) [in publication].

If a low volume road has a known heavy loading condition (such as road to/from an industrial facility), then a default that best describes that loading condition should be applied. Project-specific portable WIM data collection would be beneficial in this case to establish loading condition.

It should be understood that these loading groups or categories were based on an analysis of portable WIM data of limited quantity and limited quality, using procedures described in Report #4 for this project. Due to the limited nature of historical GDOT WIM data available to establish the three initial loading defaults, it is possible that these defaults may be redefined or additional defaults determined based on the analysis of the additional portable WIM data and the data from the future permanent WIM sites and tested using locally calibrated MEPDG models. The initial program scope, default road groups, and axle loading defaults should be reviewed within 3 years from the initial program implementation and adjustments made, if necessary.

A.3 SELECTION OF CANDIDATE PERMANENT WIM SITES TO SUPPORT MEPDG

A.3.1 Site Selection Approach

The following considerations were made in developing a list of candidate permanent WIM sites to support development of MEPDG axle loading defaults for GDOT's MEPDG implementation:

1. Provide road coverage meaningful for MEPDG applications by considering as many different road functional types that will be covered by MEPDG procedures as practically possible.
    a. Include sites representing GDOT roads with truck volumes significant for pavement design outcomes. This should include roads in the following functional classes: 01, 02, 04, 06, 11, 12, 14, and 16.
    b. Because road mileage for a given functional Class varies between the districts, prorate the number of WIM sites within each functional Class in proportion to road mileage within each district (districts with larger road mileage for a given functional Class will have a larger number of sites, all other conditions being equal). Since the Moderate loading condition is typically observed for roads with a low volume of heavy trucks, consider only mileage of roads with higher volumes of heavy trucks.
2. Assure that selected locations provide coverage of different loading conditions typically observed on Georgia roads (from analysis of GDOT's historical WIM data) to support development of MEPDG loading defaults.
    a. Because loading conditions and the nature of loads being carried may be affected by the proximity of urban centers, as well as by interstate vs. non-interstate road types, include a representative number of interstates and non-interstates, as well as rural and urban locations to avoid possible bias in computation of the defaults and to capture potential differences in loading conditions for these road types.
    b. Because some correlation was found between the volume and percentage of heavy trucks (primarily Class 9) and the loading condition, include sites that represent a wide range of design lane AADTTs and percentages of Class 9 trucks.
    c. Because regional business activities may influence truck loading conditions, include as many different GDOT districts within each default group as possible to avoid any potential regional bias.
3. Assure adequate coverage of Georgia's statewide designated as freight corridors as these roads either already have or expected to have future high truck volumes and considered high priority roads by GDOT.
4. Prioritize WIM site installation using the following considerations:
    a. Candidate WIM site locations that already had historical axle loading information should be given a high priority for short-term installation over the sites where no loading information is available. This will minimize the risk of selecting a site with atypical loading conditions.
    b. Candidate WIM site locations where no historical loading information is available should be used as mid- and long-term priorities to provide necessary time for collecting portable WIM data and assessing loading conditions at each candidate site (see table 52). Portable WIM data collection in fiscal years 2014

and 2015 is strongly recommended for sites included in mid- and long-term plans.

5. To maximize cost savings and data sharing within GDOT, where applicable, consider the following:
    a. Utilize the existing traffic monitoring infrastructure as much as possible (e.g., use permanent automated traffic recorder [ATR] sites for WIM upgrades).
    b. Utilize WIM site locations proposed by other users within GDOT (OTD's list of proposed permanent WIM sites and 2013 portable WIM data collection list, based on a request from the Office of Planning, as well as GDOT's future LTPP needs) and the FHWA HPMS program.
6. Utilize available federal guidelines for establishing WIM data programs (e.g., the FHWA Traffic Monitoring Guide [TMG]).

A.3.2 Field Site Condition Assessment

Selection of sites for permanent WIM installation should account for conditions favorable for accurate weighing in motion (i.e., the effect of vehicle dynamics due to road and traffic characteristics on WIM measurement error is minimized). This includes free flow of traffic without sudden acceleration/deceleration or lane changing, road geometry that provides straight roads segments with low grade longitudinal and transverse grade, no ramps or bridges in the vicinity of the WIM site, smooth pavement prior to the WIM site, and other considerations. A complete listing of the WIM site requirements are given in ASTM 1318, FHWA LTPP Optimum WIM Site Locator, and LTPP WIM installation Manual.

All identified candidate WIM sites locations should be subjected to a field survey prior to making the final site selection decision.

A.3.3 Number of WIM Sites

The FHWA TMG recommends a minimum of six WIM sites per default load spectrum road group, assuming that loading patterns observed within the group are fairly uniform. If a greater variability of loading condition is observed within the group, the TMG recommends either to increase the number of sites per default road group or to split the defined default group into subgroups. Based on the initially identified 3 default traffic loading conditions, at least 18 permanent WIM sites are needed to support the development of Georgia axle loading defaults.

The analysis of GDOT's portable WIM data indicated that more than one loading condition can be observed within any given road functional class. In addition, loading along certain corridors or regions (like the Port of Savannah) may be different from the initially established default groups. Therefore, it is possible that two subgroups could be identified within each initial default group. In this case, up to 36 permanent WIM sites could be needed to support the development of the MEPDG loading defaults. Furthermore, if GDOT decides to adopt a "virtual WIM" approach for selecting loading inputs by utilizing data from near-by WIM sites (i.e. averaging data from user-selected "similar" WIM sites to create NALS for the project, as presented in Interim Report #2), more than 50 permanent WIM sites may be needed.

These preliminary recommendations should be tested, using the approach recommended in the following paragraphs, once the data from the initial 18 WIM sites become available.

A.3.4 Future Validation of the Loading Defaults and the Number of WIM Sites

The final number of default road groups should be a function of pavement design sensitivity, using locally calibrated MEPDG models, to loading conditions captured at GDOT's permanent WIM sites.

Therefore, in the short-term, it is recommended to install as a minimum six WIM sites in each of the three initially defined default road group and collect 1 year of research-quality WIM data, as defined by the FHWA LTPP Specific Pavement Studies Transportation Data Collection Pooled-Fund Study 5(004). NALS developed based on these data should be used in an MEPDG sensitivity analysis with locally calibrated models to evaluate the effect of variability in the truck loading distributions on pavement design outcomes, as described below:

- If pavement design outcomes in terms of pavement thickness or pavement design life are consistent within the default group, then the group is validated.
- If the MEPDG results in pavement thickness or pavement design life that is significantly different between load spectra for sites assigned to the same default load group, then that default group needs to be split into subgroups or all default groupings should be redefined.
- If pavement design outcomes are indifferent between different groups (same resulting pavement thickness or pavement design life), then those groups producing the same results should be combined.

