Facilitating Analysts' Use of Traffic Data from the Long-Term Pavement Performance (LTPP) Program

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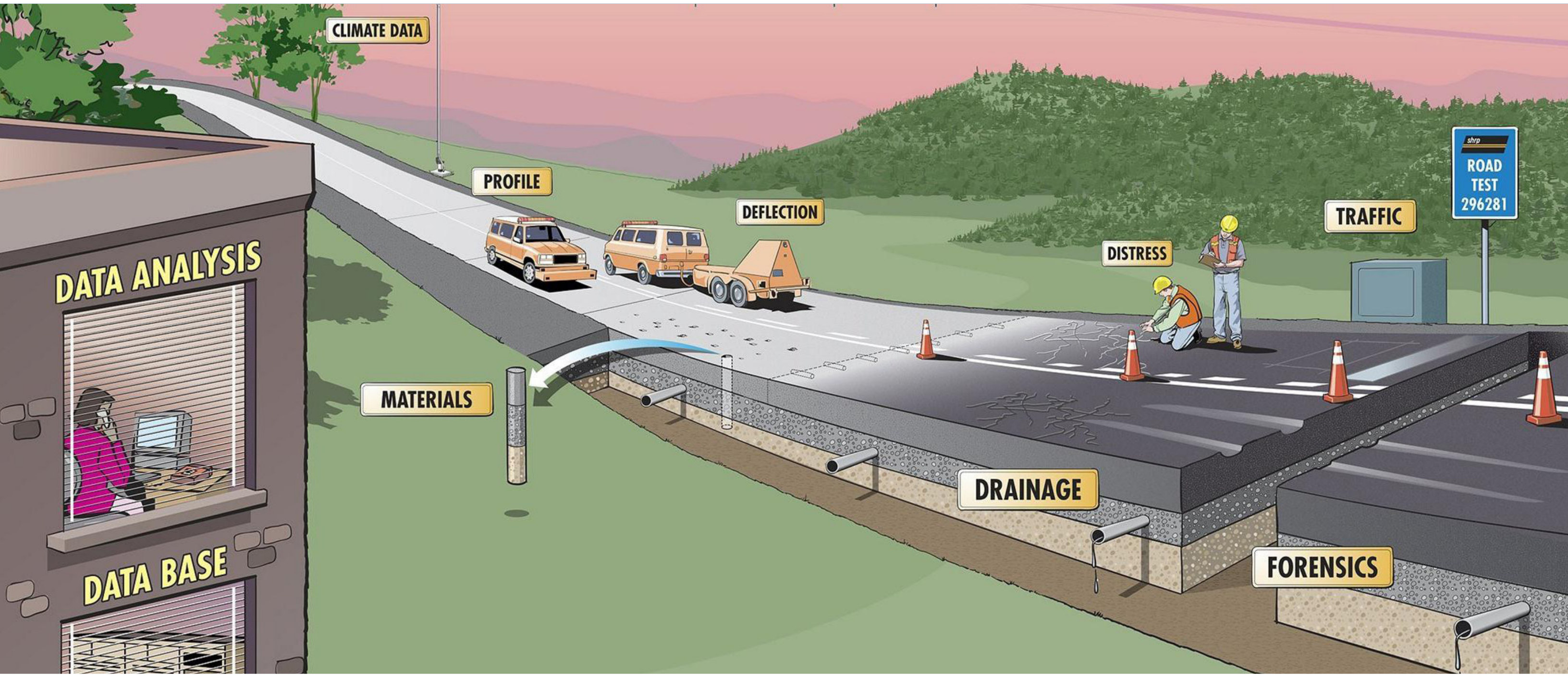

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Federal Highway Administration

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LTPP™

FOREWORD

Traffic data are an integral part of the Long-Term Pavement Performance (LTPP) database. This report describes the data analysis study performed to help LTPP database users navigate and understand LTPP traffic data and select traffic parameters that best fit their project needs. This study included the development of analysis-ready traffic datasets to support a broad variety of analysis projects that require quality traffic data.

Emergence of new-generation pavement analysis and design methods that are incorporated into AASHTOWare® Pavement ME Design™ software require traffic parameters that LTPP database tables were not originally designed to store. This study addressed LTPP database users' needs for traffic inputs in the AASHTOWare Pavement ME Design software format by developing computational methodologies and producing computed parameter tables containing necessary traffic inputs in this format for all LTPP sites.

Methodologies presented in this report can be applied to help highway agencies compute traffic statistics necessary to support pavement design, research, management, and forensic investigations.

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16. Abstract This report examines Long-Term Pavement Performance (LTPP) database users' needs for traffic data and parameters and the extent of traffic data availability in the LTPP database. It identifies and recommends new analysis-ready traffic parameters and traffic data–usability indices for inclusion in the LTPP database. This report also presents a methodology for computation of analysis-ready traffic parameters selected by the Federal Highway Administration for this study and a methodology for assessing reasonableness of historical axle loading data included in LTPP database tables for sites that do not have sufficient information about the accuracy of equipment used to collect these data. This report includes a description of LTPP database tables that include newly computed analysis-ready traffic parameters. For LTPP sites that do not have traffic data, this report explores alternative data sources and provides recommendations for using these data sources. This report includes an overview of the *User Guide for Selecting and Using Long-Term Pavement Performance Traffic Data*, which aims to help LTPP database users navigate and understand LTPP traffic data and parameters and select or compute traffic parameters that best fit their project or analysis needs.[1]		
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AADT	average annual daily traffic
AADTT	average annual daily truck traffic
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ALDF	axle load-distribution factor
APT	axles per truck
ATL	annual total load
CPT	computed parameter table
CTL	cumulative traffic load
CTV	cumulative truck volume
DOT	department of transportation
DOW	day of week
ESAL	equivalent single axle load
ETG	Expert Task Group
FHWA	Federal Highway Administration
GESAL	general equivalent single axle load
GIS	geographic information system
GPS	General Pavement Study
GUI	graphic user interface
GVW	gross vehicle weight
HPMS	Highway Performance Monitoring System
IVR	individual vehicle record
JPCP	jointed plain concrete pavement
KESAL	kilo equivalent single axle load
LEF	load equivalency factor
LTAS	Long-Term Pavement Performance 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
PCC	portland cement concrete
PLUG	*Pavement Loading User Guide*
QA	quality assurance
QC	quality control
RPPIF	relative pavement performance impact factor
SDR	Standard Data Release
SHRP	Strategic Highway Research Program
SPS	Specific Pavement Study
TMAS	Travel Monitoring Analysis System
TMG	*Traffic Monitoring Guide*
TPF	Transportation Pooled Fund Study
TRB	Transportation Research Board
TSSC	Technical Support Services Contractor
WIM	weigh-in-motion

CHAPTER 1. INTRODUCTION

BACKGROUND

A key outcome of the Long-Term Pavement Performance (LTPP) program is the delivery of a comprehensive, easily used database allowing for a wide range of pavement performance research and analysis. Using LTPP data, researchers can develop knowledge, relationships, and models to facilitate improved pavement design and reliable performance predictions. Traffic data are an integral part of the LTPP database. In the past, when researchers wanted to obtain and use these traffic data in their analyses, they were intimidated by the size of the dataset, the variety of data sources and data collection methods, and the different parameters used to characterize traffic data at LTPP sites.

This data analysis study was designed to help LTPP database users navigate and understand LTPP traffic data and select traffic parameters that best fit their project needs, including development of analysis-ready traffic datasets that could support a variety of LTPP analyses.

Challenges with Traffic Loading Data Collected at LTPP Sites

When the Strategic Highway Research Program (SHRP) initiated the LTPP program, little was known about the selection, installation, and operation of weigh-in-motion (WIM) and other automated truck traffic data collection equipment. As the LTPP program progressed, the LTPP program management team discovered that field conditions at many LTPP sites and the selected WIM equipment were not suitable for accurate WIM measurements, and the traffic data supplied by State and Provincial agencies lacked detailed information on truck traffic characteristics at those sites.

In some cases, inaccurate, poor-quality data were not included in the LTPP database. In other cases, inaccurate, poor-quality data were questioned during the initial LTPP quality assurance/quality control (QA/QC) process but ultimately included in the LTPP database because the lack of information on truck traffic characteristics could neither confirm nor deny the accuracy of data. After 20 yr of additional data collection, it became apparent that some data accepted as valid in the early years were invalid measures of truck traffic characteristics. Thus, several LTPP test sites are either missing traffic data elements or burdened by inaccurate, poor-quality data.

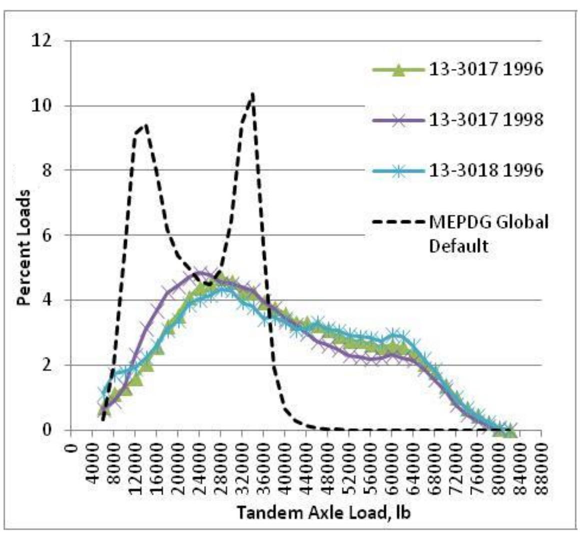
ASTM E1318-09, *Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods*, is a standard specification widely used in the United States to evaluate WIM performance and measurement accuracy.(11) This specification provides WIM measurement error tolerances for different types of WIM systems, as shown in table 1. Rating of LTPP WIM data quality using measurement accuracies provided for the three ASTM WIM types would be beneficial for LTPP traffic data users. However, only a minority of LTPP WIM sites have WIM measurement accuracy information available.

Table 1. Functional performance requirements and error tolerances for 95 percent compliance for WIM systems per ASTM E1318-09.

Function	WIM Type I	WIM Type II	WIM Type III
Wheel load	25 percent	N/A	20 percent
Axle load	20 percent	30 percent	15 percent
Axle group load	15 percent	20 percent	10 percent
Gross vehicle weight	10 percent	15 percent	6 percent
Speed	1 mph	1 mph	1 mph
Axle spacing and wheelbase	0.5 ft	0.5 ft	0.5 ft

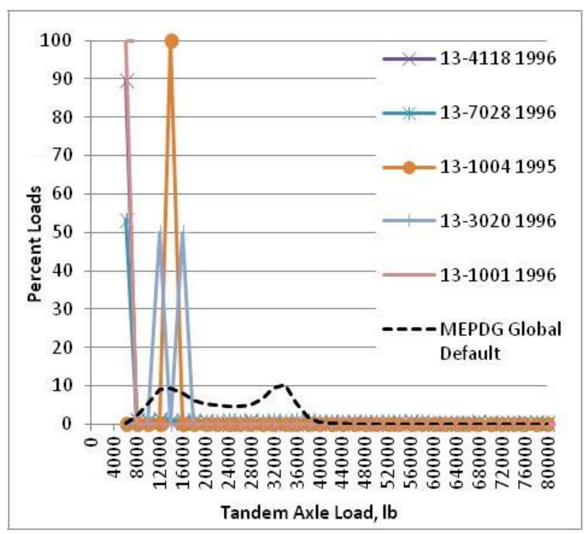
N/A = not available.

Report No. FHWA-RD-03-094, *Estimating Cumulative Traffic Loads, Volume II: Traffic Data Assessment and Axle Load Projection for the Sites with Acceptable Axle Weight Data, Final Report for Phase 2*, indicated that axle loading characteristics for more than 70 percent of General Pavement Study (GPS) WIM sites were not suitable for use in the development of pavement performance models due to their lack of accuracy.(2) For example, figure 1 illustrates annual normalized Class 9 tandem axle load spectra extracted from the January 2013 LTPP database Standard Data Release (SDR) 27 for several sites in Georgia. For the three LTPP sites shown in figure 1-A, a large percentage of the tandem axles are estimated to weigh more than 50,000 lb and as much as 80,000 lb, meaning the gross vehicle weight (GVW) for the trucks is over 100,000 lb and potentially twice as much as the legal load limit for FHWA Class 9 vehicles. Although these weights are highly unlikely and would cause significant damage to the truck if carried routinely. Therefore, data are likely erroneous, either because of errors in data transmission or the result of poor equipment performance. For the five LTPP sites shown in figure 1-B, loads are atypically low, indicating a classification error or a data collection period that was too short to capture representative truck weight distribution.



Source: FHWA.

A. Example of atypically high axle loads.

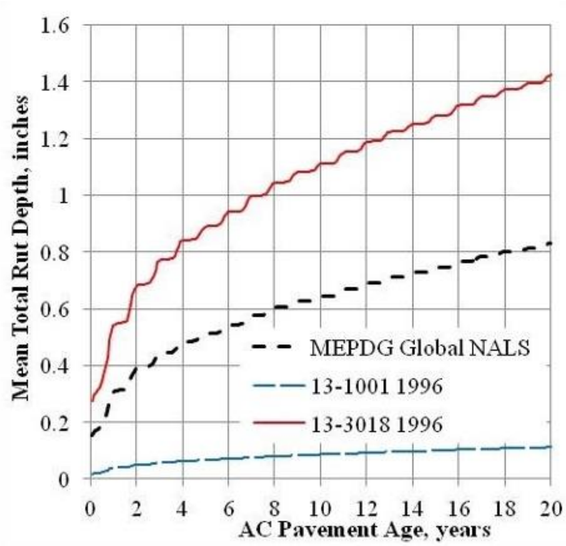


Source: FHWA.

B. Example of atypically low axle loads.

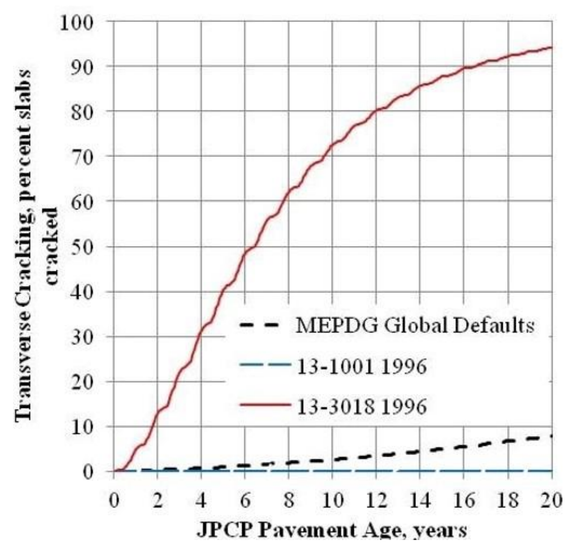
Figure 1. Graphs. Illustration of questionable tandem axle loads reported in SDR 27.

Figure 2-A and figure 2-B illustrate the differences in pavement distress prediction based on these axle load spectra for asphalt concrete (AC) and jointed plain concrete pavements (JPCPs). Questionable data could lead to different pavement distress prediction outcomes and may jeopardize the validity of conclusions from analyses using these data. In addition, several LTPP sites, particularly GPS sites, are completely missing traffic loading data.



Source: FHWA.

A. Example of total rut prediction.



Source: FHWA.

B. Example of slab cracking.

Figure 2. Charts. Comparison of distress prediction using questionable axle weight data.

Challenges with Developing Traffic Inputs for Pavement Analyses

LTPP traffic data tables were designed to provide a comprehensive view of traffic loading patterns at each LTPP test site. The downside of this design is that available traffic data are more complex and comprehensive than necessary for some types of pavement research analyses. This complexity is aggravated by missing and/or invalid data noted previously. In addition, the emergence of new-generation pavement analysis and design methods using AASHTOWare® Pavement ME Design™ software requires use of traffic parameters LTPP database tables were not originally designed to produce.(3,15) As a result, to enter LTPP traffic data into AASHTOWare Pavement ME Design software, a researcher must analyze and summarize available data to develop detailed traffic inputs representing the analysis base year conditions and traffic growth pattern for each LTPP site. Given the complexity of data in the LTPP database, such an analysis and summary significantly burden researchers.

AASHTOWare Pavement ME Design software requires a specially formatted data file for entering traffic loading inputs, such as axle load distributions representing a typical day of each calendar-month for the base design or analysis year. Prior to this data analysis study, the LTPP database did not have the capability to generate these files at the user's request.

Benefits of WIM Traffic Data from Transportation Pooled Fund Study (TPF), TPF-5(004)

Recognizing the limitations of traffic data collected during early years of the LTPP program and the need for research-quality data to support the development of improved pavement performance prediction models, the program initiated the LTPP Specific Pavement Study (SPS) Traffic Data Collection Transportation Pooled Fund Study, TPF-5(004). TPF-5(004) focused on installing highly reliable, permanent WIM systems to collect axle loading data. Using a uniform vehicle classification scheme (i.e., LTPP vehicle classification scheme), developed for that study based on FHWA 13-category classification rule set, and rigorous QC procedures, TPF-5(004) produced research-quality data (e.g., traffic volume counts by vehicle classification and traffic loading data) to support LTPP analysis projects. TPF-5(004) was designed with the support of the Transportation Research Board (TRB) Expert Task Group (ETG) on Traffic Data Collection and Analysis. The effort consisted of two principal elements: shifting data collection from highway agencies to a national, centralized effort; and standardizing data collection equipment and procedures. Additionally, guidelines for pavement smoothness, equipment calibration checks, equipment model specifications, and the LTPP vehicle classification scheme were developed and implemented for TPF-5(004) WIM sites.

Since 2003, 26 LTPP WIM sites were installed in 22 different States as part of the TPF-5(004) study to collect research-quality traffic loading data at select SPS-1, -2, -5, and -6 sites. To meet the research-quality standards of TPF-5(004), data of known calibration, meeting LTPP's WIM data accuracy requirements—for steering and tandem axles, GVW, bumper-to-bumper vehicle length, vehicle speed, and axle spacing—must be collected for 210 d within a year.[(12)] Details about LTPP SPS WIM equipment, installation, calibration, and accuracy requirements are documented in the *LTPP Field Operations Guide for SPS WIM Sites*.[(13)] Table 2 shows the criteria used to evaluate if errors observed in WIM data collected during field validations meet the criteria for the research-quality data.

Table 2. LTPP WIM data accuracy criteria for research-quality data.

Parameter	95 Percent Confidence Interval of Error
Steering axles	±20 percent
Tandem axles	±15 percent
GVW	±10 percent
Vehicle length	±3.0 percent (or 2.2 ft)
Axle length	± 0.5 ft

The LTPP program used data from the TPF-5(004) study to develop several axle loading defaults compatible with AASHTOWare Pavement ME Design software.[(4)] These defaults can be used for LTPP sites that have no axle loading data or insufficient data (i.e., lacking quality and/or quantity), and several of them were adopted by AASHTOWare Pavement ME Design software.

STUDY OBJECTIVES

This data analysis study was designed to enhance the experience of LTPP users by improving traffic data included in the LTPP database and making it easier for researchers to select traffic data needed for their specific analyses. This was accomplished by developing analysis-ready traffic parameters that could support a variety of pavement analysis objectives listed in the

Strategic Plan for LTPP Data Analysis, including analyses using AASHTOWare Pavement ME Design software.[15,16]

To assist in decision-making regarding usability of a given computed parameter, special indicators explaining the nature and applicability of computed traffic parameters were provided for each LTPP site and computed traffic parameter. These indicators were developed based on the assessed quality of data used to compute the parameter and reflect how well these data represent traffic conditions at LTPP sites. In addition, these indicators help to identify LTPP sites that are based on high-quality traffic loading data.

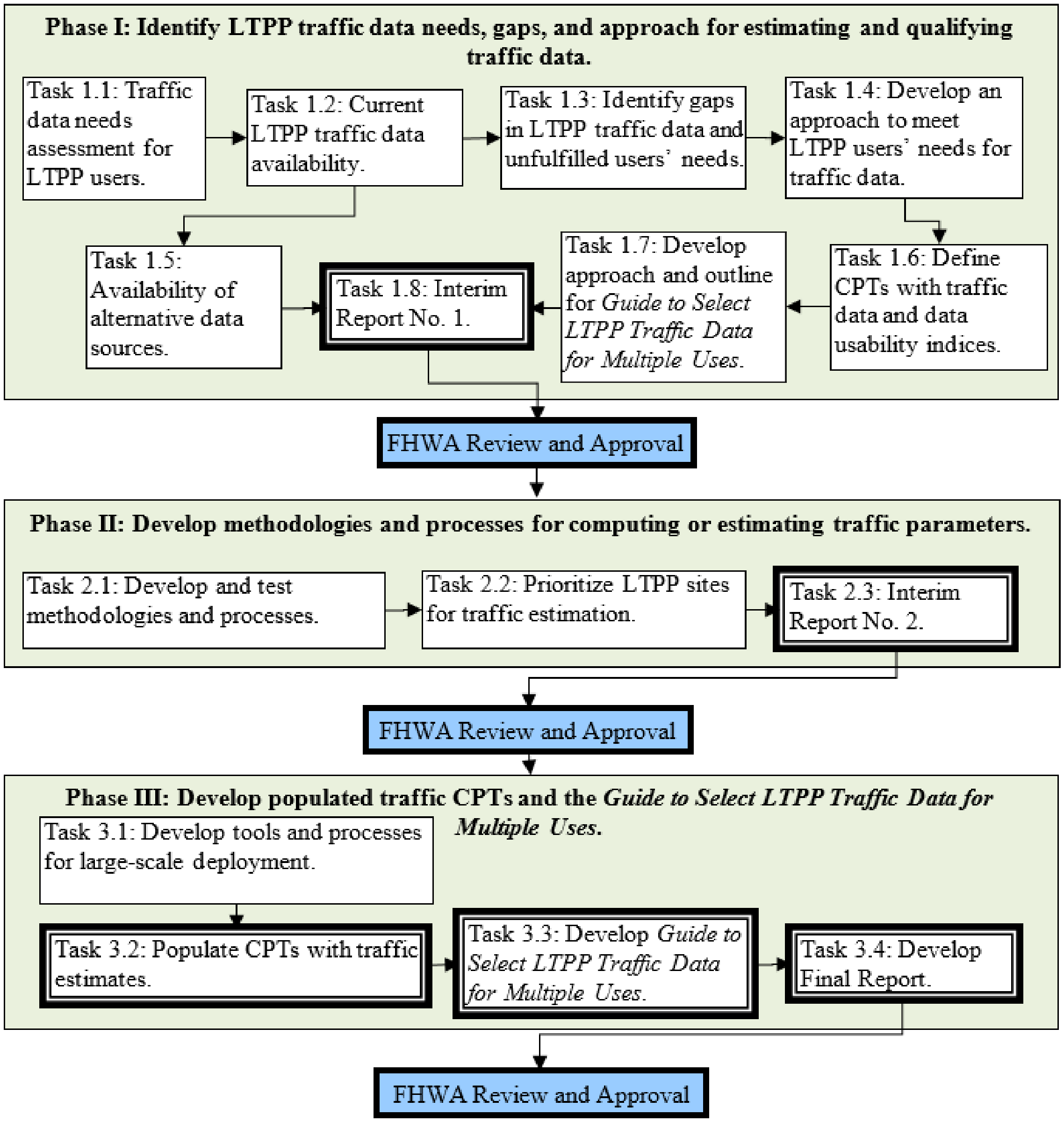
The forthcoming *User Guide for Selecting and Using Long-Term Pavement Performance Traffic Data* [1] (henceforth referred to as the "*Guide*") which walks pavement researchers through the selection of the most appropriate traffic statistics for the pavement analyses they are performing, is a product of this analysis study. The *Guide* contains examples of how to select the appropriate traffic parameter for pavement analysis or design as well as extract data from LTPP computed parameter tables (CPTs) using InfoPave™.

STUDY SCOPE

This data analysis study has three phases, which are described as follows:

- Phase I: Assessment of data needs and availability, including identification of traffic-computed parameters to be developed by the LTPP program and approaches for users to access and use these parameters.
- Phase II: Development of methodologies and processes for computing or estimating traffic parameters to meet LTPP traffic data needs defined in Phase I.
- Phase III: Development of traffic CPTs and the *Guide*.

Figure 3 is a flowchart sequencing specific task executions for each phase. Deliverables associated with each phase are shown in blocks with heavy borders.



Source: FHWA.

Figure 3. Flowchart. Work execution sequence.

STUDY OUTCOMES

The primary outcomes of this study include the following:

- CPTs meeting many traffic data users' needs not previously addressed in the LTPP database.
- Traffic data–usability indices providing information to users about data and methods used to develop different analysis-ready CPTs.

- The *Guide* describing how to select LTPP traffic parameters for different types of analyses.
- Final study report summarizing research outcomes.

CPTs and the *Guide* produced under this study aim to help reduce the time pavement researchers spend identifying and selecting LTPP traffic data and parameters, thus reducing costs of future research while improving the consistency of results and meeting objectives listed in the *Strategic Plan for LTPP Data Analysis*.[16]

A secondary outcome from the improved traffic data for LTPP sites will be lower costs and more effective State-specific calibration of pavement performance prediction models for the AASHTOWare Pavement ME Design software process. For most States, data from LTPP sites within their jurisdiction are the first choice of data for local calibration of the pavement performance prediction models for AASHTOWare Pavement ME Design software. Improved availability of traffic parameters for those LTPP sites significantly increases the use of LTPP data in local calibration efforts. Moreover, by providing guidelines, procedures, and tools for traffic estimation, the LTPP program aids States in reviewing and improving traffic data for their non-LTPP sites.

REPORT OVERVIEW

This report provides a summary of the data analysis study's objectives, methods, and findings. Contents of this report are organized into the following chapters:

- Chapter 1 contains a description of the research study background, objectives, scope, and outcomes.
- Chapter 2 provides an overview of traffic data needed to support various pavement studies (e.g., research, analysis, design, and management).
- Chapter 3 summarizes findings from the assessment of available LTPP traffic data to support user needs, describes gaps between needs and available traffic data, and provides recommendations for developing analysis-ready LTPP traffic CPTs meeting most user needs.
- Chapter 4 assesses availability of alternative data sources to help produce LTPP traffic CPTs given limitations in data availability and/or quality in the LTPP database.
- Chapter 5 provides information about analysis-ready traffic parameters selected for this study and describes the general approach for developing computed parameters.
- Chapters 6–10 describe methodologies for developing analysis-ready traffic parameters selected for this study, including examples of parameter computation.
- Chapter 11 contains a description of new LTPP traffic CPTs containing analysis-ready traffic parameters.
- Chapter 12 provides an overview of the *Guide*.
- Chapter 13 provides a summary of the results.

CHAPTER 2. TRAFFIC DATA AND PARAMETERS USED FOR PAVEMENT STUDIES

This chapter synthesizes information about traffic data used in various pavement studies, including pavement-related research, analysis, design, and management.

OVERVIEW OF TRAFFIC PARAMETERS USED FOR PAVEMENT ANALYSIS, DESIGN, AND MANAGEMENT

The types of traffic data and parameters used in pavement engineering applications are categorized by the following:

- Basic traffic data and rudimentary statistics.
- Detailed traffic data and parameters for characterization or study of traffic loading effects on pavement structure, such as pavement analysis, research, mechanistic and mechanistic–empirical pavement modeling, and forensic studies.
- Summary traffic parameters for high-level analyses, empirical pavement design and performance modeling, pavement maintenance, and management applications.(5)
- Computed parameters for use in specialized pavement analysis and design software, such as the *Mechanistic–Empirical Pavement Design Guide* (MEPDG).(3)
- Traffic metadata parameters explaining how data were collected and how parameters were computed.

Basic traffic data include either actual counts of vehicle volume, records of axle weight, or low-level aggregated statistics, such as daily and monthly traffic volume or truck volume by vehicle class summaries, or axle load count by load bin summaries reported for each sampling period. The basic data and parameters serve as an input to compute summary statistics and analysis-ready traffic parameters used in pavement engineering and management applications.

Parameters providing detailed characterizations of traffic loading are used for mechanistic and mechanistic–empirical pavement response and performance modeling. Analysis and modeling of pavement response require accurate information about wheel and axle load magnitude, load position and configuration (i.e., axle configuration and position of wheels on the pavement), area of load application or tire footprint, load duration, and time history of load application (i.e., changes in load magnitude over time). For pavement performance modeling, traffic loading history for the entire analysis period is needed (i.e., the number and magnitudes of loads reported for specified time increments used in the analysis). This information is typically collected or estimated by the traffic data collection staff within a State or Provincial highway agency.

Summary traffic parameters are useful in empirical pavement response and performance analysis and modeling, empirical pavement design procedures, and high-level analyses of pavement management models and decision support tools. For these analyses and procedures, researchers desire a single traffic summary statistic, such as the equivalent single axle load (ESAL), average annual daily truck traffic (AADTT), cumulative truck volume (CTV), or cumulative traffic load (CTL). These summary statistics are also used to identify and group road segments in categories representing different levels of traffic.

Another traffic data category contains traffic parameters used as a direct input for specialized pavement analysis or design, such as those found in the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* 1993 pavement design methodology and the newer MEPDG design and analysis software, AASHTOWare Pavement ME Design software.[3, 5,15]

BASIC TRAFFIC DATA AND LOW-LEVEL SUMMARY STATISTICS

Basic traffic data are collected to support development of the traffic parameters used in pavement applications. These data typically contain actual counts of vehicle volume aggregated to different levels or individual vehicle records. These data may be collected over a short period (typically 2 d) or longer period (continuous counting using automated data collection equipment) and reported in 15-min, hourly, or daily increments.

Basic traffic volume data include the following:

- Total vehicle volume.
- Total truck volume.
- Truck volume by vehicle class (typically FHWA Classes 4–13).[14]

Another type of basic traffic data are individual vehicle records (IVRs) from WIM systems. IVRs contain detailed information about each vehicle passage, including the following basic traffic data elements:

- Vehicle class.
- Time of each vehicle passage.
- Axle-to-axle spacing.
- Weight of each axle.
- Vehicle speed (available in some formats).

Basic traffic data have limited direct application in pavement analyses but are necessary to compute analysis-ready traffic summary parameters. Because these data have no or low levels of aggregation, they require a large storage space and may be challenging for researchers to download and analyze. However, these data are necessary for researchers to understand specific traffic characteristics and data samples used to compute aggregated summary statistics and for researchers focusing on investigating effects of different traffic characteristics on pavement response and performance.

DETAILED TRAFFIC DATA AND PARAMETERS

Traffic Parameters for Pavement Response Prediction Based on Mechanistic Models

As pavement engineering evolves from empirical to mechanistic–empirical, and then to fully mechanistic methods, the demand for more accurate and detailed traffic loading characterization continues to rise. The emerging mechanistic pavement response analysis and modeling studies focus on stresses, strains, and deflections pavements experience under each traffic load application. Pavement responses are predicted using static or dynamic mechanistic modeling methods.

Pavement responses predicted by static models (e.g., elastic, viscoelastic, elastoplastic) depend on the following traffic loading parameters:

- Load magnitude.
- Load configuration (i.e., location and number of wheel loads simultaneously applied on the pavement surface).
- Sequence of loads.
- Time and date of load application.
- Area of load application and shape of load distribution under each wheel (e.g., over the tire footprint).
- Position of wheels and axles relative to pavement or concrete slab edges.

Pavement responses predicted by dynamic models consider the dynamic effect of the applied loads. In addition to the parameters in the previous list for static modeling, dynamic models require the following additional inputs:

- Load duration.
- Rate of load application (i.e., number of load applications per time unit measure).
- Time history of load application (i.e., change in load magnitude or pressure under tire footprint over time as each wheel passes over the specific pavement location).

Existing traffic monitoring technology, especially WIM, can provide most but not all of these parameters. New advancements are required to take WIM measurement ability beyond the estimation of the static equivalent of axle or truck load weight, to accurate recording and reporting of the full time history of load application, including accurate measurement of the dynamic forces applied by the tire to the pavement and quantification of the exact area and duration of load application (e.g., load or tire footprint) and position of each tire footprint for each truck, relative to the pavement edge.

Traffic Parameters for Mechanistic–Empirical Pavement Performance Prediction

Changes in Loading over Time

Mechanistic–empirical pavement performance analysis and modeling focuses on predicting pavement distress that develops over time. Most pavement distress (e.g., cracking, rutting, faulting) develops from incremental or cumulative changes in pavement structure due to material aging, environmental impacts, and traffic loading. Therefore, for traffic loading characterization, not only must information about individual traffic loads be known, but also the sequence and cumulative number of traffic load applications leading to pavement deterioration over time. Such detailed characterization of traffic loading allows modeling of pavement responses and performance using methods where each axle load application on the pavement—expected or observed during the analysis period—is modeled and its effect on pavement response and performance predicted.

In addition to axle load frequency, information about the relative position of axle loads on pavement is also important, especially for jointed rigid pavements.

Axle Loading Distribution or Axle Load Spectrum

To provide a means for tracking and summarizing traffic load applications over time, traffic loads are summarized in an axle load spectrum (also called axle load distribution in some pavement applications).[7] The axle load spectrum represents a frequency distribution of axle loads, where counts of axle load applications, observed during a specified period, are summed and reported using predefined load bins. Recognizing the importance of load configuration, separate axle load spectra are used to summarize axle load counts for typical axle load groups: single, tandem, tridem, and quad. Depending on the intended application, load spectra could be created for an individual truck class or for all truck classes combined. In summary, the axle load spectrum input provides information about axle load magnitudes, number of axle load applications over a specified period, and load configuration. If no site-specific axle vehicle weight data are available to compute axle load spectrum, default axle weights can be selected for each vehicle class based on the primary road use.

Normalized Axle Load Spectra

Axle load spectra may express frequency of distribution by specifying axle counts or percentages of total loads in each load bin. If percentages are used to express load frequency distribution, load spectra are called normalized axle load spectra (NALS).

SUMMARY TRAFFIC PARAMETERS USED IN EMPIRICAL PAVEMENT STUDIES AND TRADITIONAL PAVEMENT DESIGN AND MANAGEMENT APPLICATIONS

Traditionally, pavement engineering relied on an empirically derived relationship between traffic summary statistics and pavement performance. Many studies of pavement response and performance still use empirical methods or statistical models to correlate pavement performance parameters (e.g., road roughness) monitored over time with traffic and environmental loads, site conditions, material properties, and construction practices. These studies frequently use a single traffic summary parameter to describe traffic and may require a complete history of changes in the selected traffic summary parameter (computed annually for the duration of analysis period), a single cumulative value aggregated over the analysis period, or one representative traffic summary value. The most frequently used traffic summary parameters are AADTT and ESAL.[6]

Challenges with Using a Single-Value Traffic Loading Summary Statistic

The definition and use of a single traffic loading summary statistic for pavement performance analyses presents several challenges. First, the relationship between traffic load magnitude and pavement performance is nonlinear, and the degree of this nonlinearity changes for different types of pavements and pavement distresses. A single-number cumulative traffic loading statistic cannot provide information if the total load is a result of many light axle loads or a few heavy axle loads that produce similar cumulative values.

The distance between truck axles plays an important role in the stress and strain distribution through different pavement layers; therefore, the number and location of simultaneously applied axle loads is also important and should be accounted for in the traffic loading summary statistic.