The results of this investigation would either validate the initial default road groups or provide support to redefine the road groupings and to revisit the mid-term and long-term plans for permanent WIM systems installation. Traffic loading inputs or defaults that result in less than 0.5 inch thickness in pavement designs provide limited practical benefit. This should be considered in final determination of the number of WIM sites.

A.3.6 MEPDG List of Candidate Sites for Permanent WIM

A.3.6.1 WIM Sites Prioritization

Table 52 includes candidate locations for permanent WIM site installations listed by GDOT's traffic site ID (usually ATR ID or ID for portable data collection location) and sorted by priority from MEPDG implementation perspective.

Sites with WIM equipment already installed are listed as "Existing" in the priority column in table 52. Although these sites do not provide optimum road coverage for development of the defaults, WIM data from all these sites are usable for development of MEPDG site-specific (level 1) inputs and defaults NALS for urban interstates.

Sites that cover road types underrepresented by the existing permanent WIM sites (such as rural interstates and non-interstate roads with significant truck traffic) and either have partial WIM system components already installed or have loading conditions that have been already identified from the historical portable WIM data are identified as "short-term" sites in the priority column in table 52. These sites are given the highest priority for installation because these could return an immediate benefit for the lowest investment cost while providing necessary WIM coverage to satisfy immediate MEPDG needs. However, if based on inputs from other GDOT WIM data users, GDOT decides to install WIM sites at locations identified as mid- or long-term in table 52, these locations could be substituted for the short-term locations, provided that similar road functional Class coverage is maintained (i.e., sites should include both rural and urban locations and cover interstate, other principal arterial, and minor arterial roads).

The total number of WIM sites necessary to support the MEPDG will depend on the approach GDOT takes for utilizing traffic loading data for pavement design (i.e. the number of loading defaults and/or use of virtual WIM approach in the long-term). This decision will be made once local calibration of MEPDG models is completed and sensitivity of these models to traffic loading is tested. At this time, a minimum of 18 WIM sites is recommended for implementation in the short term. Ideally, these sites should be distributed evenly between the following road types: (1) rural interstates, (2) urban interstates, and (3) non-interstate principal and minor arterials. To accommodate possible mid- and long-term expansion of the program, a list of 56 candidate WIM locations is provided in TABLE 52 to assure comprehensive coverage of Georgia road network.

A.3.6.2 WIM Sites Shared by Different GDOT Programs

As indicated in table 52, all but two of the proposed interstate WIM site locations are also on the OTD list of proposed permanent WIM sites. The two additional WIM site locations on I-85, identified as long-term in table 52, are not on the OTD list but are considered important for understanding changes in truck loading along the I-85 corridor.

Because OTD's list of proposed permanent WIM sites has only one non-interstate location, WIM list in table 52 shares only one non-interstate site with the OTD list. Most of the proposed non-interstate locations for permanent WIM sites, shown in table 52, were selected at existing ATR locations to minimize the cost of WIM installation while providing for wide road coverage. Where applicable, a preference was given to the sites located on Georgia's designated statewide freight corridors. However, non-interstate locations outside of Georgia's designated statewide freight corridors were also considered if they had significant truck volumes. Installing permanent WIM sites on non-interstate routes with significant volumes of heavy trucks is important for developing traffic loading defaults to use for pavement design of non-interstate roads in Georgia.

In addition, 10 of these non-interstate locations are included on the 2013 list of the portable WIM sites developed by the Office of Planning. The majority of the portable WIM locations listed by the Office of Planning do not coincide with the existing permanent ATR locations. Installing WIM sites at these locations will be significantly more expensive than upgrading ATR sites for a similar data benefit, from the MEPDG perspective. However, if GDOT decides to install permanent WIM equipment at any of these locations to serve non-MEPDG needs and if the selected location has a substantial truck volume, these locations could be substituted for the non-interstate sites with similar truck and road characteristics presented in table 52, especially for the roadways listed in table 51.

TABLE 52
Proposed Permanent WIM Sites for MEPDG Use

Traffic Site ID	Route	District	Functional Class	Priority Schedule	Portable WIM Collection prior to Permanent WIM?	Type of Traffic site	OTD Permanent WIM List or 2013 Portable WIM List?	Expected Loading Pattern	AADTT CU (Class 8+) Design Lane
207-0222	I-75/SR401	3	1	Existing	No	ATR & Permanent WIM	OTD Pilot Permanent WIM	H1/H1	1727
185-0227	I-75	4	1	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	Unknown	3212
143-0126	I-20	6	1	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	Unknown	3745
081-0347	SR300	4	2	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	H1/H2	647
065-0118	SR38/US84	4	2	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	M/H1	595
245-0218	I-20	2	11	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	Unknown	2222
021-0334	I-75	3	11	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	H1/H2	683
021-0378	I-475	3	11	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	Unknown	
127-0312	I-95	5	11	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	Unknown	2657
051-0368	I-16	5	11	Existing	No	ATR & Portable WIM	OTD Permanent WIM	M/H1	1355
039-0218	I-95	5	11	Existing	No	ATR & Permanent WIM	OTD Installed in 2013	Unknown	
067-2373	I-285	7	11	Existing	No	ATR & Permanent WIM	OTD Pilot Permanent WIM	H1	5859
265-0163	I-20/SR402	2	1	Short-Term	No	ATR & Portable WIM	OTD Permanent WIM List	H2/H2	2889
289-0183	I-16	3	1	Short-Term	No	Portable WIM	OTD Permanent WIM List	H1/H1	2000
081-0101	I-75	4	1	Short-Term	No	No ATR, Port WIM	OTD Permanent WIM List	M/H2	2000
177-0041	SR520/US82	4	2	Short-Term	No	ATR & Portable WIM		H1	691
025-0163	SR520/US82	5	2	Short-Term	No	ATR & Portable WIM		M/H2	314
009-0156	SR24	2	6	Short-Term	No	ATR & Portable WIM		M/H1	265
021-0116	SR22/US80	3	6	Short-Term	No	ATR & Portable WIM		VH1	138
089-3385	SR410/US78	7	12	Short-Term	No	ATR & Portable WIM		M/M	279
059-0087	SR15/US441	1	14	Short-Term	No	ATR & Portable WIM		M/H1	629
153-0189	SR247/US129	3	14	Short-Term	No	ATR & Portable WIM		H1	205
177-0005	SR3/US19	4	16	Short-Term	No	ATR & Portable WIM		M/M	94
147-0287	I-85	1	1	Mid-Term	Yes	ATR	OTD Permanent WIM List	Unknown	4451
285-0234	I-85/SR403	3	1	Mid-Term	Yes	ATR	OTD Permanent WIM List	Unknown	1954
277-0256	I-75/SR401	4	1	Mid-Term	Yes	ATR	OTD Permanent WIM List	Unknown	3086
189-0003	SR17/US78	2	2	Mid-Term	Yes	no ATR, planning list	Planning Port WIM 2013	Unknown	125
285-0047	SR1/US27	3	2	Mid-Term	Yes	no ATR, planning list	Planning Port WIM 2013	Unknown	
161-0189	SR19,27/US23	5	2	Mid-Term	No	ATR & Portable WIM		M/H2	515
297-0018	SR10/US78	1	6	Mid-Term	Yes(4 Days)	ATR, port WIM in 2013	Planning Port WIM 2013	Unknown	145
255-0373	SR16	3	6	Mid-Term	Yes	ATR, port WIM in 2013	Port WIM 2013	Unknown	370
051-0109	SR21/US80	5	6	Mid-Term	Yes	ATR		Unknown	576
179-0072	SR38/US84	5	6	Mid-Term	Yes(4 Days)	ATR		Unknown	146