Conventional parameters based on simple summation or averaging all applied traffic loads do not provide an effective means for correlating truck traffic loading and pavement performance. For example, two axle load spectra with the same mean load or cumulative load value may have different effects on pavement damage and associated pavement distress based on different percentages of heavy loads in the load frequency distribution and different axle configurations (i.e., different load distribution over the pavement). The limitations described in this section do not preclude using a single-value traffic loading summary statistic but should be considered when selecting an applicable parameter traffic loading.

ESAL as a Traditional Traffic Loading Summary Statistic

ESAL has been used as a traffic loading summary statistic for pavement design and analysis applications since the 1960s.[(6)] ESAL is a concept developed from data collected during the AASHO Road Test to establish a damage relationship for comparing effects of axles carrying different loads. In ESAL computation, load equivalency factors (LEFs) are used to convert a mixed stream of traffic consisting of different axle loads and configurations predicted over a design or analysis period into an equivalent number of 18,000-lb, single-axle load applications summed over that period. Thus, ESAL is a cumulative traffic loading summary statistic. Although general understanding and consensus exist in the pavement engineering community that neither ESALs nor LEFs precisely describe the relationship between axle load and specific pavement distresses like rutting or cracking, ESAL is a convenient statistic for sizing and quantifying traffic loading levels for empirical pavement analysis and design.

The ESAL value depends not only on traffic but on pavement type and thickness and a compound measure of road condition expressed through a subjective pavement serviceability index. For example, ESAL values representing the same traffic stream can change because the pavement type changes, or the pavement is rehabilitated and pavement thickness and/or roughness changes.

General ESAL

General ESAL (GESAL) is a parameter computed similarly to ESAL using LEF values for flexible pavements with a structural number of 5 and a terminal serviceability index of 2.5.[(7)] Because LEF values are set to a constant, GESALs are independent of pavement type and thickness and level and type of pavement distress. Therefore, any changes in GESAL values can be attributed directly to changes in traffic loads. This makes GESAL a more desired traffic loading summary statistic for comparison of loads or effects of loads on pavement performance between different sites. GESAL is more sensitive to the importance of heavy loads on pavement performance compared to average or total load summary statistics. However, use of the constant LEF parameters makes GESAL not applicable as a direct input to pavement design.

Traffic and Truck Volume Summary Parameters

Average annual daily traffic (AADT) and AADTT are the most widely used traffic volume parameters for pavement analyses. AADTT is more relevant for pavement analysis and management applications than AADT because trucks contribute more to pavement damage than lighter vehicles that make up most of the AADT number.

Other traffic volume statistics used in pavement analyses include the following:

- Total annual truck volume.
- Annual truck volume by vehicle class.
- Cumulative volume of Class 9 vehicles.
- Cumulative volume of heavy vehicles (FHWA Classes 4 and 6–13).

Relative Pavement Performance Impact Factor (RPPIF)

Recent developments regarding traffic loading summary statistics include RPPIF.(4) RPPIF is computed similarly to ESAL, but instead of LEFs based on data from the AASHO Road Test, it utilizes W-factors (W stands for "weight") determined through MEPDG analysis using globally calibrated distress prediction models included in National Cooperative Highway Research Program (NCHRP) Report 1-37A, *Guide for Mechanistic–Empirical Design of New and Rehabilitated Pavement Structures*.(9) The purpose of the RPPIF statistic is to compare axle loading distributions between different sites. As MEPDG models evolve, W-factors used for RPPIF computation may need updating to reflect the importance of different axle groups and axle load magnitudes for pavement performance. As with GESAL, RPPIF values are independent of pavement type and thickness and pavement distress. RPPIF is used to identify and group sites or road segments with similar traffic loading levels.

Annual Total Load and CTL

Annual total load (ATL) and CTL are estimates or summaries of all traffic loads accumulated over 1 yr (for ATL) or over the analysis period (for CTL).(8) An advantage of these statistics is that they are independent of any empirically derived relationships that relate load to damage. However, ATL and CTL cannot be used to infer whether trucks are empty or loaded and whether ATL or CTL values are affected by the number or weight of trucks (i.e., a small number of heavy trucks and a large number of light trucks may produce the same ATL or CTL values).

Traffic Load Grouping Statistic

Some pavement analyses need only a general traffic loading characterization to rank traffic loading at a site, such as light, moderate, or heavy loading categories. A recent LTPP data analysis study used MEPDG simulations to analyze pavement performance under different axle load spectra.(4) Differences in predicted pavement performance were then used to define loading categories and sort axle load spectra. Based on the researchers' findings, NALS assigned to these traffic loading categories are likely to lead to different prediction outcomes for pavement thickness (difference of 0.5 inch) or service life (difference of 20 percent), assuming similar truck types and volumes. The traffic loading categories are shown in table 3. Sites with axle loads in the same loading category can be grouped together based on similar per-truck or per-axle loading.

Table 3. Definition of axle loading categories based on percent of heavy loads in load spectrum.

Traffic loading Category or MEPDG Default Category	Singles ≥ 15 kip (Percent)	Tandems ≥ 26 kip (Percent)	Tridems ≥ 39 kip (Percent)	Quads ≥ 54 kip (Percent)
Very light (VL)	<3	0	N/A	N/A
Light (L)	<10	<10	N/A	N/A
Moderate (M)	10–30	10–30	N/A	N/A
Heavy (H)	>30	30–50	<50	<30
Very heavy (VH)	N/A	>50	>50	>30

1 kip = 4,448.2216 N; N/A = not applicable.

Average GVW

A distribution of average GVW for all classes combined, or GVW spectrum, can be used to identify the truck loading category for a site, as shown in table 4.

Table 4. Definition of truck loading categories.

Truck Loading Category	Heavy Trucks (≥60,000 lb) in GVW Spectrum (Percent)
Very light (VL)	<3
Light (L)	<10
Moderate (M)	10–30
Heavy (H)	30–50
Very heavy (VH)	>50

If sites have similar vehicle class distributions with one dominant heavy truck class (e.g., FHWA Class 9), average GVW can be used to identify sites with similar or different traffic loading. For example, average GVW can be used to identify if trucks are primarily empty, primarily loaded, or have moderate loading (i.e., half of the trucks are loaded, and half are empty).

Recommendation for Selecting a Traffic Loading Summary Statistic

Selecting a traffic summary statistic should be based on the analysis intent and the perceived relationship between load and pavement distress. No single traffic loading summary parameter exists that works equally well for different LTPP analysis applications. The main reason is differences in sensitivity of pavement distresses to load magnitude and the number of axle load applications.

Weighted summary parameters like ESAL, GESAL, and RPPIF generally have a stronger correlation with load-related pavement distresses than parameters based on simple load summation or averaging. For pavement performance measures where the number of load applications is more important than the relative distribution of loads between trucks, parameters based on simple summation or averaging of loads (like CTL and ATL) provide a viable alternative, especially when used for roads with similar trucks that serve similar purposes.

Parameters based on total truck volume are a poor choice for studying distresses sensitive to truck loads. If no loading information is available, total volume of trucks in heavy vehicle classes (FHWA Classes 4 and 6–13) is more appropriate than total traffic volume or total truck volume statistics.

The following recommendations are provided to aid in selecting a traffic loading summary parameter for use in empirical analyses, based on the type of pavement distress being studied:

- If pavement distress is primarily caused by repeated load applications (e.g., raveling), a summary loading statistic that accurately describes the number of load applications should be used, such as AADTT, CTV, CTL, or total number of axle loads for vehicles in FHWA Classes 4–13.

- If pavement distress is primarily caused by repeated heavy axle loads (e.g., fatigue cracking), a summary loading statistic that properly accounts for the number of heavy load applications should be used, such as ESAL, GESAL, or RPPIF. Alternative statistics that can be used are the number and average weight of Class 9 vehicles or combination unit trucks.

- If pavement distress is caused by overloaded trucks or axles (e.g., rigid pavement slab cracking), a summary loading statistic that accurately describes the number or percentage of fully loaded and overloaded axles should be used. Alternative statistics that can be used are the number and average weight of heavy trucks or RPPIF.

- If the cause of pavement distress is not known but perceived to be load-related and a single traffic loading summary parameter is desired in the analysis, GESAL is an appropriate statistic. GESAL has a formulation and meaning similar to ESAL, thus is easily understood by pavement engineers. However, unlike ESAL, GESAL is independent of pavement-related variables and recognizes the higher significance of heavier traffic loads for pavement performance. GESAL is computed based on an actual axle load spectrum and considers truck volume (i.e., number of axle load applications). GESAL should not be used as a direct input for pavement design.

- If a user needs a traffic loading statistic free of any adjustments with respect to significance of load to pavement damage development, ATL or CTL should be used. Alternatively, if the road use is dominated by one heavy truck class (e.g., FHWA Class 9), average GVW in combination with the total number of FHWA Class 9 vehicles could be used.

- If performing high-level empirical analyses where the specific mechanism of deterioration is of lesser importance and the focus is on evaluating the whole road network or parts of the network serving specific functions (e.g., evaluation of the difference in performance between freight routes and routes primarily used for local services and delivery of goods), ATL or CTL may be used (annual total load values or cumulative load over the analysis period).

- If no site-specific vehicle weight data are available to compute axle or truck weight for use as summary loading statistic, default axle weights can be selected for individual truck classes (i.e., FHWA Classes 4–13) based on the primary road facility use. The *LTPP Pavement Loading User Guide* (PLUG) contains a database of default values.[(10)] These default weights, in combination with site-specific truck volume and vehicle classification data, can be used to estimate traffic loads and compute the traffic loading summary statistic of choice for any LTPP site.

Table 5 summarizes different traffic summary parameters and specifies the types of analyses for which these parameters are appropriate.

Table 5. Traffic summary parameters.

Parameter	Description or Meaning	Recommended Use and Limitations
AADT	Basic traffic summary statistic to measure average daily road use by all vehicular traffic.	Use to quantify road importance for pavement management applications, to quantify road utilization, and as an input for safety and congestion studies.
AADTT	Traffic summary statistic to measure average daily road use by trucks and buses (FHWA Classes 4–13).	Use to quantify road importance for pavement management and freight planning applications. Not sufficient as a single summary statistic for evaluating effects of traffic loads on pavement performance.
CTV	Traffic summary statistic to measure total road use by heavy vehicles (FHWA Classes 4–13). Can be cumulated and reported annually or for the analysis duration.	Use in analyses of effects of traffic on nonstructural pavement distresses or as a supplemental input in analyzing effects of traffic on structural pavement response and performance. Not sufficient as a single summary statistic for evaluating effects of traffic on structural pavement performance.
Cumulative volume of FHWA Class 9 trucks	Traffic summary statistic used to measure road use by FHWA Class 9 trucks. Can be cumulated and reported annually or for the analysis duration.	Use in analyses of pavement performance as a ranking measure to identify roads with low, medium, and high volume of FHWA Class 9 trucks. Not sufficient as a single summary statistic for evaluating effects of traffic on structural pavement performance.
Cumulative volume of heavy trucks (FHWA Classes 4 and 6–13)	Traffic summary statistic used to measure road use by vehicles in FHWA Classes 4 and 6–13. Can be cumulated and reported annually or for the analysis duration.	Use in analyses of pavement performance as a ranking measure to identify roads with low, medium, and high volume of heavy loaded trucks. Not sufficient as a single summary statistic for evaluating effects of traffic on structural pavement performance.
Annual ESAL	Basic traffic loading summary statistic that uses LEF developed from the AASHO Road Test to convert traffic stream to an equivalent number of 18,000-lb single axle loads (based on expected effects on pavement serviceability).	Historically used as a primary traffic loading parameter to relate pavement performance with traffic loading. Caution: ESAL is affected by nontraffic parameters (e.g., pavement structure, thickness, and serviceability). If used as a direct input to analyze pavement response or performance, the analyst must consider limitations associated with ESAL.

Parameter	Description or Meaning	Recommended Use and Limitations
Cumulative ESAL	Basic traffic loading summary statistic using LEF developed from the AASHO Road Test to convert traffic stream to an equivalent number of 18,000-lb single axle loads accumulated over time (i.e., analysis or design period).	Historically used as a primary traffic loading parameter to relate pavement performance with traffic loading or for design pavement. Used as a traffic input for the AASHTO *Guide for Design of Pavement Structures*. Caution: ESAL is affected by nontraffic parameters (e.g., pavement structure, thickness, and serviceability). If used as a direct input to analyze pavement response or performance, the analyst must consider limitations associated with ESAL.
Annual GESAL	GESAL is similar to ESAL but with pavement structure and condition inputs set to constant values. Therefore, GESAL is not affected by changes in pavement type, thickness, or serviceability parameters.	Use to relate pavement performance with traffic loading or to compare traffic loading between different sites. If used in analysis, the analyst must consider limitations and assumptions associated with GESAL formulation.
Cumulative GESAL	Cumulative GESAL is a traffic loading summary statistic similar to cumulative ESAL but with pavement structure and condition inputs set to constant values. Cumulative GESAL is accumulated over time (i.e., analysis or design period).	Use to relate pavement performance with traffic loading or to compare traffic loading between different sites. If used in analysis, the analyst must consider limitations and assumptions associated with GESAL formulation.
Annual RPPIF	RPPIF is computed similar to ESAL but with factors estimated based on MEPDG simulations and normalized to fully loaded 34,000-lb tandem axle loads instead of 18,000-lb single axle loads.	Use as an input parameter to relate pavement performance with traffic loading, especially for distresses sensitive to heavy axle load applications. If used in analysis, the analyst must consider limitations and assumptions associated with annual RPPIF.
Cumulative RPPIF	Cumulative RPPIF is computed similar to cumulative ESAL but with LEF estimations based on MEPDG simulations and normalized to fully loaded 34,000-lb tandem axle loads instead of 18,000-lb single axle loads.	Use to relate pavement performance with traffic loading, especially for distresses sensitive to heavy axle load applications. If used in analysis, the analyst must consider limitations and assumptions associated with cumulative RPPIF.

Parameter	Description or Meaning	Recommended Use and Limitations
ATL	An estimate of the total weight of all vehicles in FHWA Classes 4–13 applied to pavement during the year.	Use to relate pavement performance with traffic loading. If used in analysis, the analyst must consider limitations and assumptions associated with ATL.
CTL	An estimate of the total weight of all vehicles in FHWA Classes 4–13 applied to pavement over time.	Use to relate pavement performance with traffic loading. If used in analysis, the analyst must consider limitations and assumptions associated with CTL.
Average GVW for each vehicle class (FHWA Classes 4–13)	Average GVW for each vehicle in FHWA Classes 4–13, considering all available axle weight data.	Use to identify or group LTPP sites with similar per-truck loading for specific types of trucks. Average GVW for each vehicle class does not contain information about truck volume or total loading experienced by an LTPP site. In combination with AADTT by vehicle class information, average GVW for each vehicle class can be used to define average daily traffic loading associated with each vehicle class (i.e., FHWA Classes 4–13) at an LTPP site.
Average GVW (FHWA Classes 4–13 combined)	Average GVW for an LTPP site for vehicles in FHWA Classes 4–13 combined, considering all available axle weight data.	Used to identify or group LTPP sites with similar per-truck loading. Average GVW does not contain information about truck volume or total loading experienced by an LTPP site. In combination with AADTT information, average GVW can be used to characterize average daily truck traffic loading or total truck traffic loading (i.e., FHWA Classes 4–13 combined) at an LTPP site.

Parameter	Description or Meaning	Recommended Use and Limitations
Cumulative number of heavy axle load applications for FHWA Classes 4–13 combined	Cumulative number (i.e., axle count) of axles weighing over 75 percent of Federal legal load limit per LTPP site, considering all available axle weight data.	Use to characterize exposure of an LTPP site to heavy axle loads, compare traffic loading between LTPP sites, or group LTPP sites with similar traffic loading (i.e., similar exposure to heavy axle loads). Cumulative number of heavy axle load applications for all vehicle classes combined is useful for analyses where pavement responses and performance are highly affected by heavy loads and may not be applicable for analyses where the total number of loads is more important than the total load.
Average percent of heavy axle load applications for FHWA Classes 4–13 combined	Average percentage of axles weighing over 75 percent of Federal legal load limit per LTPP site, considering all available axle weight data.	Use to characterize exposure of an LTPP site to heavy traffic loads, compare traffic loading between LTPP sites, or group LTPP sites with similar traffic loading. Average percent of heavy axle load applications for all vehicle classes combined is useful for analyses where pavement responses and performance are highly affected by heavy loads and may not be applicable for analyses where the total number of loads is more important than the total load.
Axle loading category for each vehicle class (FHWA Classes 4–13) and for each axle type/group (i.e., single, tandem, tridem, quad, penta+).	Axle loading category for each vehicle class (FHWA Classes 4–13) and for each axle type/group (single, tandem, tridem, quad, penta+) based on a percentage of heavy axles (i.e., light, moderate, heavy, very heavy).	Use to identify or group sites with similar per-axle loading for specific types of trucks. Allows to identify heaviest axles by class and axle group. Axle loading category for each vehicle class and for each axle type/group describes how heavy different truck axles are but does not contain information about truck volume.
Truck loading category	Truck loading category is determined based on the percentage of heavy trucks in the combined GVW distribution of vehicles in FHWA Classes 4–13: very light, light, moderate, heavy, or very heavy.	Use to identify or group LTPP sites with similar percentage of heavy trucks or similar average per-truck loading. Truck-loading category does not provide information about how many trucks contributed to this distribution.

TRAFFIC PARAMETERS USED IN AASHTOWARE PAVEMENT ME DESIGN SOFTWARE

MEPDG Traffic Parameters

Pavement engineering is undergoing a paradigm shift from empirical to mechanistic–empirical design methods with the goal of eventually developing mechanistic design methods. In contrast with empirical design methods that included only one traffic summary parameter (ESAL) for over 50 yr, mechanistic–empirical design methods require extensive use of a large number of traffic input parameters.

Many mechanistic–empirical pavement performance analyses use the MEPDG method and products like AASHTOWare Pavement ME Design software, which uses a defined set of traffic input parameters in a specific format. Table 6 describes the traffic parameters required for analyses and design based on the MEPDG method.

Table 6. Traffic input parameters required by AASHTOWare Pavement ME Design software.

MEPDG Input Parameter	Parameter Description
ALDF	ALDF represent a percentile axle load distribution for a typical day of each calendar month for a typical design/analysis year. One set of ALDF are provided for each vehicle class (FHWA Classes 4–13), axle group type (i.e., single, tandem, tridem, quad), and calendar month. ALDF remain constant between analysis years.
Vehicle class volume distribution	One representative percentile distribution of truck volume by vehicle class (FHWA Classes 4–13) is provided to represent a vehicle class distribution for the base design or analysis year.
Monthly adjustment factors	One representative set of 12 monthly coefficients is provided for each vehicle class (FHWA Classes 4–13) to represent differences in truck volumes between different calendar months for the base design or analysis year.
Hourly distribution factors	One representative set of 24 hourly factors showing the average percentage of total daily truck volume for each hour. Values are the same for all truck classes. Hourly distribution factors only apply to portland cement concrete (PCC) pavements.
Number of axles per truck	One representative set of values showing the average number of single, tandem, tridem, and quad axles for each truck class (FHWA Classes 4–13).
Base (first) year AADTT for design lane	One value representing average annual daily volume of vehicles in FHWA Classes 4–13 for the base design or analysis year. If base (first) year AADTT for design lane is used in AASHTOWare Pavement ME Design software in place of two-way AADTT, also enter the following values: percent trucks in design direction is 100, and percent trucks in design lane is 100. Alternative inputs include: MEPDG base (first) year two-way AADTT, percent trucks in design direction, and percent trucks in design lane.

MEPDG Input Parameter	Parameter Description
Base (first) year two-way AADTT	Two-way AADTT computed for the base design or analysis year.
Percent of trucks in design direction	Percent of trucks in design direction for the base design or analysis year.
Percent of trucks in design lane	Percent of trucks in design lane for the base design or analysis year.
Vehicle class annual volume growth rate for each truck class (FHWA Classes 4–13)	Growth rate (percent) for each truck class (FHWA Classes 4–13). Used together with the growth function (linear or compound) to estimate truck volume over the analysis or design period from the base design or analysis year AADTT values.
Vehicle class growth function	Type of truck volume growth function (linear or compound) for each vehicle class (FHWA Classes 4–13). Applied together with the growth rate to estimate truck volume over the analysis or design period from the base design or analysis year AADTT values.
Operational speed	Average speed in mph of heavier trucks through the project limits. If not available, use defined as-posted speed limit value.
Axle spacing	Average representative axle spacing in inches for tandem, tridem, and quad axles.
Average wheelbase length and corresponding percentage of trucks	Average wheelbase length in feet and corresponding percentages of trucks with wheelbases that fall in the following three categories: short (≤12 ft), medium (>12 ft and ≤15 ft), and long (>15 ft and ≤20 ft). For multiunit and combination trucks, only wheelbase of the truck power-unit (i.e., first unit) is considered. Used for top-down JPCP cracking model only.
Average axle width	Distance in feet between two outside edges of an axle. Constant between all truck classes. Only needed for rigid pavement designs.
Mean wheel location	Mean distance in inches from the outer edge of the wheel to the pavement marking. Mean wheel location is constant between all truck classes and does not change with time.
Truck wander standard deviation	Standard deviation from the mean wheel location. Computed in inches based on measurements from the lane marking.
Dual tire spacing	Dual tire spacing is constant between all truck classes and does not change with time.

ALDF = axle load-distribution factors.

Traffic Loading Defaults for MEPDG

Recognizing the emerging state of WIM technology, the limited number of sites reporting WIM data, and the need for research-quality WIM data to support LTPP research, the LTPP program installed and maintained WIM equipment at SPS WIM sites in 22 States. This effort proved that collecting consistently high-quality WIM data (satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 over long periods (10 yr or more) is possible with proper maintenance and calibration.[11, 12, 13] Data from LTPP SPS WIM sites have been used to develop new-generation traffic loading defaults for use with the MEPDG method.[4] These defaults were included in AASHTOWare Pavement ME Design software for national and international use. FHWA developed LTPP PLUG to help users select and use these defaults.(10) LTPP is expanding its WIM program to cover more sites across the United States as part of its Warm-Mix Asphalt Overlay of Asphalt Pavements Experiment. Several States are also working on or have completed developing their own MEPDG traffic loading defaults.

MEPDG Parameters Requiring Special Input Formats and Tools

MEPDG input for ALDF requires a table with over 19,000 data entries representing normalized axle load-distribution for a typical day for each of the 12 calendar months for a base analysis year. This distribution is required for each vehicle class (FHWA Classes 4–13) and each axle type/group (i.e., single, tandem, tridem, and quad). Due to the large size of MEPDG input for ALDF, the preferable way to enter it into AASHTOWare Pavement ME Design software is to upload an axle load-distribution file in .xml format. Like axle load distribution, a monthly traffic volume adjustment input required by AASHTOWare Pavement ME Design software requires 120 entries and can be imported in .txt format.

Accuracy of Weight Data

Emerging mechanistic and MEPDG methods demand accurate measurements of traffic loads. To provide accurate predictions of stresses, strains, and deflections in a pavement structure, weight measurements should be as accurate as those used for weight enforcement. For MEPDG methods, accuracy of WIM data should satisfy the performance requirements of Type I WIM systems for ASTM E1318-09.(11)

CHAPTER 3. ASSESSMENT OF LTPP USERS' NEEDS AND AVAILABLE LTPP TRAFFIC DATA SOURCES

This chapter identifies traffic data and computed parameters necessary to support different types of LTPP data analyses, specifies whether these parameters were computed and stored by the LTPP program at the beginning of this study, and describes the benefits of these parameters. Recommendations are provided at the end of this chapter for additional traffic data and/or parameters that should be made available to LTPP users.

PURPOSE OF LTPP TRAFFIC DATA AND LTPP USERS' PRIORITIES

To better understand the traffic data and computed parameters needs of LTPP users, a review was conducted of previously published LTPP documentation, including LTPP experiment design documents, the *Strategic Plan for Long-Term Pavement Performance Data Analysis,* selected LTPP and NCHRP data analysis reports, and reports and documentation generated under TPF-5(004).[16,17]

In addition, a series of discussions took place between the study research team with members of the LTPP team, LTPP Customer Support Service Center (CSSC) representatives, TRB ETG for LTPP Special Activities members, and LTPP traffic data collectors and data analysis contractors. Topics discussed included types of traffic data and parameters needed, data quality and quantity, data storage and accessibility, and the minimum data availability requirements to support different LTPP experiments and analyses. As a result of these discussions, the following LTPP traffic data uses were identified and are listed in order of importance:

- To support the analysis plan outlined in the *Strategic Plan for Long-Term Pavement Performance Data Analysis*, including development of analysis-ready traffic datasets.
- To support current and future pavement design procedures used by State and Provincial highway agencies, such as development of enhanced mechanistic–empirical pavement design models and local calibration of these models, including development of traffic inputs required for these analyses, such as MEPDG traffic inputs and traffic loading summary statistics like ESAL.
- To support studies aimed at improving pavement performance and cost allocation models supporting the Highway Performance Monitoring System (HPMS) by providing traffic inputs compatible with HPMS traffic data requirements.
- To promote and highlight the LTPP program's importance through sharing and expanding research-quality traffic data collected by the LTPP program.

GOAL OF LTPP TRAFFIC DATA AVAILABILITY ASSESSMENT

The LTPP traffic data availability assessment activity focused on the availability of traffic parameters needed to support LTPP data analyses rather than data available to compute traffic parameters. Traffic parameters needed to support various LTPP data analyses were identified in chapter 2.

AVAILABILITY OF BASIC AND DETAILED TRAFFIC DATA AND PARAMETERS

LTPP Data Sources for Basic and Detailed Traffic Data and Parameters

Table 7 summarizes basic traffic data and parameters and identifies corresponding LTPP data sources.

Table 7. Availability of basic and detailed traffic data and parameters in LTPP database.

Parameter	Description and Use	LTPP Data Source
Hourly distribution of daily truck traffic volume for each monitoring day or hourly truck volumes	Use for developing MEPDG inputs and defaults. Limited direct application.	Data from LTAS table HH_CL_CT can be used to compute this parameter.
Daily total traffic volume for each monitoring day	Use to compute AADT. Limited direct application.	LTAS table DD_VOL has this parameter.
Daily truck traffic volume for each monitoring day	Use to compute AADTT. Limited direct application.	Data from LTAS table DD_CL_CT can be used to compute this parameter.
Daily truck traffic volume by vehicle class (FHWA Classes 4–13) for each monitoring day	Use to compute AADTT by vehicle class and MEPDG normalized vehicle class distribution. Limited direct application.	LTAS table DD_CL_CT has this parameter.
Monthly truck volume by vehicle class for each monitoring month	Use to compute MEPDG monthly truck volume adjustment factors.	Data from LTAS table MM_CT can be used to compute this parameter.
Monthly ADTT volume by class for each monitoring month	Use to compute AADTT by vehicle class.	Data from LTAS table MM_CT can be used to compute this parameter.
Percent trucks (FHWA Classes 4–13) for each monitoring year	Use to estimate AADTT from AADT when no vehicle classification is available or in studies that require truck volume but truck volume data are not available for each year. Limited direct application.	Data from LTAS table YY_CT (where TRF_data_type is 4) can be used to compute this parameter.
Axle weight distribution in the form of a daily axle load spectrum for each monitoring day for each vehicle class (FHWA Classes 4–13) and each axle group type (i.e., single, tandem, tridem, quad, penta+)	Use to develop representative monthly NALS for MEPDG input. Use to develop MEPDG defaults. Limited direct application.	LTAS table DD_AX has this parameter.

Parameter	Description and Use	LTPP Data Source
Axle weight distribution in the form of monthly axle load spectra for each monitoring month with at least 7 DOW data available for each vehicle class (FHWA Classes 4–13) and each axle group type (i.e., single, tandem, tridem, quad, penta+)	Use to develop representative monthly NALS for MEPDG input. Use to develop MEPDG defaults. Limited direct application.	Data from LTAS table DD_AX or MM_AX can be used to compute this parameter.
Axle weight distribution in the form of annual axle load spectra for each monitoring year for each vehicle class (FHWA Classes 4–13) and each axle group type (i.e., single, tandem, tridem, quad, penta+)	Use to compute annual ESAL. Limited direct use of this statistic.	LTAS table YY_AX and SDR table TRF_MONITOR_AXLE_DISTRIB have this parameter.
Monthly normalized axle weight distribution for each monitoring month with at least 7 DOW data available for each vehicle class (FHWA Classes 4–13) and each axle group type (i.e., single, tandem, tridem, quad, penta+)	Use to develop representative monthly NALS for MEPDG input. Use to develop MEPDG defaults. Limited direct use of this statistic.	Data from SDR table TRF_MEPDG_AX_DIST or LTAS table DD_AX or MM_AX can be used to compute this parameter.
Annual normalized axle weight distribution for each monitoring year for each vehicle class (FHWA Classes 4–13) and each axle group type (i.e., single, tandem, tridem, quad, penta+)	Use to develop MEPDG defaults. Limited direct use of this statistic.	SDR table TRF_MEPDG_AX_DIST_ANL has this parameter.
Average number of axles of each axle group type (i.e., single, tandem, tridem, quad, penta+) per vehicle class (FHWA Classes 4–13) for each year with WIM data	Use to develop MEPDG inputs and defaults. Limited direct use of this statistic.	SDR table TRF_MEPDG_AX_PER_TRUCK has this parameter.

Parameter	Description and Use	LTPP Data Source
Axle-to-axle spacing for tandem axle configurations based on WIM data for each year	Use to develop MEPDG axle spacing inputs and defaults. Limited direct use of this statistic.	No LTPP table available but can be computed from IVR weight files.
Axle-to-axle spacing for tridem axle configurations based on WIM data for each year	Use to develop MEPDG axle spacing inputs and defaults. Limited direct use of this statistic.	No LTPP table available but can be computed from IVR weight files.
Axle-to-axle spacing for quad+ axle configurations for each year with WIM data	Use to develop MEPDG axle spacing inputs and defaults. Limited direct use of this statistic.	No LTPP table available but can be computed from IVR weight files.
Average axle spacing and percentile distribution of the tractor unit wheelbase of tractor–semitrailer combination trucks (FHWA Classes 8–13) in three categories: short (≤12 ft), medium (>12 and ≤15 ft), and long (>15 ft and ≤20 ft) for each year with WIM data	Use to develop MEPDG wheelbase input and defaults. Limited direct use of this statistic.	No LTPP table available but can be computed from IVR weight files.
Average axle spacing and percentile distribution of all axle spacings from vehicles in FHWA Classes 4–13 in three categories: short (≤12 ft), medium (>12 and ≤15 ft), and long (>15 ft and ≤20 ft) for each year with WIM data	Use to develop MEPDG axle spacing inputs and defaults. Limited direct use of this statistic.	No LTPP table available but can be computed from IVR weight files.
Average and standard deviation of outer wheel location from pavement lane marking based on all axle passages for vehicles in FHWA Classes 4–13	Use to develop MEPDG inputs and defaults. Wheel location is measured in inches from the outer edge of the wheel to the pavement marking for each axle and vehicle passage. Limited direct use of this statistic.	Not available. This information is not collected by the LTPP program.

DOW = day of week; LTAS = Long-Term Pavement Performance Traffic Analysis Software.

Availability Assessment and Recommendations for Basic and Detailed Traffic Data and Parameters

As shown in table 7, most basic traffic parameters are directly available in LTAS or SDR database tables while other parameters can be computed based on LTPP traffic data. LTPP data users can obtain these parameters either by request through the LTPP CSSC or ltppinfo@dot.gov or directly through InfoPave.

Gaps in the availability of detailed parameters identified in table 7 include lack of information about load position and configuration, tire footprint information, time history of each load application (i.e., changes in location and magnitude of loads over time as truck tires roll over a pavement section), and the magnitude of dynamic forces applied to the pavement. These parameters are likely to become more important as pavement design moves to more advanced mechanistic modeling. The research study team recommends that the LTPP program investigate the feasibility of collecting these data elements in the future.

AVAILABILITY OF ANALYSIS-READY TRAFFIC PARAMETERS

Need for Analysis-Ready Traffic Datasets

Assessment of LTPP database user needs and review of available LTPP traffic data (using SDR 27) indicated that the LTPP database contained insufficient analysis-ready traffic parameters. Analysis-ready traffic parameters are summary statistics representing traffic in the form of computed values used as direct inputs to analysis models. In addition, analysis-ready traffic parameters are used as direct traffic inputs for pavement design and analysis tools, such as the AASHTO *Guide for Design of Pavement Structures* and AASHTOWare Pavement ME Design software. Analysis-ready traffic parameters are the most frequently requested data from the LTPP database and represent a high priority for LTPP database users. The main analysis-ready traffic parameters missing from or incomplete in the LTPP database are those used directly with AASHTOWare Pavement ME Design software, including axle loading frequency distributions, truck traffic growth parameters, and parameters providing information about relative position of axle loads on the pavement.

Analysis-ready traffic parameters contain information relevant to achieving LTPP analysis objectives (e.g., AADTT for each analysis year and cumulative ESAL computed for years corresponding to distress data collection years over the analysis period). To compute analysis-ready parameters, systematic procedures are applied to available data, including review of data from multiple sampling periods and multiple data sources, identification and investigation of outliers, estimation of missing traffic data, and computation or estimation of traffic parameters suitable for a direct analysis input.

Why Analysis-Ready Traffic Parameters Should Be a Priority for LTPP

Previous LTPP studies involving pavement response and performance prediction required significant effort to develop analysis-ready traffic input parameters. Efforts included reviewing available traffic data, identifying questionable data and outliers (either due to limited samples or traffic monitoring equipment lacking calibration or improperly calibrated), rationalizing unexpected traffic trends, and projecting traffic parameters over the pavement analysis period from limited and sometimes contradictory site-specific data samples.

Many LTPP sites did not have any traffic loading information, thus limiting their use in analyses. In the past, this situation led to two outcomes: either a portion of the research effort was diverted from the analysis of pavement performance to development of comprehensive traffic inputs (as in cases of analyses requiring MEPDG-type traffic inputs) or the analysis was not executed to its full potential because traffic data availability was limited. The latter led to either a reduced number of LTPP sites used in analyses or use of traffic parameters that were available but did not have a direct correlation with pavement performance, such as using traffic volume data in lieu of insufficient traffic loading data.

How Analysis-Ready Traffic Data and Parameters Are Used

Analysis-ready traffic parameters are provided in a ready-to-use format as a direct input in the majority of LTPP analyses. These parameters are summary statistics or application-specific input parameters supporting a broad range of research topics related to pavement response and performance modeling and analysis. Analysis-ready traffic parameters are also used as inputs in the AASHTO *Guide for Design of Pavement Structures* and AASHTOWare Pavement ME Design software.[3,5]

Based on the intended application, analysis-ready traffic parameters can be categorized as follows:

- Parameters for detailed characterization of traffic loading for mechanistic and mechanistic–empirical pavement response and performance analysis and modeling.
- Summary traffic parameters for empirical pavement response and performance analysis and modeling and for use in high-level analyses.

Detailed review of these parameters is provided in chapter 2. The following section summarizes the availability assessment of analysis-ready traffic parameters in the LTPP database.

LTPP Traffic Data Sources to Support Mechanistic Pavement Response Prediction and Modeling

Review of available LTPP traffic data sources shows that, while raw data are available to compute most needed parameters, these parameters are not available as analysis-ready values. As such, significant effort is needed to compute traffic inputs for pavement response analyses. Table 8 summarizes traffic parameters necessary for mechanistic pavement response prediction and modeling and LTPP data sources that can be used to obtain these parameters.