Traffic Site ID	Route	District	Functional Class	Priority Schedule	Portable WIM Collection prior to Permanent WIM?	Type of Traffic site	OTD Permanent WIM List or 2013 Portable WIM List?	Expected Loading Pattern	AADTT CU (Class 8+) Design Lane
213-0212	SR2/US441	6	6	Mid-Term	Yes (4 Days)	ATR & Portable WIM		Unknown	221
135-0298	I-85/SR403	1	11	Mid-Term	Yes	ATR		Unknown	3749
051-0387	I-95	5	11	Mid-Term	Yes	ATR	OTD Permanent WIM List	Unknown	3048
275-0074	SR35/US319	4	14	Mid-Term	No	ATR & Portable WIM		M/H1	220
031-0187	SR 73/US 301	5	14	Mid-Term	Yes	ATR	Portable WIM 2013 (Planning?)	Unknown	400
063-1023	SR3/US19,41	7	14	Mid-Term	Yes	ATR		Unknown	202
139-0183	SR13	1	16	Mid-Term	Yes (4 Days)	ATR		Unknown	70
121-5225	SR42/US23	7	16	Mid-Term	Yes (4 Days)	ATR		Unknown	103
011-0103	SR15/US441	1	2	Long-Term	Yes (4 Days)	ATR		Unknown	144
319-0125	US 441	2	2	Long-Term	Yes	no ATR, planning list	Planning Port WIM 2013	Unknown	162
061-0109	SR1/US280	4	2	Long-Term	Yes (4 Days)	ATR		Unknown	150
227-0237	SR 5/515	6	2	Long-Term	Yes	ATR & Portable WIM	Portable WIM 2013 (Planning?)	Unknown	357
115-0081	SR20/US411	6	2	Long-Term	No	ATR & Portable WIM		M/M	468
303-0001	SR15	2	6	Long-Term	Yes (4 Days)	no ATR, planning list	Planning Port WIM 2013	Unknown	208
229-0163	SR32	5	6	Long-Term	Yes (4 Days)	ATR		Unknown	111
089-3354	I-285	7	11	Long-Term	Yes	ATR	OTD Permanent WIM List	Unknown	4090
121-0516	I-85/SR403	7	11	Long-Term	Yes	ATR		Unknown	3350
135-0241	SR316	1	12	Long-Term	Yes	ATR		Unknown	1382
021-0158	SR11/US12	3	14	Long-Term	Yes (4 Days)	ATR		Unknown	300
299-0007	SR4/US1,23	5	14	Long-Term	Yes	ATR		Unknown	477
015-0178	SR61/US411	6	14	Long-Term	No	ATR & Portable WIM		M/H1	210
097-0323	SR6	7	14	Long-Term	Yes	no ATR, planning list	Planning Port WIM 2013	Unknown	
171-0127	SR7/US41	3	16	Long-Term	Yes	ATR	Port WIM 2013	Unknown	230
089-3205	SR155	7	16	Long-Term	Yes	no ATR, planning list	Planning Port WIM 2013	Unknown	

A.3.7 Number and Placement of WIM Sensors

For MEPDG use of WIM data, the WIM sensor should be placed in the truck lane (lane with the highest percentage and volume of combination unit trucks), either in each direction of traffic or in the direction where the higher percentage of heavy trucks is observed, based on the analysis of portable WIM data obtained at each site. However, other non-MEPDG WIM data users may require placement of WIM sensors in each traffic lane.

If funding permits, full lane, double threshold configuration is recommended for higher accuracy and potentially longer performance period. Under budget constraints, half-lane staggered configuration could also be used.

A.4 SELECTION OF CANDIDATE PORTABLE WIM SITES TO SUPPORT MEPDG

A.4.1 Objectives

Portable WIM data serve several objectives in relation to MEPDG implementation in Georgia:

1. Portable WIM data are used to confirm mid- and long-term candidate locations for permanent WIM site installation by assessing loading information obtained from a WIM data sample.
2. Portable WIM data are used to understand loading conditions on different roads throughout the Georgia road network to aid in selecting traffic loading defaults for MEPDG for different road types.
3. Portable WIM data are used to obtain project-specific loading information that can be used to select the most suitable loading input from GDOT's MEPDG traffic loading data library.
4. Portable WIM data are used to understand changes in loading conditions along major freight corridors in Georgia.
5. Portable WIM data are used to understand potential differences in loading conditions by direction of traffic and for selecting the design lane for pavement design.

A.4.2 Coverage Recommendations

As the highest priority for portable WIM data collection, portable WIM data should be collected and analyzed, and loading conditions should be assigned to all the sites included in the mid- and long-term lists of candidate sites for permanent WIM installation listed in table 52 as Y1 or Y2 for portable data collection. The outcomes of the analysis may affect the recommendations for mid- and long-term candidate permanent WIM sites.