Table 8. Traffic parameters for mechanistic pavement response modeling and LTPP sources.

Input Parameter	Parameter Description	LTPP Data Source
Vehicle class and axle configuration for each vehicle passage	Description of a vehicle class (FHWA Classes 4–13), truck body type, and axle configuration for each vehicle passage, including number and spacing of axles.	LTPP WIM IVR files stored offline.

Input Parameter	Parameter Description	LTPP Data Source
Axle-to-axle spacing for each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Distance between pairs of consecutive vehicle's axles for each vehicle passage.	LTPP WIM IVR files stored offline.
Axle load, both static and dynamic, for each axle for each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Static weight estimated by WIM system for each axle for each vehicle passage.	LTPP WIM IVR files stored offline.
Wheel load for each axle for each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Static weight estimated by WIM system for each axle for each vehicle passage.	This information is available from WIM controller but is not stored by the LTPP program.
Duration of each axle or wheel load application	Time during which axle load was applied on monitored pavement section. Used for dynamic pavement response modeling only.	This information is not collected by the LTPP program but can be obtained from WIM controller records.
Time history of changes in load magnitude for each axle or wheel passage	Dynamic load magnitude estimated based on WIM signal for each millisecond during axle passage over the WIM sensor. Used for dynamic pavement response modeling only.	This information is not collected by the LTPP program but can be obtained from WIM controller records.
Wheel location on the pavement associated with each axle and vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Wheel location measured in inches from the outer edge of the wheel to the pavement marking for each axle and vehicle passage.	This information is not collected by the LTPP program but can be obtained from specially configured quartz-piezo sensor arrays.
Truck wander	Standard deviation from the mean wheel location, computed in inches based on measurements from the lane marking.	This information is not collected by the LTPP program but can be computed from wheel location records.
Tire footprint area for each axle associated with each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Tire footprint area of each axle and vehicle passage.	This information is not collected by the LTPP program.

Input Parameter	Parameter Description	LTPP Data Source
Axle width with each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Distance in feet between two outside edges of an axle.	This information is not collected by the LTPP program but can be collected using staggered WIM sensor arrays. The default value may be appropriate due to expected low variability of this parameter.
Dual tire spacing with each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Distance in feet between two tires.	This information is not collected by the LTPP program. The default value may be appropriate due to expected low variability of this parameter.
Tire pressure for wheel of each vehicle or annual average for each vehicle class (FHWA Classes 4–13)	Tire pressure can be used as an alternative means for computing size of tire footprint.	This information is not collected by the LTPP program.
Truck speed for each vehicle passage or annual average for each vehicle class (FHWA Classes 4–13)	Truck speed in mph.	This information is not collected/reported by the LTPP program but can be obtained from available LTPP WIM IVR for each vehicle passage.

Availability Assessment and Recommendations for Parameters Supporting Mechanistic Pavement Response Prediction and Modeling

Many of the parameters presented in table 8 are not collected or reported by the LTPP program, mainly because the program was designed for long-term monitoring of pavement performance rather than investigating pavement responses immediately after each load application. Some traffic parameters used for pavement response modeling can be obtained from IVR collected by WIM systems, such as estimate of static axle and/or wheel loads for each vehicle, axle spacing, and vehicle speed. Other parameters can be computed using time histories of the changes in WIM sensor signals collected by WIM data-processing units.

Additional data collection is required to accurately measure the location of wheel load with respect to pavement edge, size of the tire footprint, and distribution of loads under the tire footprint. Tire footprint position can be obtained using currently available technologies by using specially configured quartz-piezo WIM sensor arrays. WIM sensors technologies capable of measuring tire footprint or estimating tire pressure are being developed by WIM sensor manufacturers and should be coming to the market in future years.

Based on analysis of available LTPP data and the design of LTPP experiments, a very limited number of LTPP sites can support fundamental research of mechanistic pavement response modeling. In mechanistic pavement response modeling and analysis, pavement responses due to traffic loads are predicted using laws and principles of the mechanics of materials and compared to the same responses measured in the field. Mechanistic pavement responses are characterized by stresses, strains, or deflections induced in pavement layers under traffic loading. Only those

LTPP sites where these pavement responses are monitored under actual known traffic loading can be used for development or verification of mechanic pavement response models. In addition to traffic parameters, mechanistic pavement response modeling requires extensive pavement material characterization (i.e., extensive testing and coring); in-situ measurement of stresses, strains, and deflections in pavement layers; and in-situ environmental data collection. Only two LTPP dynamic load response sites, one each in in Ohio and North Carolina, have the necessary measured pavement response information to support fundamental research of mechanistic pavement response modeling.

The effort required to collect data necessary for mechanistic pavement response modeling may be too high compared to possible benefits and contributions to overall LTPP program objectives; thus, these parameters represent a low priority compared to other traffic data needs, such as development of analysis-ready traffic parameters for use in AASHTOWare Pavement ME Design software.

LTPP Traffic Data Sources to Support Mechanistic–Empirical Pavement Performance Prediction

Although pavement response analysis and modeling studies focus on stresses, strains, and deflections that pavement experience under each traffic load application, pavement performance analysis and modeling studies focus on pavement distresses (e.g., cracking, rutting, faulting) that develop over time. To provide a means for tracking and summarizing traffic load applications over time, traffic loads are summarized in an axle load spectrum. The axle load spectrum input provides information about axle load magnitudes, the number of axle load applications over a specified period at different magnitudes, and load configuration (i.e., number of axles in each axle load group). In addition to the axle load spectrum, information about the relative position of axle loads on the pavement is also important for pavement performance modeling.

Table 9 summarizes traffic parameters necessary for mechanistic–empirical pavement performance modeling and LTPP data sources that can be used to obtain these parameters.

Table 9. Traffic parameters for generic mechanistic–empirical pavement performance modeling and LTPP sources.

Input Parameter	Parameter Description	LTPP Data Source
Axle load spectrum	Axle load spectrum is a frequency distribution of the number of axle load applications by load bins (or load ranges) where a number of axle load applications observed during a specified period is reported using predefined load bins. Separate axle load spectra are used to summarize axle loading for typical axle load groups: single, tandem, tridem, and quad+. Axle load spectra can be created for an individual truck class or for all truck classes combined. Axle load spectra can represent daily, monthly, or annual traffic loading summaries. This input must cover the whole analysis period, using time increments specified for analysis, so the number of axle load application can be used to model incremental changes in pavement structure over the selected analysis period.	This parameter is available in LTPP database tables DD_AX, MM_AX, YY_AX, and TRF_MONITOR_AXLE_DISTRIB for each year with WIM data.
Number of axles per truck	Average number of single, tandem, tridem, and quad axles for each truck class (FHWA Classes 4–13).	This parameter is available in the LTPP database table TRF_MEPDG_AX_PER_TRUCK for each year with sufficient WIM data.
Axle spacing	Average axle spacing in inches for tandem, tridem, and quad axles.	This parameter is not available in the LTPP database but can be computed from LTPP WIM IVR files.
Axle spacing distribution	Frequency of longitudinal spacing of consecutive axles in feet, excluding spacing within multi-axle groups. Use to model locations of loads for JPCP pavements.	This parameter is not available in the LTPP database but can be computed from LTPP WIM IVR files.
Average axle width	Distance in feet between two outside edges of an axle. Use for rigid pavement analysis only.	This information is not collected by the LTPP program but can be collected using staggered WIM sensor arrays, video samples, or truck fleet surveys.

Input Parameter	Parameter Description	LTPP Data Source
Operational speed	Posted speed limit or average speed (in mph) of heavier trucks (FHWA Classes 6–13) through project limits.	This information is not collected/reported by the LTPP program but can be obtained from IVR records following the new FHWA *Traffic Monitoring Guide* (TMG) format.
Dual tire spacing	Distance in inches from the center of one tire to the next for the tire assemblies located on the same axle and in the same wheel path.	This information is not collected by the LTPP program.
Tire pressure	One value representing hot tire inflation pressure.	This information is not collected by the LTPP program.
Mean wheel location	Distance in inches from the outer edge of the wheel to the pavement marking. Use to model the location of the load.	This information is not collected by the LTPP program but can be collected using specially configured quartz-piezo WIM sensor arrays or from video samples.
Truck wander	Standard deviation from the mean wheel location, computed in inches, based on wheel location measurements from the lane marking. Use to model the location of the load.	This information is not collected by the LTPP program.

Availability Assessment and Recommendations for Parameters Supporting Mechanistic–Empirical Pavement Performance Prediction

Although some parameters identified in table 9 are readily available in LTPP database tables, significant effort is required for users to process data and compute other parameters (e.g., axle spacing and axle spacing distribution). Yet, for a few parameters (e.g., truck wander, mean wheel location, operational speed), the LTPP database contains no information.

The LTPP program should consider computing the parameters identified in table 9 if supporting data are available (See the LTPP Data Source column), and storing the parameters in LTPP database tables.

LTPP Traffic Data Sources to Support MEPDG Applications with AASHTOWare Pavement ME Design Software

A complete assessment of traffic parameters required for all MEPDG analyses involving AASHTOWare Pavement ME Design software is shown in table 10. The assessment presented reflects the status of LTPP data as of SDR 27. As a result of this study, the most critical input parameters listed in table 10 were created in a format compatible with AASHTOWare Pavement ME Design software and are available in the LTPP database as analysis-ready CPTs, as described in chapter 11.

Table 10. MEPDG traffic input parameters and LTPP sources assessment using SDR 27.

MEPDG Input Parameter	Parameter Description	LTPP Data Source
MEPDG ALDF	One representative NALS for each vehicle class (FHWA Classes 4–13), axle group type (i.e., single, tandem, tridem, quad), and calendar month. NALS represent an axle load distribution for a typical day for each calendar month for a base design/analysis year and remains constant for the analysis or design period.	Information to compute this parameter is available in the LTPP database in monthly and annual summary statistics for each year with data satisfying the data availability requirements of NCHRP 1-37A. These data are not readily applicable, as AASHTOWare Pavement ME Design software input requires one representative distribution instead of by-year data.
MEPDG vehicle class volume distribution	One representative normalized distribution of vehicles in FHWA Classes 4–13 to represent an average vehicle class distribution for the base design/analysis year.	Information to compute this parameter is available in the LTPP database in annual summary statistics for each year with data satisfying the data availability requirements of NCHRP 1-37A. These data are not readily applicable, as AASHTOWare Pavement ME Design software input requires one representative distribution instead of by-year data.
MEPDG monthly adjustment factors	One representative set of 12 monthly coefficients is provided for each vehicle class (FHWA Classes 4–13) to represent differences in truck volumes between different calendar months for the base design/analysis year. The sum for all months for one truck class is 12.	Information to compute this parameter is available in the LTPP database in monthly summary statistics for each year with data. These data are not readily applicable, as AASHTOWare Pavement ME Design software input requires one representative set of factors for each LTPP site.
MEPDG hourly distribution factors	One representative set of 24 hourly factors showing the percentage of daily total truck traffic for each hour. Values are the same for all truck classes and only apply to truck volume. This input parameter only applies to PCC pavements.	Information to compute this parameter is available in the LTPP database for each year with data. These data are not readily applicable, as AASHTOWare Pavement ME Design software input requires one representative set of factors for each LTPP site.

MEPDG Input Parameter	Parameter Description	LTPP Data Source
MEPDG number of axles per truck	One representative set of values showing the number of axles per truck class (FHWA Classes 4–13), which provides the average number of single, tandem, tridem, and quad axles for each truck class (FHWA Classes 4–13).	Information to compute this parameter is available in the LTPP database. These data are not readily applicable, as AASHTOWare Pavement ME Design software input requires one representative set of factors for each LTPP site.
MEPDG base (first) year AADTT for LTPP lane	One value representing average annual daily volume of vehicles in FHWA Classes 4–13 for the base design/analysis year. Use this value in AASHTOWare Pavement ME Design software in combination with the following MEPDG parameters: percent trucks in design direction is 100 percent, and percent trucks in design lane is 100 percent.	Information to compute this parameter is available in the LTPP database for most LTPP sites. Additional effort is required from LTPP users to determine if available AADTT values accurately represent desired base year conditions.
MEPDG base (first) year two-way AADTT	Two-way AADTT computed for the base design/analysis year.	Information to compute this parameter is available in the LTPP database for limited years for most LTPP sites. Additional effort is required from LTPP users to determine if available AADTT values accurately represent desired base year conditions.
MEPDG base (first) year two-way AADT	Two-way AADT computed for the base design/analysis year. This parameter and percent trucks are only included in MEPDG software for agencies that do not compute AADTT.	Information to compute this parameter is available in the LTPP database for limited years for most LTPP sites. Additional effort is required from LTPP users to determine if available AADT values accurately represent desired base year conditions.
Number of lanes in design direction	Number of lanes in design direction (i.e., direction of LTPP lane).	This parameter is available in LTPP database table SHRP_INFO.
Percent of trucks in design direction	Percent of trucks in design direction (i.e., direction of LTPP lane) for the base design/analysis year.	This parameter is not available in the LTPP database. Because the LTPP database already contains design lane AADTT values, this parameter is not necessary.

MEPDG Input Parameter	Parameter Description	LTPP Data Source
Percent of trucks in design lane	Percent of trucks in design lane (i.e., LTPP lane) for the base design/analysis year.	This parameter is not available in the LTPP database. Because the LTPP database already contains design lane AADTT values, this parameter is not necessary.
MEPDG vehicle class annual volume growth rate by vehicle class	Growth rate in percent for each truck class (FHWA Classes 4–13) from the base design/analysis year.	This parameter is not available in the LTPP database.
MEPDG truck traffic growth function by vehicle class	Linear or composite growth function by vehicle class (FHWA Classes 4–13) from the base design/analysis year.	This parameter is not available in the LTPP database.
Operational speed	Posted speed limit or average speed of heavier trucks (FHWA Classes 6–13) through the project limits in mph.	This parameter is not available in the LTPP database.
MEPDG axle spacing for tandem, tridem, and quad axles	Average representative axle spacing in inches for tandem, tridem, and quad axles.	This parameter is not available in the LTPP database but can be computed from WIM IVR files for LTPP WIM sites.
MEPDG average wheelbase length and corresponding percentage of trucks with wheelbases in the following categories: short, medium, and long	Average wheelbase length in feet and the corresponding percentages of trucks with wheelbases that fall in the following categories: short (≤12 ft), medium (>12 ft and ≤15 ft), and long (>15 ft and ≤20 ft). For multiunit and combination trucks, only the wheelbase of the truck power-unit (i.e., first unit) is considered. Use for top–down JPCP cracking model only. Current MEPDG model uses values computed for FHWA Classes 8–13 only.	This parameter is not available in the LTPP database but can be computed from WIM IVR files for LTPP WIM sites.
MEPDG average axle width	Distance in feet between two outside edges of an axle. This parameter is constant between all truck classes. Use for rigid pavement designs only.	This parameter is not available in the LTPP database.

MEPDG Input Parameter	Parameter Description	LTPP Data Source
MEPDG mean wheel location	Distance in inches from the outer edge of the wheel to the pavement marking. This parameter is constant between all truck classes and does not change over time.	This parameter is not available in the LTPP database.
MEPDG truck wander standard deviation	Standard deviation from the mean wheel location, computed in inches, based on measurements from the lane marking.	This parameter is not available in the LTPP database.
MEPDG dual tire spacing	This parameter is constant between all truck classes and does not change over time.	This parameter is not available in the LTPP database.
MEPDG tire pressure	One value representing hot tire inflation pressure. This parameter is constant between all truck classes and does not change over time.	This parameter is not available in the LTPP database.

Availability Assessment and Recommendations for Parameters Supporting MEPDG Applications with AASHTOWare Pavement ME Design Software

The Phase I review of available LTPP data sources indicated that some input parameters required by AASHTOWare Pavement ME Design software are not provided in LTPP SDRs, while others are provided in a format not readily applicable as an AASHTOWare Pavement ME Design software input.

None of the parameters included in the LTPP TRF_MEPDG series of tables can be used directly with AASHTOWare Pavement ME Design software, mainly because these tables contain values from multiple years, while AASHTOWare Pavement ME Design software requires one representative input for each parameter. This input is typically computed based on data from years that passed QC checks for vehicle classification and heavy axle loading data accuracy or reasonableness (when accuracy cannot be quantified). Currently, LTPP database users rely on personal judgement to determine data suitability when computing representative values. This requires additional effort and professional judgement, especially when large deviations in traffic parameters exist between different years of data.

The parameters presented in table 10 are the most frequently requested LTPP traffic parameters, as many State and Provincial highway agencies are implementing the MEPDG method and conducting local calibrations of pavement performance models. These efforts require extensive use of traffic inputs that States/Provinces do not have; the LTPP database is the only available national traffic data source with the necessary information to compute these inputs. The availability of AASHTOWare Pavement ME Design software traffic inputs is beneficial to all State/Provincial LTPP users as well as LTPP researchers using AASHTOWare Pavement ME Design software for their analyses.

The LTPP program should consider computing the parameters identified in table 10 if supporting data are available (See the LTPP Data Source column) and storing the parameters in LTPP database tables. In addition, due to the anticipated high demand for these data, these parameters should be given a high implementation priority for display or access within InfoPave. For parameters that do not have supporting LTPP data, the LTPP program should consider conducting a limited data sampling and compute LTPP defaults or providing references to national defaults or default values assigned to LTPP sites.

LTPP Traffic Data Sources Supporting Empirical and High-Level Pavement Management Analyses

Typically, a traffic summary parameter is a one-value summary statistic providing information about traffic or truck volume or loading. Traffic summary parameters are typically used to study the empirical relationship between traffic volume and/or load and pavement performance. Traffic summary parameters are also used as an input for decision support or prioritization algorithms with higher-level pavement maintenance and management modeling. These traffic summary parameters were discussed in detail in chapter 2.

Table 11 summarizes different traffic summary parameters and specifies LTPP data sources that were available in SDR 27 during Phase I of this study. In Phase III of this study, many of the parameters listed in table 11 were developed and are currently available in InfoPave. These traffic summary parameters are presented in chapter 11.

Table 11. Traffic summary parameters and LTPP data sources.

Parameter	Parameter Description	LTPP Data Source
AADT	Basic traffic summary statistic to measure average daily road use by all vehicular traffic.	TRF_HIST_VOLUME_COUNT, TRF_MON_EST_ESAL, and TRF_HIST_EST_ESAL tables.
AADTT	Traffic summary statistic to measure average daily road use by trucks and buses (FHWA Classes 4–13).	TRF_MON_EST_ESAL, TRF_HIST_EST_ESAL, and TRF_HIST_VOLUME_COUNT tables.
Cumulative truck traffic volume	Traffic summary statistic to measure total road use by heavy vehicles (FHWA Classes 4–13). Can be cumulated and reported annually or for the analysis duration.	This parameter is not available in the LTPP database, but an annual cumulative total can be computed using data from the TRF_MONITOR_LTPP_LANE table. At some sites, this parameter can be computed for the whole pavement service life.

Parameter	Parameter Description	LTPP Data Source
Cumulative volume of FHWA Class 9 trucks	Traffic summary statistic used to measure road use by FHWA Class 9 trucks. Can be cumulated and reported annually or for the analysis duration.	This parameter is not available in the LTPP database, but an annual cumulative total can be computed using data from the TRF_MONITOR_LTPP_LANE table. At some sites, this parameter can be computed for the whole pavement service life.
Cumulative volume of heavy trucks (FHWA Classes 4 and 6–13)	Traffic summary statistic used to measure road use by vehicles in FHWA Classes 4 and 6–13. Can be cumulated and reported annually or for the analysis duration.	This parameter is not available in the LTPP database, but an annual cumulative total can be computed using data from the TRF_MONITOR_LTPP_LANE table. At some sites, this parameter can be computed for the whole pavement service life.
Annual ESAL	Basic traffic loading summary statistic that uses LEF developed from the AASHO Road Test to convert traffic stream to an equivalent number of 18,000-lb single axle loads (based on expected effects on pavement serviceability).	TRF_ESAL_COMPUTED, TRF_MON_EST_ESAL, and TRF_HIST_EST_ESAL tables.
Cumulative ESAL	Basic traffic loading summary statistic that provides ESALs accumulated over time (i.e., analysis or design period).	This parameter is not available in the LTPP database but can be computed using data from TRF_ESAL_COMPUTED, TRF_MON_EST_ESAL, and TRF_HIST_EST_ESAL tables.
Annual GESAL	GESAL is similar to ESAL but with pavement structure and condition inputs set to constant values. Therefore, GESAL is not affected by changes in pavement type, thickness, or serviceability parameters.	This parameter is not available in the LTPP database.
Cumulative GESAL	Cumulative GESAL is a traffic loading summary statistic similar to cumulative ESAL but with pavement structure and condition inputs set to constant values. Cumulative GESAL is accumulated over time (i.e., analysis or design period).	This parameter is not available in the LTPP database.

Parameter	Parameter Description	LTPP Data Source
Annual RPPIF	RPPIF is computed similar to ESAL but with LEF estimations based on MEPDG simulations and normalized to fully loaded 34,000-lb tandem axle loads instead of 18,000-lb single axle loads.	At the time of Phase I of this study, this parameter was under development by the LTPP program (See the RPPIF_NALS_ANNUAL table).
Cumulative RPPIF	Cumulative RPPIF is computed similar to cumulative ESAL but with LEF estimations based on MEPDG simulations and normalized to fully loaded 34,000-lb tandem axle loads instead of 18,000-lb single axle loads.	This parameter is not available in the LTPP database.
ATL	An estimate of the total weight of all vehicles in FHWA Classes 4–13 applied to pavement during the year.	This parameter is not available in the LTPP database.
CTL	An estimate of a total weight of all vehicles in FHWA Classes 4–13 applied to pavement over time.	This parameter is not available in the LTPP database.
Average GVW for each vehicle class (FHWA Classes 4–13)	Average GVW for each vehicle in FHWA Classes 4–13, considering all available axle weight data.	This parameter is not available in the LTPP database.
Average GVW (FHWA Classes 4–13 combined)	Average GVW for an LTPP site for vehicles in FHWA Classes 4–13 combined, considering all available axle weight data.	This parameter is not available in the LTPP database.
Cumulative number of heavy axle load applications for all vehicle classes combined	Cumulative number (i.e., axle count) of axles weighing over 75 percent of Federal legal load limit per LTPP site, considering all available axle weight data.	This parameter is not available in the LTPP database.
Average percent of heavy axle load applications for all vehicle classes combined	Average percentage of axles weighing over 75 percent of Federal legal load limit per LTPP site, considering all available axle weight data.	This parameter is not available in the LTPP database.
Axle loading category for each vehicle class (FHWA Classes 4–13) and for each axle type/group	Axle loading category for each vehicle class (FHWA Classes 4–13) and for each axle type/group based on a percentage of heavy axles (i.e., light, moderate, heavy, very heavy).	This parameter is not available in the LTPP database.

Parameter	Parameter Description	LTPP Data Source
Truck loading category	Truck loading category is determined based on the percentage of heavy trucks in the combined GVW distribution of vehicles in FHWA Classes 4–13 (i.e., very light, light, moderate, heavy, or very heavy).	This parameter is not available in the LTPP database.

Availability Assessment and Recommendations for Parameters Supporting Empirical and High-Level Pavement Management Analyses

The LTPP program should consider expanding the available LTPP traffic loading summary parameters to include, at a minimum, GESAL, ATL, average GVW, axle and truck loading category. This will provide LTPP users with options to characterize traffic loading using single-value summary statistics beyond ESAL.

LTPP Traffic Data Availability Assessment and Recommendations for Parameters Supporting Model Development for HPMS

Most HPMS traffic parameters are not currently available in the LTPP database. The main challenge in adding these parameters to the LTPP database is that HPMS parameters are computed and reported for the entire roadway section, while LTPP traffic parameters are computed and reported for the LTPP lane only. For two-directional roads, HPMS requires all traffic statistics be reported as bidirectional values (i.e., traffic data collected for individual lanes in the same direction of travel are combined, and values characterizing each direction of travel are provided in the database).

To accommodate the use of LTPP data for future enhancement of pavement performance models used by HPMS, such as cost allocation models, the HPMS traffic parameters listed in table 12 are needed for LTPP sites and experiments that are likely to be used for enhancements of HPMS models. In addition to HPMS needs, these parameters can be used for LTPP analyses where correlations between traffic observed in the LTPP lane and overall roadway traffic are considered as well as for analyses, where knowledge about pavement performance in the LTPP lane alone is not enough to draw conclusions about expected roadway performance.

Table 12. HPMS traffic parameters and available LTPP data sources.

Parameter	Descriptions and Instructions	LTPP Data Availability
AADT for the roadway	All AADTs must reflect DOW, seasonal, and axle correction factors, as necessary; no other adjustment factors can be used. Growth factors should be applied if AADT is not derived from current year counts. AADT is an average daily value representing all days of the reporting year.	This parameter is available in TRF_HIST_VOLUME_COUNT, TRF_MON_EST_ESAL, and TRF_HIST_EST_ESAL tables.

Parameter	Descriptions and Instructions	LTPP Data Availability
Single-unit truck and bus AADT for the roadway	Location-specific measured values are requested based on traffic counts taken on a minimum 3-yr cycle.	This parameter is not available in the LTPP database but can be computed based on available data. Additional data requests or data expansion techniques may be necessary to expand data from the LTPP lane to the roadway.
Peak hour single-unit truck and bus volume as a percentage of total AADT for the roadway	Calculated by dividing the number of single-unit trucks and buses (FHWA Classes 4–7) during the hour with the highest total volume (i.e., peak hour for total traffic, not the hour with the most truck traffic) by AADT (i.e., total daily traffic).	This parameter is not available in the LTPP database but can be computed based on available data. Additional data requests or data expansion techniques may be necessary to expand data from the LTPP lane to the roadway.
Combination truck AADT for the roadway	Combination trucks are defined as vehicles in FHWA Classes 8–13. AADT values are updated annually to represent current year data.	This parameter is not available in the LTPP database but can be computed based on available data. Additional data requests or data expansion techniques may be necessary to expand data from the LTPP lane to the roadway.
Percent peak combination trucks as a percentage of the applicable roadway section's AADT	This value is calculated by dividing the number of combination trucks during the hour with the highest total volume (i.e., peak hour for total traffic, not the hour with the most truck traffic) by AADT (i.e., total daily traffic).	This parameter is not available in the LTPP database. Additional data requests may be necessary.
K-factor	Peak hour volume as a percentage of AADT for the roadway.	This parameter is not available in the LTPP database but can be computed based on available raw traffic data. Additional data requests or data expansion may be necessary.
Directional factor	Percent of design hour volume (30th largest hourly volume for a given calendar year if deriving from continuous traffic monitoring site, or peak hour volume if deriving from short-term counts) flowing in the higher volume direction (i.e., peak direction).	This parameter is not available in the LTPP database. Additional data requests or data collection may be necessary.
Future AADT for the roadway	A 20-yr forecast of two-way AADT (one-way for one-directional roads).	This parameter is not available in the LTPP database. Additional data requests may be necessary.

Parameter	Descriptions and Instructions	LTPP Data Availability
Capacity of a roadway	The capacity of the roadway as estimated by the State/Provincial or local agency. The capacity of a roadway facility is the maximum reasonable hourly rate at which vehicles can be expected to transverse a point or a uniform section of lane or roadway.	This parameter is not available in the LTPP database. Additional data requests may be necessary.
Truck location indicator (the National Truck Network)	Indicator of a roadway section that is a component of the National Truck Network.	This parameter is not available in the LTPP database. Additional data requests may be necessary.

DOW = day of week.

Currently, LTPP traffic data are not available to develop most of HPMS traffic parameters. To make these parameters available through the LTPP database, additional data should be acquired from State/Provincial highway agencies. This would require sending additional traffic data requests to participating State/Provincial agencies to identify data availability for LTPP site locations, additional traffic data processing by LTPP analysts, and development of the new LTPP traffic data tables or data fields in existing tables. Costs and benefits of these recommendations should be weighed against LTPP program—and broader FHWA—objectives.

An alternative approach is presented in *Estimating Design Lane Truck Volumes from HPMS Traffic Data for Long-Term Pavement Performance Analyses*, which shows how HPMS traffic data parameters can be converted to design lane estimates, consistent with truck volume and vehicle class parameters reported for LTPP sites. With this approach, current LTPP pavement performance models can be used with HPMS traffic data.

AVAILABILITY OF LTPP TRAFFIC METADATA PARAMETERS

What Are Metadata?

Metadata are used to reference documentation or methodologies explaining how LTPP traffic data were collected (including measurement accuracy of equipment) and processed (i.e., quality checked and summarized) and how traffic parameters were computed. These data provide supporting information that helps LTPP analysts understand traffic parameters and evaluate their applicability based on analysis objectives. LTPP database metadata parameters include codes, values, or references to established procedures or documentation. Available sources of LTPP traffic metadata are described in the following paragraphs.

Traffic Data Collection Equipment

The SITE_EQUIPMENT_INFO table contains information about traffic monitoring equipment used at LTPP sites. The SITE_EQUIPMENT_INFO table identifies the type of data collected (e.g., volume, classification, and weight) and the traffic monitoring equipment, type of sensors, and vehicle classification scheme used. The SITE_EQUIPMENT_INFO table does not provide information on installation, maintenance, validation, or calibration; this information is entered in TRF_CALIBRATION_AVC, TRF_CALIBRATION_WIM, and TRF_EQUIPMENT_MASTER tables. Equipment installation and maintenance information remains offline as a hard copy using Traffic Data Sheets 14 and 15.

Accuracy of Traffic Data Collection Equipment

The following tables contain information about calibration of traffic monitoring equipment used at LTPP sites, including measurement error statistics used to infer measurement accuracy:

- TRF_CALIBRATION_AVC—calibration of automated vehicle classifiers.
- TRF_CALIBRATION_WIM—calibration of WIM devices.

In addition, Traffic Data Sheet 11 contains information about calibration of traffic volume counters.

Traffic Data Availability

The following tables contain information about traffic data availability (based on the number of days data were collected during each monitored year for which traffic data were accepted):

- TRF_Monitor_LTPP_Ln—shows the number of days with vehicle classification data in the COUNT_DAYS field.
- TRF_Monitor_LTPP_Ln—shows the number of days with vehicle/axle weight data in the WEIGHT_DAYS field.

Shared LTPP Traffic Sites

For some LTPP sites, no traffic data are provided in LTPP traffic tables because one traffic site is used for multiple LTPP sites. The record of shared data is maintained in the SHRP_INFO table. The CLASS_SITE field in the SHRP_INFO table identifies the reference LTPP site for vehicle classification and volume information, and the WIM_SITE field identifies the reference LTPP site for axle loading and truck weight information.

Linking LTPP Traffic Data Tables to LTPP Sites

Traffic data source (or traffic site ID) is identified in the LTPP database by STATE_CODE and SHRP_ID fields in the SHRP_INFO table. If the traffic data source is site-specific, traffic site ID is the same as LTPP site ID for a given LTPP site. If the traffic data source is site-related, traffic site ID is different from LTPP site ID for a given LTPP site. In the latter case, the traffic data source is referencing a different LTPP site ID. Therefore, one traffic site ID can be a source of traffic data for more than one LTPP site. Thus, the number of the LTPP traffic site IDs is smaller in comparison to the number of LTPP site IDs provided in the LTPP database.

Methods Used for Computing LTPP Traffic Parameters

The following tables contain information about computing different LTPP traffic parameters:

- SITE_FACTOR_INFO—contains factors used to convert samples of monitored vehicle volume data to annual estimates based on the practices implemented by different State/Provincial and local highway agencies. These data are derived from LTPP transmittal sheets submitted by highway agencies.

- TRAFFIC_CLASS_CONVERT—document vehicle classification schemes used for data within LTAS. The TRAFFIC_CLASS_CONVERT table provides information about conversion from a classification scheme used by State/Provincial and local highway agencies to that described in the FHWA TMG, if a conversion must be done.

- TRF_ESAL_INPUTS_SUMMARY—contains factors used in annual ESAL computations.

Limitations of and Concerns Related to LTPP Traffic Metadata

During the literature search for this study, no LTPP documents or database reference tables were found containing information about methods and procedures used to compute several traffic parameters currently available in the LTPP database, including the following:

- MEPDG monthly and annual axle load distributions.
- MEPDG hourly volume factors.
- MEPDG monthly volume factors.
- MEPDG axle per class coefficients.

This raises a concern about the accuracy and applicability of parameters that may be based on partial data, where the estimation process was used to compute monthly or annual summary statistics, and parameters that may be based on data from poorly calibrated WIM devices.

Recommendations Related to Traffic Metadata Parameters

The LTPP program should consider documenting the formulas and procedures used for computing all traffic parameters (e.g., AADT, AADTT, ESAL, annual vehicle class distribution, annual axle load spectra). This information should be available, upon request, to LTPP users. The program should also include references to these metadata sources in the *Guide*.(1)

Proposed Traffic Data–Usability Indices

Metadata can help LTPP users determine the applicability of different traffic parameters for specific pavement analysis applications by providing information about equipment used to collect data, data sampling, and the data estimation process. For example, WIM data collected using portable WIM systems with piezo-polymer sensors are likely to be less accurate (due to technology and sampling duration limitations) than data collected by a permanently installed and calibrated load cell WIM system. Traffic loading parameters computed based on data from a portable WIM system may not be applicable for direct use in MEPDG analyses but can be used to make an informed selection of MEPDG traffic loading defaults. Although pieces of supporting information can be found in several LTPP tables, there is no way for pavement researchers who are not familiar with traffic loading data collection and parameter estimation processes to judge how accurate and applicable traffic loading parameters computed based on these data are.

One of the objectives of this study was to develop traffic data–usability indices to help pavement analysts assess the accuracy of LTPP traffic parameters and their applicability for selected analysis methods.

While developing an approach for computing these indices, initially the research team considered indices providing an estimate of statistical confidence associated with a given parameter. However, given the need to combine multiple years of data into a single set of estimates (e.g., providing only one representative axle load spectra or ESAL value cumulated over multiple years per site), the need to estimate missing/unreliable values at some sites based on little direct knowledge, and the lack of information about equipment used to collect data and unknown performance characteristics of that equipment, it was concluded this approach cannot be successfully implemented. Therefore, the decision was made to use a set of descriptive indices containing parameter usage recommendations based on available information about data collected at each LTPP site. These indices are set on a simple ordinal scale where lower index values indicate better data availability and quality and wider usability of the parameter for pavement analysis applications.

The proposed site-level traffic data–usability indices are described in chapter 10. These indices are assigned to each LTPP site included in analysis-ready CPTs described in chapter 7 and stored in these CPTs. These indices are intended to help LTPP database users identify sites with traffic data meeting their analysis criteria based on data quantity and quality—or data rationality when data quality cannot be determined.

In addition to site-level traffic data–usability indices, it is recommended that LTPP traffic data managers assign similar indices, as applicable, to each LTPP site and each month with WIM data reported in the LTPP database. These indices should indicate whether reported WIM data summaries are Type I, Type II, or unknown based on ASTM E1318-09 data accuracy criteria. For unknown WIM types, it would beneficial to identify whether any data rationality rules were broken for each month with WIM data.