In addition, portable WIM data should be collected annually, with a long-term goal to cover over time all Georgia roads in functional classes 01, 02, 04, 06, 11, 12, 14, and 16 with AADTT of Class 9 trucks over 200 per design lane. It is recommended that portable WIM site locations change from year to year to achieve comprehensive road coverage over time, with higher priority given to the sites within HPMS traffic volume and classification samples (to satisfy FHWA's need for traffic loading data) and to the sites identified by other WIM data users (such as GDOT's planning and freight studies).

Finally, as part of the pavement design process for high-priority roads, project-specific WIM data samples taken for 2 to 7 days (duration depends on daily volume of heavy trucks, minimum sample of 200 Class 9 trucks) should be collected as part of special studies, along with vehicle classification and volume data, to aid in selecting the design lane and in identifying best-fit MEPDG loading inputs from the nearby permanent WIM sites or NALS defaults.

For all portable WIM sites, collected axle weight data should be analyzed, NALS computed, and loading conditions assigned for each site based on NALS analysis. This information should be added annually to the GDOT's MEPDG traffic loading database (PLUG database) to expand knowledge of traffic loading conditions observed on different roads in Georgia and to aid in selection of loading inputs and defaults for the future pavement designs.

A.4.3 Data Collection Recommendations

A.4.3.1 Duration of Portable WIM Sample

Historically, GDOT has collected 2-day WIM samples using portable WIM devices. This approach is no longer recommended by the FHWA TMG, because the resulting data usually are low quality and include a lot of dispersion or variability in axle weights. However, the advantage of this approach is very low-cost data collection.

Analysis of GDOT's portable WIM data indicates that usable information about traffic loading conditions can be obtained from 2-day sample, at least in a descriptive form, for roads with a heavy volume of Class 9 trucks. However, usability of these data is diminished for roads with design lane daily volume of Class 9 trucks less than 200, and very little usability is found in data for roads with design lane daily volume of Class 9 trucks less than 100. Therefore, for roads with design lane daily volumes of Class 9 trucks less than 200, it is recommended that GDOT collect at least a 4-day sample (Monday through Thursday) or a week-long (7-day) sample.

It is recommended that GDOT conducts a pilot study to determine the optimum duration of data collection for roads with different truck volumes (based on Class 9 volumes). This outcome will be of particular importance to MEPDG use but also may be relevant for establishing performance measures for freight analysis based on WIM data, as both of these applications require detailed knowledge of truck loads.

A.4.3.2 Portable WIM Calibration

Currently, GDOT's contractor uses front axles of Class 9 trucks to auto-calibrate portable WIM systems. This procedure does not assure accurate measurements of heavy axle loads, as evident in two-thirds of all portable WIM data samples being collected. It is recommended that fully loaded Class 9 calibration trucks of known weight should be used for in-situ calibration of portable WIM sites (using GVW or tandem axle weights) prior to data collection to assure that heavy axle weights are not biased (i.e., mean measurements error from calibration truck runs is less than 2 percent) and a spread of measurement errors is within ASTM 1318 accepted tolerances.

A.4.3.3 Use of Permanent WIM Sensors for Portable ("Hybrid") WIM Data Collection

The new (2013) FHWA TMG guidelines for States' WIM program coverage recommend use of a new type of "portable" WIM sites capable of producing high-quality WIM data. Unlike the traditional portable WIM sites, this is accomplished by installing permanent in-road WIM sensors (for example, Kistler-Quartz) and using a limited number of portable WIM data processing units to collect data at each site with a rate of 1 week per month for 12 months or 1 week per season (i.e., every 3 months) for 4 seasons. This approach provides some cost savings on the number of WIM data processing units but requires more personnel hours to visit sites frequently throughout the year to install/replace/calibrate portable WIM units. However, the benefit is higher quality WIM data than currently being collected using portable WIM systems with WIM sensors temporarily mounted on the top of the pavement.

It is recommended that GDOT conduct a pilot study to test this approach using four ATR sites that already have WIM Kistler sensors installed and evaluates cost and benefit of such approach. If data quality is acceptable for using these data for defaults and projected cost over time is less than for the permanent WIM site, then based on TMG recommendations up to four of six WIM sites needed to support each default load group could be hybrid sites with permanent in-road WIM sensors and portable WIM data processing unit.

A.5 WIM CALIBRATION

Systematic field WIM calibration is very important for collecting high-quality WIM data for MEPDG use. This applies to both portable and permanent WIM sites. Calibration shall be performed in accordance with the ASTM 1318 and methods recommended by the equipment manufacturer. The LTPP Field Operations Guide for SPS WIM Sites [5] is recommended for detailed guidance on calibration procedures.

When performing WIM calibration, special attention should be paid to minimizing weight measurement bias by keeping the mean error between the measured and static axle weights of the calibration truck as close to zero as possible.

Use of the auto-calibration mode is not recommended because it forces the equipment to use a compensation factor (or multiple factors) based on expected weight values from industry standards rather than actual weight measurements from the site, which may be quite different.

For the permanent WIM sites, calibration should be planned on an annual basis, unless WIM data for the site suggest some other interval. Potential calibration drift between field calibration sessions should be checked monthly or bi-weekly (by comparing current NALS against reference NALS computed using 2 weeks of data after calibration), and calibration activities should be scheduled or data flagged if data analysis indicates likely measurement bias over 5 percent.

For the portable WIM sites, calibration should be done after equipment is set at the monitoring site. A fully loaded Class 9 truck or other similar heavy truck of a known weight should be used as a calibration vehicle.

A.5.1 Calibration Trucks

Loaded Class 9 trucks are recommended as calibration trucks for Georgia WIM sites because this type of truck is the dominant heavy truck observed on Georgia roads. Use of two trucks is preferred: one fully loaded and another partially loaded. If only one truck is being used due to budgetary constraints, use a fully loaded truck to assure accurate measurement of heavy loads.

Calibration test trucks should be in good operating condition, with loads that are not susceptible to shifting, harmonics, moisture gain or loss, and are securely anchored.

[5] http://www.tfhrc.gov/pavement/ltpp/spstraffic/index.htm

A.5.2 WIM Performance Evaluation and Calibration

Initial calibration is recommended after the new WIM site has been installed. After initial calibration, annual calibration is recommended. Following are recommendations for calibration procedures:

1. Making no adjustments to the system, conduct 10 to 20 runs per calibration truck at the various operating speeds (typical to the site location) and temperatures and compute differences between static and WIM-based GVW and axle weights. Weight measurement accuracy evaluation should focus on satisfying the following two parameters:

    a. The mean error (or measurement bias) in weight measurements, considering all calibration truck runs, should be less than +/-2% of the true static weight value.

    b. The range of error, as measured by 2 standard deviation (or 95 percent confidence, using student t-distribution for small samples), should be within performance parameters provided in the ASTM 1318 for Type I WIM systems.