RECOMMENDATIONS BASED ON ASSESSMENT OF LTPP USER NEEDS AND CURRENT TRAFFIC DATA AVAILABILITY

This section summarizes recommendations developed by the research team.

Analysis-Ready Traffic Parameters

Many traffic parameters used for pavement analysis were identified through the user needs assessment. These parameters were discussed in detail in chapter 2. Some of these parameters support the original research of pavement response and performance modeling, while other parameters are used as inputs into pavement analysis and design tools that were created as a result of the original LTPP research efforts. With LTPP program maturity, higher emphasis is being placed on data analysis and model development using LTPP data. Therefore, analysis-ready traffic parameters are of the most interest and use to LTPP researchers.

The research team recommends the LTPP program make analysis-ready traffic parameters described in this report available to LTPP users, to the extent possible, especially parameters serving a large pool of LTPP users, such as those needed for AASHTOWare Pavement ME Design software traffic inputs and other core parameters described in the next section.

Core Traffic Parameters

Traffic parameters presented in tables 5 through 11 support different LTPP analysis needs. Some were further designated by the research team as core parameters. These core parameters, presented in table 13, are analysis-ready traffic parameters likely to be used in many types of LTPP analyses and likely to have a significant effect on analysis outcomes. Parameters identified as new or revised in table 13 require developing new or revised LTPP data tables. Parameters identified as existing have missing values in LTPP data tables for some pavement in-service years and require estimating those values to fill in the blanks.

Table 13. Identified core traffic parameters.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
1	AADTT	LTPP empirical analyses where truck volume is important, network-level pavement management analyses, and analyses where traffic is used as a secondary parameter.	Vehicle classes used: FHWA Classes 4–13 combined. Based on measured or estimated data for each year pavement site was in service up to the end of site participation in the LTPP experiment.	Existing for some years. New estimated parameter for years without monitored or historical data (approximately 25 percent of all years).
2	AADTT by vehicle class	LTPP empirical analyses where truck volume for specific truck classes is important, analyses where truck volume is aggregated for specific truck classes, and analyses where traffic is used as a secondary parameter.	Applies to each FHWA vehicle Class 4–13. Based on measured or estimated data for each year pavement site was in service up to the end of site participation in the LTPP experiment.	New.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
3	Annual ESAL	LTPP empirical analyses where a single-value traffic loading statistic is desired, network-level pavement management analyses, empirical analyses of load-related distresses, and pavement design using the AASHTO *Guide for Design of Pavement Structures* (1993 or earlier versions).	Vehicle classes used: FHWA Classes 4–13 combined. Based on measured or estimated data for each year pavement site was in service up to the end of site participation in the LTPP experiment.	Existing for some years. New for years without monitored or historical data.
4	Annual GESAL	LTPP empirical analyses where a single-value traffic loading statistic is desired for quantifying and comparing traffic loads between sites.	Vehicle classes used: FHWA Classes 4–13 combined. Based on measured or estimated data for each year pavement site was in service up to the end of site participation in the LTPP experiment.	New.
5	Annual total load	LTPP empirical analyses where a single-value traffic loading statistic is desired for quantifying and comparing traffic loads between sites.	Vehicle classes used: FHWA Classes 4–13 combined. Based on measured or estimated data for each year pavement site was in service up to the end of site participation in the LTPP experiment.	New.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
6	MEPDG ALDF	Analyses using MEPDG models and software tools and analyses for enhancing, developing, and calibrating MEPDG models.	Applies to each FHWA vehicle Class 4–13 and axle group (single, tandem, tridem, and quad). One representative set of normalized ALDF for each LTPP site in MEPDG format. These values represent axle load distribution for a typical day for each of 12 calendar months. These factors should be computed separately for each vehicle class (FHWA Classes 4–13) and each axle type or group (i.e., single, tandem, tridem, and quad). These parameters can be computed from measured data or from LTPP NALS default values.	New or revised. The existing TRF_MEPDG_AX_DIST_ANL table provides values by year. Further summarization and analysis is required to compute representative monthly MEPDG input in a format compatible with AASHTOWare Pavement ME Design software.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
7	MEPDG truck volume growth rate	Analyses using MEPDG models and software tools; analyses for enhancing, developing, and calibrating MEPDG models; and all LTPP analyses requiring truck traffic volume estimation for the analysis period.	Applies to each FHWA vehicle Class 4–13. One value computed separately for each vehicle class (FHWA Classes 4–13) and for FHWA Classes 4–13 combined from the first year since the LTPP site opened to traffic to each year with a change in pavement structure or change in experiment type up to the end of site participation in the LTPP experiment.	New.
8	MEPDG truck volume growth function	Analyses using MEPDG models and software tools; analyses for enhancing, developing, and calibrating MEPDG models; and all LTPP analyses requiring truck traffic volume estimation for the analysis period.	Applies to each FHWA vehicle Class 4-13. Descriptive parameter indicating either linear or compound function associated with the MEPDG truck volume growth rate parameter for each vehicle class (FHWA Classes 4–13) and for FHWA Classes 4–13 combined.	New.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
9	MEPDG vehicle class volume distribution	Analyses using MEPDG models and software tools; analyses for enhancing, developing, and calibrating MEPDG models; and analyses focusing on effects of different truck types on pavement performance.	Vehicle classes used: FHWA Classes 4–13. One representative normalized vehicle volume by class distribution in MEPDG format. These parameters can be computed from measured data or use NCHRP 1-37A MEPDG defaults.	New or revised. The existing TRF_MEPDG_VEH_ CLASS_DIST table provides values by year. Further summarization and analysis is required to compute representative MEPDG input.
10	MEPDG number of axles per truck	Analyses using MEPDG models and software tools and analyses for enhancing, developing, and calibrating MEPDG models.	Applies to each FHWA vehicle Class 4–13 and axle group (single, tandem, tridem, quad). One set of representative numbers of axles per truck. These parameters can be computed from site-specific measured total truck and total axle count data or assigned using LTPP MEPDG default values.	New or revised. The existing TRF_MEPDG_AX_ PER_TRUCK table provides values by year. Further summarization and analysis is required to compute representative MEPDG input.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
11	MEPDG monthly adjustment factors	Analyses using MEPDG models and software tools and analyses for enhancing, developing, and calibrating MEPDG models. Primarily used for the sites with data supporting analysis of seasonal changes.	One set of representative monthly truck volume adjustment factors for each vehicle class (FHWA Classes 4–13) for sites with sufficient seasonal truck volume data. A default value of "1" should be used for sites with insufficient seasonal data.	New or revised. Similar parameters are provided in the TRF_MEPDG_ MONTH_ADJ_FA CTR table by year. Further summarization and analysis is required to compute representative MEPDG input.
12	Monthly NALS	Development of LTPP traffic loading defaults and studies of load-related pavement distress prediction models for situations where seasonal changes in pavement response and performance are considered. Also used to compute site-specific MEPDG ALDF.	Monthly estimates of normalized monthly axle load distribution and total number of axles for each FHWA vehicle Class 4–13 and each axle type (i.e., single, tandem, tridem, and quad) for LTPP sites with WIM systems performing within ASTM E1318-09 accuracy requirements for Type I WIM sensors. Provide for each month with data satisfying ASTM E1318-09 accuracy requirements for Type I WIM sensors.	New or revised. Similar parameters are provided in table MM_AX by DOW but require further summarization to obtain normalized monthly axle load distribution for each month.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
13	Annual axle loading distribution	Analyses involving development or enhancement or mechanistic–empirical pavement performance models. Also used to develop default axle loading distributions or default axle load spectra for AASHTOWare Pavement ME Design software analyses.	Annualized frequency distribution of the number of axle load applications by load bins (or load ranges) where a number of axle load applications of different magnitudes observed or estimated over a year is summarized and reported using predefined load bins. Reported separately for axle load groups (i.e., single, tandem, tridem, and quad) and for individual truck classes (FHWA Classes 4–13).	Existing for some years. These data are actual counts and not the projected full-year loading summary (i.e., computed only for dates when actual axle weight data were collected). This parameter is available in the YY_AX and TRF_MONITOR_ AXLE_DISTRIB tables for each year with WIM data.

Core Item No.	Core Parameter	Used for these Analyses	Description	New or Existing LTPP Parameter or Indicator
14	Traffic data–usability indices	Provides information about WIM data quantity and quality—or rationality if quality cannot be quantified—to help users make informed decisions about traffic loading data applicability for analysis. Used to identify LTPP sites with loading data acceptable as site-specific inputs (i.e., MEPDG Level 1) and sites that may be better served by default values.	Indicator on an ordinal scale linked to the table providing WIM data quantity and quality or rationality information for each indicator value. Also contain recommendations about applicability of traffic loading parameter for pavement analyses.	New.

DOW = day of week.

Data Availability for Core Traffic Parameters

The research team further assessed the availability of core parameters for LTPP traffic sites. Using SDR 28 (the latest SDR available at the time of the assessment), 847 unique LTPP traffic sites were identified. These traffic sites provide data for one or more LTPP GPS pavement sites and LTPP SPS sections. Results of the core data availability assessment are summarized in table 14. For each LTPP traffic site, traffic data availability for different traffic parameters was assessed for each year a site was in service. The results are reported as percentages of all site-years either with or without a given traffic parameter.

Table 14. Availability of core traffic parameters by LTPP traffic site and year count.

Core Item No.	Traffic Parameter	Number of LTPP Traffic Sites		Percent of Site-Years for All LTPP Traffic Sites Combined	
		With Parameter	Without Parameter	With Parameter	Without Parameter
1	AADTT	840	7	97 percent	3 percent
2	AADTT by vehicle class**	0	0	54 percent	46 percent
3	Annual ESAL	765	82	55 percent	45 percent
4	Annual GESAL**	N/A	N/A	0 percent	100 percent
5	Annual total load**	N/A	N/A	21 percent	79 percent
6	MEPDG ALDF (monthly)**	N/A	N/A	N/A	N/A

Core Item No.	Traffic Parameter	Number of LTPP Traffic Sites		Percent of Site-Years for All LTPP Traffic Sites Combined	
		With Parameter	Without Parameter	With Parameter	Without Parameter
7	MEPDG truck volume growth rate (percent)**	N/A	N/A	N/A	N/A
8	MEPDG truck volume growth function**	N/A	N/A	N/A	N/A
9	MEPDG vehicle class volume distribution*	707	140	N/A	N/A
10	MEPDG number of axles per truck*	438	409	N/A	N/A
11	MEPDG monthly adjustment factors*	606	241	N/A	N/A
12	Monthly NALS or axle weight distributions*	290	557	10 percent	90 percent
13	Annual axle weight distributions**	724	123	27 percent	73 percent
14	Traffic loading data indicator	N/A	N/A	N/A	N/A

*Further summarization of available LTPP traffic data is required to compute this parameter.
**New proposed parameter.
N/A = not applicable: for MEPDG parameters, only one set of representative values is needed instead of values reported by year.

Addressing Missing Core Traffic Parameters

Table 14 indicated several LTPP traffic sites are missing core traffic parameters identified in this study. Some parameters are not reported in the LTPP database, and others have missing values for some years. To ensure the maximum number of LTPP sites are available for pavement analyses, the research team recommends estimating parameters for missing years using data from available years or by assigning default values. The research team recommends including these estimated parameters and defaults in the LTPP database on an LTPP site ID level to facilitate traffic data extraction queries. For parameters currently not included in the LTPP database, the research team recommends developing new CPTs.

Use of Traffic Estimates for Years without Traffic Data

For most LTPP traffic sites, core traffic parameters are available only for selected years of pavement service life and do not cover all years from site construction to the end of site participation in the LTPP experiment. These parameters were developed for years when data were collected or when the State/Provincial highway agencies reported their estimates. Most analyses of long-term pavement performance require traffic inputs for each year in pavement service life. One of the gaps identified through the data availability assessment was a lack of information or tools available for analysts to estimate core traffic parameters for the years prior to each site's incorporation into the LTPP experiment.

Traffic Data–Usability Indices

Although a considerable amount of axle loading data were found in LTPP database tables, there are concerns with WIM data quality for LTPP sites not equipped with Type I WIM sensors (most LTPP WIM sites) and appropriate use of parameters computed based on WIM data. Specific concerns include parameters computed based on data collected using WIM equipment that was out of calibration or by WIM equipment with piezo-ceramic or piezo-polymer sensors prone to calibration drift over time and additional errors due to temperature change sensitivity. Only 178 of 847 identified WIM sites have sensors satisfying ASTM E1318-09 accuracy requirements for Type I WIM systems, and even these systems need periodic calibration to ensure accurate data collection. To ensure appropriate use of WIM-based parameters, all available annual and monthly axle loading distributions should be assessed for data accuracy (where supporting measurement accuracy and sample size information is available) or data rationality (where supporting measurement accuracy information is not available). Based on the results of this assessment, data–usability indices should be assigned to all available axle loading distributions to provide guidance to pavement analysts on applicable data use.

Analysis-Ready Traffic Parameters for Direct Input to AASHTOWare Pavement ME Design Software

Another major limitation found by the research team through the review of the available LTPP traffic parameters is a lack of analysis-ready traffic parameters that can be used as a direct input into AASHTOWare Pavement ME Design software. Most input requirements for AASHTOWare Pavement ME Design software were developed after the LTPP traffic database and data-processing tools were designed. As a result, many of traffic parameters currently included in the TRF_MEPDG series of tables require further summarization and analysis to be used as AASHTOWare Pavement ME Design software inputs.

AASHTOWare Pavement ME Design software is the primary tool for conducting MEPDG analyses using LTPP data. Therefore, development of analysis-ready traffic parameters for direct input into AASHTOWare Pavement ME Design software is recommended by the research team as a high priority for the LTPP program. Table 15 summarizes MEPDG inputs that can be developed using currently available traffic data.

Table 15. MEPDG traffic input parameters supported by LTPP traffic data.

MEPDG Input Parameter	Parameter Description	LTPP Data Source
ALDF	One representative NALS for a typical day for each calendar month (January to December) for a base design/analysis year to be provided for each vehicle class (FHWA Classes 4–13), axle group type (i.e., single, tandem, tridem, quad), and month of a calendar year. NALS represent the axle load distribution with percentage of loads reported by load bins. Due to the large size of this input parameter table, MEPDG software accepts uploads of specially formatted input files.	Information to compute this parameter is available in the LTPP database in daily, monthly, and annual axle load distributions for each year with data but is not readily applicable as an AASHTOWare Pavement ME Design software input. One representative distribution should be provided for each LTPP site. For LTPP sites where computation of individual monthly NALS is not feasible, the same values should be provided for each month of a calendar year.
Vehicle class volume distribution	One representative normalized distribution of vehicles in FHWA Classes 4–13 is used to represent an average vehicle class distribution for the base design/analysis year. The sum for all truck classes is 100.	Information to compute this parameter is available in the LTPP database in annual distributions for each year with data but is not readily applicable as an AASHTOWare Pavement ME Design software input. One representative distribution should be provided for each LTPP site.
Monthly adjustment factors	One representative set of 12 monthly coefficients is provided for each vehicle in FHWA Classes 4–13 to represent differences in truck volumes between different months for the base design/analysis year. The sum for all months for one truck class is 12.	Information to compute this parameter is available in the LTPP database in monthly factors for each year with data but is not readily applicable as an AASHTOWare Pavement ME Design software input. One representative set of factors should be provided for each LTPP site.
Hourly distribution factors	One representative set of 24 hourly factors showing the percentage of total truck traffic for each hour. The sum for all hours is equal to 100. Values are the same for all truck classes and only apply to truck volume. This input parameter only applies to PCC pavements.	Information to compute this parameter is available in the LTPP database for each year with monitoring data but is not readily applicable as an AASHTOWare Pavement ME Design software input. One representative set of factors should be provided for each LTPP site.

MEPDG Input Parameter	Parameter Description	LTPP Data Source
Number of axles per truck	One representative set of values showing the number of axles per truck class and (FHWA Classes 4–13) provides the average number of single, tandem, tridem, and quad axles for each truck class (FHWA Classes 4–13).	Information to compute this parameter is available in the LTPP database but is not readily applicable as AASHTOWare Pavement ME Design software input. One representative set of factors should be provided for each LTPP site.
Base year (first year) AADTT (LTPP lane)	One value representing the average annual daily volume of vehicles in FHWA Classes 4–13 for the base design/analysis year. Use this value in the MEPDG in combination with the following MEPDG parameters: percent trucks in design direction is 100 percent, and percent trucks in design lane is 100 percent.	Information to compute this parameter is available in the LTPP database for most years for most LTPP sites. Additional effort is required from an analyst to determine if available AADTT values accurately represent desired base year conditions. If the base year is not in the LTPP database, an analyst must "backcast" that year's AADTT from available data.
Axle spacing for tandem, tridem, and quad axles	Average representative axle spacing in inches for tandem, tridem, and quad axles.	This parameter is not available in the LTPP database but can be computed from WIM IVR files.
Average wheelbase length and percentage of trucks with wheelbases that fall in short, medium, and long categories	Average wheelbase length and the corresponding percentages of trucks with wheelbases that fall in the following categories: short (≤12 ft), medium (>12 ft and ≤15 ft), and long (>15 ft and ≤20 ft). For multiunit and combination trucks, only the wheelbase of the truck power-unit (i.e., first unit) is considered. Use for top–down JPCP cracking model only. Current MEPDG model uses values computed for vehicles in FHWA Classes 8–13 only.	This parameter is not available in the LTPP database but can be computed from WIM IVR files.

Traffic Parameters Beneficial for LTPP Analyses but Not Included in the LTPP Database

Table 16 lists traffic parameters identified though the LTPP user needs assessment that are not currently available in the LTPP database. These parameters serve many of the LTPP strategic analysis objectives identified in table 16. Additionally, table 16 includes a column identifying if the parameter is considered by LTPP users to be core and likely to have high influence on pavement analysis outcomes.