    If the initial performance evaluation shows the site to be functioning with sufficient accuracy and without systematic bias, per ASTM 1318 requirements for Type I WIM systems, then go to step 5. Otherwise go to step 2.

2. Analyze test truck data from the initial performance evaluation to determine the system's calibration adjustment factors. Make necessary changes to calibration adjustment factors.

3. Perform a second performance evaluation using the procedures detailed in step 1. If the second performance evaluation shows the site to be functioning with sufficient accuracy, then go to step 5. Otherwise, go to step 4.

4. If analysis of the data obtained from the second performance evaluation does not meet the ASTM 1318 performance requirements for Type I WIM systems, then the system has failed performance requirements. In this case, further troubleshoot reasons for WIM system failure, including but not limited to the following actions:

    a. Recalibrate the system using different test trucks.

    b. Assess pavement condition before and immediately after WIM site and investigate any truck bouncing in the vicinity of WIM site.

    c. Make WIM software adjustments.

    d. Reinstall or replace and install pavement sensors.

    e. Replace or make adjustments to electronics components.

5. Report calibration results, including WIM system performance parameters (precision and bias). For a report template, we recommend using the LTPP WIM System Field Calibration and Validation Summary Report format.

A.6 WIM DATA PROCESSING AND QUALITY CHECKS FOR MEPDG USE

Development of traffic loading inputs for MEPDG use is a multi-step process. The accuracy of traffic loading inputs is dependent on data quality and data quantity. Therefore, QC of data should be viewed as an essential part of WIM data processing.

WIM data processing and QC requirements are provided in the following sections:

- Daily data downloads and rudimentary QC checks
- Data summarization for MEPDG use
- Data validity QC checks
- Data reasonableness QC checks

A.6.1 Daily Data Downloads and Rudimentary Quality Checks

The primary goal of daily data downloads and rudimentary QC checks is to identify any missing or invalid data. The following activities are recommended to provide systematic data management and timely identification of operational issues with WIM equipment:

- Download (auto poll) the WIM system's binary data file(s) containing WIM data on a daily basis to a designated space on a local area network (Monday through Friday). Data files downloaded on the Monday of each week should also include downloads of the previous Friday through Sunday.
- If the first attempt to download data is unsuccessful, make two additional attempts to download the data from the site. If the site cannot be connected to, or rings busy after three attempts, notify the WIM program manager so that corrective action can be initiated.
- Using WIM vendor software, generate Traffic Monitoring Guide (TMG) W-files in ASCII format. These files should be saved to a designated folder on an OTD office computer or to a mass storage device.
- Using WIM vendor software, screen downloaded files for missing or invalid data and print error report. When procuring WIM vendor software, we recommend specifying software capabilities for screening information included in W-files to identify missing or corrupt (unexpected) data and provide error summary reports. Rudimentary checks performed by WIM vendor software should include the following, as a minimum:
    a. Identify, count, and report records with missing values in any required column of W-file.
    b. Identify, count, and report records with characters other than specified data type for a given column.
    c. Identify, count, and report unclassified and partial vehicles missing or having additional axles for a given vehicle class.
    d. Identify, count, and report records with axle spacing out of range for a given vehicle class.
    e. Identify, count, and report records with axle weights out of range for a given vehicle class.
    f. Identify, count, and report records with the left and right wheel weights of any axle having a difference of 40 percent or more.
    g. Identify, count, and report records where total weight is different from sum of axle weights.

h. Identify and remove empty lines in PVR records.
i. Identify and remove extra characters (other than specified for W-file format) at the end of the rows in PVR records.
j. Report total count of vehicles in FHWA vehicle classes 4-13.
k. Report percentage of Class 9 vehicles among vehicle classes 4-13.
l. Report average GVW of Class 9 vehicles.
m. Report average steering axle weight of Class 9 vehicles.
n. Report average axle spacing between 2rd and 3rd axles of Class 9 vehicles.

Note: Additional data validity and reasonableness QC checks should be conducted on a monthly basis using processed data (see sections covering WIM data validity and reasonableness checks below).

- Review error reports, compare summary statistics from items j-n in the list above with the historical average values for a given site. Identify WIM sites that have excessive number of records with errors or changes in summary statistics over 5 percent. Report findings to WIM program manager.
- Remove from further processing records, where problems (error flags) were identified through rudimentary checks. WIM vendor software should have capability of removing records, where problems were identified and reported, based on user's action request.
- Organize all downloaded files in folders by WIM site ID. Filing system should reflect the time period for which data were collected.
- It is also recommended to compute on the daily basis the Daily Key Summary Parameters described in the following section.

A.6.2 WIM Data Summarization for MEPDG Use

A set of database tables should be developed to store intermediate computed traffic loading parameters and other statistics for MEPDG use. This includes WIM data summaries aggregated on a daily, monthly, and annual basis.

Using these aggregated data, representative MEPDG traffic loading input parameters could be computed for each WIM site and used as MEPDG Level 1 inputs. Representative site-specific traffic loading input parameters computed for each WIM site will also be used to develop GDOT's traffic loading defaults (MEPDG Level 2 and 3 inputs).

Necessary traffic loading parameters are described in the following paragraphs.

A.6.2.1 Daily Key Summary Parameters

Daily traffic volume and loading summary statistics are used to compute monthly summary statistics. In addition, daily statistics could be used to troubleshoot the issues identified in the daily rudimentary QC reports. These computations could be conducted on daily, weekly, bi-weekly, or monthly basis. For each WIM site, compute the following parameters for each day of WIM data and store these computed parameters in the database tables:

- Day, month and year being analyzed
- Daily total truck volume for classes 4-13
- Normalized (percentile) vehicle Class distribution (classes 4-13)
- Daily count of unclassified vehicles
- Average weight of unclassified vehicles for the day being analyzed

- Axle load spectrum for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad) for the day being analyzed
- Average GVW of Class 9 vehicles for the day being analyzed
- Average tandem axle weight of Class 9 vehicles for the day being analyzed
- Average single axle weight of Class 9 vehicles for the day being analyzed
- Average percentage of Class 9 tandem axles weighting more than 26 kips for the day being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 34 kips for the day being analyzed.
- Hourly truck volume by vehicle Class (for vehicle classes 4-13)
- Average axle-to-axle spacing for tandem, tridem, and quad axle groupings.

A.6.2.2 Monthly Key Summary Parameters

Monthly summary statistics are used to conduct data reasonableness checks and to compute annual summary statistics. These computations should be conducted on a monthly basis to assure prompt identification of WIM system calibration drift. For each WIM site, compute the following summary statistics for each month of data and store these computed parameters in database tables:

- Month and year being analyzed
- Number of days with WIM data in the month being analyzed
- Average total daily truck volume for classes 4-13 for the month being analyzed
- Normalized (percentile) vehicle Class distribution (classes 4-13) for the month being analyzed
- Average daily count of unclassified vehicles for the month being analyzed
- Average weight of unclassified vehicles for the month being analyzed
- Normalized (percentile) axle load spectrum and total number of axles for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) for a typical day of the month being analyzed
- Average GVW of Class 9 Vehicles for the month being analyzed
- Average tandem axle weight of Class 9 vehicles for the month being analyzed
- Average single axle weight of Class 9 vehicles for the month being analyzed
- Average percentage of Class 9 tandem axles weighting more than 26 kips for the month being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 34 kips for the month being analyzed.
- Average axle-to-axle spacing for tandem, tridem, and quad axle groupings.

A.6.2.3 Annual Key Summary Parameters for Each WIM Site

Annual summary statistics are used to compute representative traffic loading statistics for each WIM site and MEPDG Level 1 traffic loading inputs. These computations should be conducted on an annual basis. For each WIM site, compute the following summary statistics for each year of WIM data and store these computed parameters in database tables:

- Year being analyzed
- Number of days with WIM data in the year being analyzed
- Average Annual Daily Truck Volume for classes 4-13 for the year being analyzed

- Normalized (percentile) vehicle Class distribution (classes 4-13) for the year being analyzed
- Normalized (percentile) truck volume distribution by calendar month for classes 4-13 for the year being analyzed.
- Normalized (percentile) hourly vehicle Class distribution (classes 4-13) for the year being analyzed
- Normalized (percentile) axle load spectrum and average annual daily total number of axles for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad) for the average day of the year being analyzed
- Axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) for the year being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 26 kips for the year being analyzed.
- Average percentage of Class 9 tandem axles weighting more than 34 kips for the year being analyzed.

A.6.2.4 Representative Traffic Loading Summary Parameters for Each Permanent WIM Site

Representative traffic loading statistics are used to compute site-specific MEPDG Level 1 traffic loading inputs using WIM data from permanent WIM sites. These statistics are also used in computation of traffic defaults. Computation of representative traffic loading statistics is accomplished by averaging annual summary loading statistics from all or selected years with WIM data. Representative site-specific traffic loading statistics should be updated every year.

For each WIM site, the following representative traffic loading summary statistics should be computed and stored in database tables:

- WIM site ID and site information (road name, location, type of WIM).
- Average Annual Daily Truck Volume for classes 4-13.
- Normalized (percentile) vehicle Class distribution (classes 4-13).
- Normalized (percentile) monthly truck volume distribution for classes 4-13.
- Normalized (percentile) hourly vehicle Class distribution (classes 4-13).
- Normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) representing the average day of the year.
- Normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) representing the average day for each of 12 calendar months.
- Axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad).
- Average percentage of Class 9 tandem axles weighting more than 26 kips.
- Average percentage of Class 9 tandem axles weighting more than 34 kips.

A.6.2.5 Representative Traffic Loading Summary Parameters for Each Portable WIM Site

Representative traffic loading statistics are computed for each portable WIM site for a lane with the highest truck traffic volume (classes 4-13). These computations are done separately for each direction of traffic. These summary statistics are computed for each site using all portable WIM data collected (2-7 day samples). These statistics are used to identify and describe traffic loading conditions observed at portable WIM sites. For each portable WIM site, compute the following representative traffic loading summary statistics and store these computed parameters in database tables:

- WIM site ID and WIM site information (road name, location, type of WIM).
- Dates when portable WIM sample was collected.
- Duration of portable WIM data collection in days.
- Average Daily Truck Traffic Volume for classes 4-13.
- Normalized (percentile) vehicle Class distribution (classes 4-13).
- Representative Normalized Axle Load Spectra based on portable WIM sample, for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad).
- Axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad).
- Percentage of Class 9 tandem axles weighting more than 26 kips.
- Percentage of Class 9 tandem axles weighting more than 34 kips.
- Assigned traffic loading category.

A.6.2.6 GDOT's Axle Loading Defaults

GDOT's axle loading defaults (Level 2 and 3 MEPDG inputs) are computed by averaging selected site-specific representative traffic loading summary statistics from permanent WIM sites. We recommend that GDOT's axle loading defaults should be updated every 1-3 years at the beginning of the program and every 3-5 years once the program matures. The following representative traffic loading summary statistics should be computed and stored in database tables:

- Traffic Loading Default ID.
- Default Description.
- Recommended road type applicability for the default.
- Default normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad) representing the average day of the year. Multiple defaults representing different loading conditions are recommended.
- Default axle per Class coefficients for each vehicle Class (4-13) and each axle type (single, tandem, tridem, and quad). A single set of default values is recommended.

A.6.3 Data Validity QC Checks

The following QC checks are recommended to assess the validity of collected WIM data. Most of these checks were developed by LTPP for the LTAS software to assure that research-quality WIM data are collected and summarized for the LTPP program. LTAS is considered benchmark software for WIM data QA. These checks are conducted using daily and monthly summary tables described in the previous sections:

- Using hourly truck volume distribution (for vehicle classes 4-13), conduct the following checks:
    a. 1:00 a.m. traffic volume > 1:00 p.m. traffic volume.
    b. 8 or more hours of consecutive zero volume check.
    c. 4 or more hours of static non-zero volume volumes.
    d. Traffic volume (classes 1-15) of 2500 or greater for any specific hour for any lane.

Note any observations that did not pass the checks and investigate possible reasons. If differences are caused by WIM malfunction, remove data from further summarization.

- Using daily or monthly NALS tables, conduct the following checks:
    a. Class 9 tandem NALS graph or table – evaluate stability/repeatability of distribution shape and location of peak loads for normalized distribution.
    b. Class 9 steering NALS graph or table – evaluate stability/repeatability of distribution shape and location of peak loads for normalized distribution.

  Note any significant differences (5 percent or more) from historical averages over time and investigate possible reasons. If differences are caused by WIM malfunction or calibration drift, remove data from further summarization.

- Using monthly axle load summary tables, conduct the following checks:
    a. SAWA check for Class 9 vehicles
    b. ESAL per vehicle variance over multiple months and/or years.
    c. Average tandem axle spacing for Class 9 vehicles – evaluate variance or stability/repeatability over multiple months and/or years.

  Note any significant differences (5 percent or more) from historical averages over time and investigate possible reasons. If differences are caused by WIM malfunction or calibration drift, remove data from further summarization.

- If the same WIM site uses different algorithms for classifying data based on AVC and WIM site functionality, additional checks are recommended:
    d. Atypical pattern in vehicle Class distribution.
    e. Average traffic volume match.
    f. Match of weight and classification volumes by type of vehicle.

  Note any significant differences (5 percent or more) and investigate possible reasons. If differences are caused by WIM malfunction, classification algorithm error, or calibration drift, remove data from further summarization.

A.6.4 Data Reasonableness QC Checks

The purpose of data reasonableness checks is to identify anomalies or changes in truck load distributions that may result from possible WIM calibration drift. These checks are recommended to assure accuracy of WIM data for pavement design. These checks are conducted using the Reference data set defined below. Results of WIM data reasonableness checks could be used in prioritizing and scheduling WIM calibration activities.

A.6.4.1 Reference Data Set

- The first two weeks of data following a successful WIM calibration and validation activity should be considered the reference data set for each WIM site. Data for days when the truck volumes and/or operating characteristics may not be typical, such as a major holiday, should not be included in the reference data set. In this case, substitute the same day(s) of the week from the following week in the reference data set sample.
- These data, converted to TMG W-file format, should be clearly marked as the reference data set and saved to a designated folder on the network. Include time period when these data were collected in the file or folder name.

- Using the reference data set, the following summary statistics should be developed and stored in the database tables for each WIM site:
    - WIM Site ID
    - Time period covering collection of the reference data set
    - Average total daily truck volume for classes 4-13
    - Normalized (percentile) vehicle Class distribution for classes 4-13
    - Average daily count of unclassified vehicles
    - Average weight of unclassified vehicles
    - Axle load spectrum for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad)
    - Normalized (percentile) axle load spectrum for each vehicle Class (4-13) and each axle type (single , tandem, tridem, and quad)
    - Average GVW of Class 9 Vehicles
    - Average tandem axle weight of Class 9 vehicles
    - Average single axle weight of Class 9 vehicles
    - Average percentage of Class 9 tandem axles weighting more than 26 kips
    - Average percentage of Class 9 tandem axles weighting more than 34 kips

- A data analyst or traffic engineer should review the reference data set to confirm and/or establish the expectations of data quality and traffic characteristics for the site. This review should include, as a minimum, analysis of loading distribution for Class 9 vehicles, including identification of load bins with peak single axle load, load bins with unloaded and loaded peak tandem axle loads, percentage of single axles over 20 kips, percentage of tandem axles over 26 kips, percentage of tandem axles over 34 kips, and identification of vehicle classes representing over 20 percent of total truck load (over 20 percent of total ESAL).
- A data analyst or traffic engineer should identify and explain any unique, site-specific loading conditions (such as significant differences between NALS from the reference data set and the default NALS used for a particular road type). These explanations should be saved in a format that could be easily accessed in the future (such as a comment field in the NALS database table for the reference data set). After the review is successfully completed, the statistics computed based on the reference data set should be used as the baseline for comparison until the next field calibration/validation is performed on the WIM system.
- If review of the reference data set indicates any anomalies that may be attributed to malfunctioning of the WIM system, the WIM program manager should be notified.
- The following reasonableness checks based on the reference data set are recommended. These checks should be performed monthly using monthly summary statistics (see section 9.9.2.2 Monthly Key Summary Parameters) computed for each permanent WIM site.
    a. Use statistics computed based on the Reference Data Set and monthly summary statistics, compare values for the month being analyzed with the values based on the reference data set.
    b. Note any deviations over 3 percent over reference set values. Monitor these deviations on a monthly basis.
    c. Report deviations over 5 percent to WIM program manager for scheduling WIM field evaluation for possible calibration drift.

- If significant differences (5 percent or more) are observed between current monthly summary statistics and the statistics based on the reference data set, investigate possible reasons. While WIM malfunction or calibration drift may be some of possible reasons, other events could contribute to these changes, such as seasonal changes in average truck loads or changes in loading triggered by construction or other special events. These causes and explanations should be documented and should be made available to data users when data from the WIM site are requested. If differences are caused by WIM malfunction, classification algorithm error, or calibration drift, remove data from further summarization.

A.7 ACTION PLAN

This statewide traffic loading data collection plan identifies short-term, medium-term, and long-term WIM-related activities to support GDOT's MEPDG implementation. This plan focuses on satisfying the needs of the GDOT's pavement designers for the truck axle loading data necessary for implementation of the MEPDG design method in Georgia. It is anticipated that over time, as the WIM data program matures, additional WIM data users will come forward. Therefore, it is recommended for this plan to be reviewed and revised at the beginning of the mid- and-long-term activities outlined in this plan to take advantage of data sharing across multiple GDOT WIM data user groups.

The target date for completion of different activities identified in this plan is listed by year followed by a number (1, 2, 3…7+) that indicates the target year for completion of the identified activity, with the count starting from Year 1 of the WIM program implementation. It is recommended that, as the program matures, these numbers are periodically reviewed and updated.

A.7.1 Short-Term Activities

The focus of short-term activities is to construct enough permanent WIM sites necessary to support development of Georgia-specific traffic loading defaults while assuring maximum cost sharing with other programs. Short-term action items are summarized below:

1. For candidate locations identified as "Short-Term" priority in table 52, conduct site visits to evaluate if site conditions are favorable for collecting accurate WIM data in accordance with ASTM 1318 and FHWA LTPP Optimum WIM Site Locator requirements. Revise list of WIM candidates based on field findings of site suitability for accurate WIM measurements. This is a high-priority short-term activity, as the outcome will affect the final list of candidate sites for permanent WIM installations. (Year 1)
2. For locations where the loading condition is unknown (mid- and long-term candidates), collect a portable WIM data sample to establish loading conditions. Review identified loading conditions and make sure that at least six sites are identified to represent each of the three default loading conditions. Revise WIM candidates list based on findings. (Years 1-2)
3. If, based on site assessments, some of the candidate locations for short-term WIM installation are removed from further consideration, identify if any of the default groups (identified by loading condition) has less than six candidate WIM sites representing specific default loading condition (at least in one direction of travel). If such a default group is identified, use sites from the mid-term list for short-term WIM installation to increase the number of sites representing default loading conditions to six. (Year 2)

4. Conduct a pilot study to test the “hybrid” WIM system (with portable WIM unit and permanent WIM sensor) approach recommended by the FHWA TMG for collecting high-quality portable WIM data at four ATR sites that already have Kistler sensors installed. Collect WIM data at each site with a rate of 1 week per month for 12 months or 1 week per season (i.e., every 3 months) for 4 seasons at each hybrid WIM site. Assess collected data quality and costs of such hybrid WIM sites and compare to quality of data and costs of permanent WIM sites. If data are found adequate and more cost-effective for development of the loading defaults, four of the six permanent WIM sites for each default load group may be hybrid sites (Year 1-2).
5. Install permanent WIM sites using candidates from the short-term list that passed field conditions test. (Years 1-3)
6. For mid-term candidate locations that passed loading condition analysis, evaluate if site conditions are favorable for collecting accurate WIM data in accordance with ASTM 1318 and FHWA LTPP Optimum WIM Site Locator requirements. Revise WIM mid-term candidates list based on findings. (Year 3)
7. Continue with portable WIM data collection and updates to MEPDG traffic loading library database to expand knowledge of traffic loading conditions observed on different roads in Georgia (Years 1-3).
8. In case of funding constraints, prioritize WIM installation to have at least six non-interstate permanent WIM sites installed and operated by the end of Year 3 (this is assuming that at least six permanent WIM sites will be installed on the interstates to satisfy other (non-MEPDG) GDOT needs for WIM data).
9. Institute WIM calibration requirements that assure accuracy of heavy weight measurements and WIM data QC/QA requirements for both portable and permanent WIM data collection activities (Years 1-3).
10. Implement annual WIM validation, calibration, and maintenance program.
11. Institute procedures for computing site-specific NALS and other summary statistics listed in section 9.9 using WIM data from permanent and portable WIM sites and upload NALS to MEPDG traffic loading library database. (Years 1-3).

A.7.2 Mid-Term Activities

The focus of mid-term activities is to use data from newly installed permanent WIM sites to validate or revise GDOT’s preliminary MEPDG traffic loading defaults using Georgia-specific WIM data. Using locally calibrated MEPDG pavement performance prediction models, the sensitivity of MEPDG outcomes to these defaults should be tested to determine the number of MEPDG loading defaults and WIM sites needed to support each default (preliminarily, three loading defaults are proposed, with about six WIM sites needed to support each default, 18 WIM sites total). Based on the outcome, the decision will be made whether the WIM program should be extended to cover WIM site locations identified on the mid- and long-term lists. In addition, plans developed by other WIM data user groups should be evaluated to see if some of the proposed future WIM locations could serve multiple users.

Mid-term action items are summarized below:

1. Before installation of permanent WIM sites from the mid-term list, use data from GDOT’s permanent WIM sites and locally calibrated MEPDG models to compute Georgia-specific loading defaults and test sensitivity of MEPDG outcomes to these defaults. Based on outcomes of MEPDG tests, assess whether the three preliminary loading defaults should be kept or if this number should be increased or decreased. See

section 3.4 *(Validation of the Loading Defaults)* for further guidance. Revise preliminary loading defaults using Georgia specific data from permanent WIM sites (Year 4).

2. Make revisions to the mid-term WIM candidates list (in TABLE 52), as necessary. Consider any changes in priorities, as well as inputs from other programs, such as Georgia LTPP, Office of Planning, and Office of Transportation Data (Year 4).
3. Install permanent (and/or portable “hybrid”) WIM sites at candidate locations from the mid-term list that passed field conditions test (Years 5-6).
4. Continue with WIM data collection and NALS computation at installed permanent WIM sites from the short-term list (Years 4-6).
5. Continue with portable WIM data collection and updates to MEPDG traffic loading database to expand WIM data coverage across the State and populate the GDOT PLUG traffic loading library database with additional information about traffic loading conditions observed on different roads in Georgia (Years 4-6).
6. Compute site-specific NALS annually using WIM data from permanent and portable WIM sites and upload NALS to the GDOT PLUG traffic loading library database (Years 4-6).
7. Update NALS defaults as data from more WIM sites become available and upload them annually or biannually to the GDOT PLUG traffic loading library database (Years 4-6).

A.7.3 Long-Term Activities

The focus of long-term activities is to use data from all available Georgia permanent WIM sites to update Georgia-specific traffic loading defaults and to evaluate the benefit of further expansion of the WIM program to support a virtual WIM approach for development of MEPDG loading inputs. Some of these activities have a specific target year for completion while others are designed as annual or cyclic activities. The completion date for the latter case is identified as 7+ in the list below.

Long-term action items are summarized below:

1. Use data from short- and mid-term permanent WIM sites to update MEPDG loading defaults (Year 7).
2. Using data from locally calibrated MEPDG models and available site-specific WIM data, evaluate cost-benefit of using the virtual WIM approach (i.e. averaging data from user-selected “similar” WIM sites to create NALS for the project) instead of Level 2 defaults for development of MEPDG loading inputs (Year 7).
3. If cost-benefit analysis supports further extension of the WIM program, proceed with installation of WIM sites from the long-term list. Otherwise, set forth a plan for a perpetual 3-year update cycle of the loading defaults based on WIM data from short- and mid-term WIM sites (Years 7).
4. Make revisions to long-term WIM installation plan, as necessary. Consider any changes in priorities, as well as inputs from other programs, such as Georgia LTPP, planning or freight studies (Year 7).
5. For WIM sites that completed their service life cycle, move the site to a new location (new road) using locations specified on mid- (if any unused) and long-term lists. (Years 7-10)
6. Continue with WIM data collection and NALS computation at installed permanent WIM sites from the short- and mid-term lists (Year 7+).

7. Continue with portable WIM data collection and updates to MEPDG traffic loading library database to expand knowledge of traffic loading conditions observed on different roads in Georgia (Year 7+).
8. Compute site-specific NALS annually using WIM data from permanent and portable WIM sites and upload NALS to the PLUG traffic loading library database (Year 7+).
9. Update NALS defaults annually as new permanent WIM sites are added to the program. Once all permanent WIM sites are installed and operational, update defaults once every 3 years. Upload NALS defaults to the GDOT PLUG traffic loading library database (Year 7+).