The research team recommends that the parameters listed in table 16 be made available, to the extent possible, in the LTPP database. Availability of these parameters will enhance LTPP traffic data usability. As a minimum, the research team recommends including in the LTPP database new traffic parameters, identified in table 16, as core traffic parameters for all LTPP sites that have sufficient nontraffic data for use in future pavement performance studies.

Table 16. Traffic parameters not included in the LTPP database but used for pavement applications.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
MEPDG base (first) year AADTT LTPP lane	AADTT for the first full year the pavement was first open to traffic and for each year where a major structural pavement rehabilitation event took place. This value can be either estimated (i.e., backcasted from later data) or computed based on available traffic monitoring data. This is a major traffic input required by AASHTOWare Pavement ME Design software. Truck volumes inside AASHTOWare Pavement ME Design software cannot be estimated without this value.	Use in all LTPP pavement performance analyses using the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models. Use in all LTPP analyses requiring a time history of truck volumes or CTV values. When a base year AADTT value for the LTPP lane is used in AASHTOWare Pavement ME Design software, the percent trucks in the direction of travel variable and the percent trucks in the design lane values should be set to 100 percent.	1, 5, 6, 7, 8	Yes	LTPP data and supplemental sources (e.g., HPMS) are available to help compute this parameter. Analytical effort is required to review available annual AADTT values and compute base year values for each LTPP site.

MEPDG vehicle class growth function	Either a linear or compound growth curve that best describes changes in truck volume over the pavement's service life from the first year the pavement was open to traffic to the end of the experiment or to the last year with data (if still in the experiment) and, where applicable, from each year where major structural pavement rehabilitation took place to the end of that experiment or to the last year with data (if still in the experiment). This is a major traffic input required by AASHTOWare Pavement ME Design software. Truck volumes inside AASHTOWare Pavement ME Design software cannot be estimated without this function. This parameter is also used to estimate CTV.	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models. Use in all LTPP analyses requiring estimates of truck volumes by year or CTV over an analysis period.	1, 5, 6, 7, 8	Yes	LTPP data and supplemental sources (e.g., HPMS) are available to compute this parameter. Analytical effort is required to develop the appropriate growth trend for each LTPP site.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
MEPDG vehicle class growth rate	The annual growth rate (percent) for each truck class (FHWA Classes 4–13) from the year pavement was first open to traffic to the end of the experiment or to the last year with data (if still in the experiment) and, where applicable, from each year where major structural pavement rehabilitation took place to the end of that experiment or to the last year with data (if still in the experiment). This is a major traffic input required by AASHTOWare Pavement ME Design software. Truck volumes inside AASHTOWare Pavement ME Design software cannot be estimated without this function.	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models. Use in all LTPP analyses requiring estimates of truck volumes by year or CTVs over an analysis period.	1, 5, 6, 7, 8	Yes	LTPP data and supplemental sources (e.g., HPMS) are available to compute this parameter. Analytical effort is required to develop the appropriate growth trend for each LTPP site.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
MEPDG vehicle class volume distribution	One normalized distribution of vehicles in FHWA Classes 4–13 is used to represent average vehicle class distribution for the base design/analysis year. The sum for all truck classes is 100. This is a major traffic input required by AASHTOWare Pavement ME Design software. Truck volumes and axle loads associated with individual vehicle classes inside AASHTOWare Pavement ME Design software cannot be estimated without this value.	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models. Use in LTPP analyses where truck type and configuration effect pavement response and performance.	1, 5, 6, 7, 8	Yes	Annual values are available for some years in the TRF_MEPDG_VEH_ CLASS_DIST table. Analytical effort is required to review available annual values and compute one representative distribution for each LTPP site.

MEPDG ALDF	One representative normalized distribution (i.e., axle load spectrum) is provided for each vehicle class (FHWA Classes 4–13), axle group type (i.e., single, tandem, tridem, quad), and each calendar month (January to December) to represent loads for a typical day for each calendar month for a base design/analysis year for each LTPP site. Due to the large size, the primary method of uploading this input parameter into AASHTOWare Pavement ME Design software is by a specially formatted input file. This is a major traffic input required by AASHTOWare Pavement ME Design software. Truck loads associated with individual vehicle classes inside	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models. Use to compute ESAL and other summary loading statistics. Use to assess how heavy truck loads are for a given LTPP sites. Use for load-related pavement response and performance analysis.	1, 5, 6, 7, 8	Yes	Annual values are available in the TRF_MEPDG_AX_DIST_ANL table, and monthly DOW summaries are available in the MM_AX table to compute representative values for the AASHTOWare Pavement ME Design software input. Analytical effort is required to review available annual and, where available, monthly values and compute base year values for each LTPP site. Significant effort is needed to identify and remove data collected by low accuracy or uncalibrated WIM systems from the summarization effort. Default values are assigned to sites with insufficient or poor site-specific WIM data.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
	AASHTOWare Pavement ME Design software cannot be estimated without this value.				
MEPDG number of axles per truck	One set of representative values describing number of axles per truck is used to estimate the number of axle loads for each of the 10 vehicle classes (FHWA Classes 4–13) for each LTPP site. This is a major traffic input required by AASHTOWare Pavement ME Design software. Number of axle loads associated with individual vehicle classes cannot be estimated without this value inside AASHTOWare Pavement ME Design software.	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models.	1, 5, 6, 7, 8	Yes	Annual values are available in the TRF_MEPDG_AX_PER_ TRUCK table to compute representative values for the AASHTOWare Pavement ME Design software input. Also, these parameters can be computed from site-specific measured total truck and total axle count data or assigned using LTPP MEPDG default values.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
MEPDG monthly adjustment factors	One set of representative monthly truck volume adjustment factors is provided for each vehicle class (FHWA Classes 4–13) for each LTPP site with sufficient seasonal truck volume data. A default value of "1" for each month is used for sites with insufficient seasonal data.	Use for analyses using MEPDG models and software tools and for analyses for enhancing, developing, and calibrating MEPDG models for LTPP sites with data supporting analysis of seasonal changes.	1, 3, 5, 6, 7, 8	No	Similar parameters are provided in the TRF_MEPDG_MONTH_ ADJ_FACTR table by year. Further summarization and analysis is required to compute one representative distribution for each LTPP site.
MEPDG hourly distribution factors	One representative set of 24 hourly factors showing the percentage of total truck traffic (FHWA Classes 4–13 combined) occurring in each hour. The sum for all hours is equal to 100. This distribution is used to prorate truck volumes for hours when concrete slab curling or warping is observed.	Use for analyses using MEPDG models and software tools and for analyses for enhancing, developing, and calibrating MEPDG models for LTPP sites with JPCP.	1, 5, 6, 7, 8	No	Information to compute this parameter is available in the TRF_MEPDG_HOURLY _DIST table for each year with monitored truck volume. Further summarization is required to compute one representative set of factors for each LTPP site.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
Axle spacing for tandem, tridem, and quad axles	One representative average axle spacing in inches is input for tandem, tridem, and quad axles. This statistic is used to calculate pavement responses in mechanistic models.	Use for mechanistic-based pavement response and performance modeling, including the MEPDG method.	1, 5, 6, 7, 8	No	This parameter is not available in the LTPP database but can be computed from WIM IVR files stored in the LTPP database.
Average wheelbase and corresponding percentage of vehicles in FHWA Classes 8–13 with a tractor-semitrailer power-unit in short, medium, and long wheelbase categories, plus additional percentage of other trucks with axle spacing in these ranges	Average wheelbase and corresponding percentages of trucks with a tractor-semitrailer power-unit that falls in the following categories (determined based on concrete slab length): short (≤12 ft), medium (>12 ft and ≤15 ft), and long (>15 ft and ≤20 ft) axles. Also included is the percentage of other trucks with axle spacing in these ranges, excluding axle spacing within multi-axle groups.	Use for mechanistic-based pavement response and performance modeling of JPCP, including the MEPDG method.	1, 8	No	Significant data processing effort is needed to extract and summarize data from WIM IVR files stored in the LTPP database.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
Operational speed	Posted speed limit in mph or average speed of heavier trucks (FHWA Classes 6–13) through the project limits.	Use for mechanistic-based pavement response and performance modeling of AC pavements, including the MEPDG method.	1, 2, 5, 6, 7, 8	No	This information can be obtained from IVR records submitted using the TMG IVR record format or from LTPP Inventory Sheets.
MEPDG base (first) year two-way AADT (AASHTOWare Pavement ME Design software base year two-way AADT)	Two-way AADT for the first full year pavement was open to traffic and for each year where major structural pavement rehabilitation took place. This value can either be estimated (i.e., backcasted from later data) or computed based on available traffic monitoring data. An alternative parameter is MEPDG base (first) year AADTT for the LTPP lane.	Use in combination with the percentage of trucks to estimate AADTT. When available, AADTT parameter is preferred over AADT for LTPP studies.	1, 8	No	This parameter is used only when LTPP lane AADTT values are not available. Additional analytical effort is required to determine if available AADT values accurately represent, or can be used to characterize, base year conditions.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
Percent of trucks in AADT volume	Average percent of trucks in the two-way AADT estimate.	Use in combination with the two-way AADT parameter to estimate AADTT. When available, AADTT parameter is preferred over AADT and percent trucks.	1, 8	No	This parameter is used only when LTPP lane AADTT values are not available.
Percent of trucks in design direction	Average percent of trucks in the design direction (i.e., direction of travel of the LTPP lane) for the base design/analysis year.	Use in combination with the two-way AADT parameter to estimate LTPP lane AADTT inside AASHTOWare Pavement ME Design software.	1, 8	No	This parameter is used only when LTPP lane AADTT values are not available. Raw data may exist to compute this parameter.
Percent of trucks in design lane	The percentage of vehicles in the two-way AADT estimate that are trucks (i.e., FHWA Classes 4–13).	Use in combination with the two-way AADT, to compute AADTT for the LTPP lane. Use in high-level analyses to identify LTPP sites with similar levels of truck usage.	1, 5, 6, 8	No	This parameter is needed primarily when LTPP lane AADTT values are not available. Information to compute this parameter is available in the YY_CT table.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
MEPDG mean and standard deviation of wheel location	Mean distance and its standard deviation in inches from the outer edge of the wheel to the pavement marking. These are AASHTOWare Pavement ME Design software inputs.	Use in combination with axle width, axle spacing, and wheelbase parameters to model location of the load on the pavement. Use for mechanistic pavement response and performance analysis and modeling.	1, 5, 7, 8	No	This information is not collected by the LTPP program. It can be collected using specially configured quartz-piezo WIM sensor arrays or from video samples.
Dual tire spacing	This is an AASHTOWare Pavement ME Design software input.	Use in mechanistic pavement response and performance analysis and modeling to determine the location of the load on the pavement.	1, 5, 7, 8	No	This information is not collected by the LTPP program. It can be collected using specially configured quartz-piezo WIM sensor arrays or from video samples.
Tire pressure	One value representing hot tire inflation pressure. This is an AASHTOWare Pavement ME Design software input.	Use to compute the pavement/tire interaction area for mechanistic pavement response and performance analysis.	1, 5, 7, 8	No	This information is not collected by the LTPP program.
Average axle width	Distance in feet between the two outside edges of an axle. Use for rigid pavement analysis only. This is an AASHTOWare Pavement ME Design software input.	Use in mechanistic pavement response and performance analysis and modeling to determine the location of the load on the pavement.	1, 5, 7, 8	No	This information is not collected by the LTPP program. It can be collected using staggered WIM sensor arrays or from video samples or truck fleet surveys.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
Annual GESAL	Based on the measured or estimated axle loading data in the LTPP lane for FHWA Classes 4–13 combined. This value is computed for each year the pavement site was in service up to the end of the site's participation in the LTPP experiment.	Use in LTPP empirical analyses where a single-value traffic loading statistic is desired, and also for quantifying and comparing traffic loads between sites.	1, 5, 6, 7	Yes	Computed using available axle load spectra, AADTT in the test lane, and truck growth trends.
ATL	Based on measured or estimated GVW data in the LTPP Lane for FHWA Classes 4–13 combined. This value is computed for each year the pavement site was in service up to the end of the site's participation in the LTPP experiment.	Use for LTPP empirical analyses where a single-value traffic loading statistic is desired and for quantifying and comparing traffic loads between sites.	1, 5, 6, 7	Yes	Computed using available GVW data and truck growth trends.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
Monthly NALS	Normalized monthly axle load distribution and total number of axles for each vehicle class (FHWA Classes 4–13) and each axle type (i.e., single, tandem, tridem, and quad) for LTPP sites with WIM systems performing within ASTM E1318-09 accuracy requirements for Type I WIM sensors. Provided for each month with data satisfying ASTM E1318-09 accuracy requirements for Type I WIM sensors.	Use for computing traffic loading defaults and mechanistic–empirical studies of load-related pavement distresses when seasonal changes in pavement response and performance are considered.	1, 5, 6, 8	Yes	Similar parameters are provided in the MM_AX table by DOW but require further summarization to obtain normalized monthly axle load distributions for each month.
Traffic data–usability indicators*	An ordinal scale indicator summarizing the quantity, quality, and recommended applicability of WIM data and computed traffic load estimates.	Use as an aid to help users make informed decisions about traffic data or parameter applicability for specific, detailed analyses.	1, 5, 6, 7, 8	Yes	These indicators identify LTPP sites with loading data acceptable as Level 1 (i.e., site-specific) MEPDG inputs and sites that may be better served by default values.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
AADTT by vehicle class	AADTT by vehicle class for FHWA Classes 4–13. Based on measured or estimated data for each year a pavement site was in service up to the end of the site's participation in the LTPP experiment.	Use in LTPP empirical analyses where truck volume for specific truck classes is important, analyses where truck volume needs to be aggregated to simpler truck classes, and analyses where truck volume is used as a secondary parameter.	1, 5, 6	No	LTPP data are available for parameter computation.
Percent trucks in LTPP Lane	Percentage of vehicles in the LTPP lane that are trucks (FHWA Classes 4–13).	Use in combination with AADT to compute AADTT for the LTPP lane. Used in high-level analyses to identify LTPP sites with similar levels of truck usage.	1, 5, 6, 8	No	Information to compute this parameter is available in LTAS table the YY_CT.
Cumulative truck traffic volume	Traffic summary statistic used to measure total road use by vehicles in FHWA Classes 4–13, from the day the road opened to traffic to the end of service life or the end of the site's participation in the LTPP experiment. Should be accumulated and reported annually.	Use in empirical analyses of effects of traffic on nonstructural pavement distresses. Use as a supplemental input in analyses of effects of traffic on structural pavement response and performance.	1, 5, 6	No	Computed using available truck volume data and truck growth trends for vehicles in FHWA Classes 4–13.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective	Core Parameter Identifier	Comment
Cumulative volume of FHWA Class 9 trucks	Traffic summary statistic used to measure road use by FHWA Class 9 vehicles from the day the road opened to traffic to the end of service life or the end the site's participation in the LTPP experiment. Should be accumulated and reported annually.	Use as a heavy truck traffic indicator in empirical analyses of pavement performance for LTPP sites with dominant FHWA Class 9 trucks.	1, 5, 6	No	Computed using available truck volume and truck growth trends for vehicles in FHWA Class 9.
Cumulative volume of heavy trucks (FHWA Classes 4 and 6–13)	Traffic summary statistic used to measure road use by vehicles in FHWA Classes 4 and 6–13 from the day the road opened to traffic to the end of service life or the end of the site's participation in the LTPP experiment. Should be accumulated and reported annually.	Can be used as an input in empirical analyses of pavement performance when traffic loading data are not available.	1, 5, 6	No	Computed using truck volume data and truck growth trends for vehicles in FHWA Classes 4 and 6–13.

*Metadata
DOW = day of week.

CHAPTER 4. ALTERNATIVE TRAFFIC DATA SOURCES

PURPOSE OF ALTERNATIVE DATA SOURCES

In this study, the research team evaluated the availability and applicability of alternative traffic data sources to address the limitations in LTPP traffic data quality or availability. This chapter includes assessment of available alternative traffic data sources and recommendations for using data from non-LTPP sources.

Because pavement performance is site-specific, using available, valid, site-specific data is the analysts' first choice for creating summary traffic statistics. Unfortunately, there are times when no data are present in the LTPP database for a specific LTPP site or data present are unreliable and need replacing by other data sources. This chapter discusses the availability of other data sources that can be used to help supply data for key traffic data items or insight that can be used to identify the best defaults to use when site-specific data are not available. Basic traffic data items for which alternative sources of data are explored in this chapter include the following:

- AADT.
- AADTT.
- Truck volumes by FHWA vehicle classification.
- Hourly truck-volume distributions.
- Truck-weight (i.e., axle load) distributions.

Each of these basic traffic data items are discussed in the following sections. In some cases, one dataset may serve as an alternative data source for more than one of these basic traffic data items. Key aspects of each of these sources are discussed the first time they are recommended. This discussion is referenced, but not repeated, each time that source is considered as an alternative data source.

AADT

AADT is the most commonly used measure of traffic on a roadway. It is not especially significant for most pavement analyses, but engineers often use it to get a quick idea of the size or importance of the roadway with which they are working. AADT is also used for many traditional pavement analyses as a way of quickly computing approximate ESAL loading values. In these cases, AADT is multiplied by the percentage of trucks and then the State/Province's ESAL/truck statistic to estimate daily pavement loads. Having the AADT statistic in the database is of low to moderate importance.

Most LTPP sites have at least a few years of AADT statistics either supplied by the State/Provincial highway agency or computed from traffic monitoring data collected specifically for the LTPP program. These values can be compared against each other as an initial QA test.

Best Alternative Data Source

If additional AADT values are needed, such as to fill gaps in temporal data coverage, the best source for obtaining these data is the HPMS. The HPMS dataset is submitted annually to FHWA by each State for computing statewide vehicle-miles traveled, which is a statistic used in the allocation of the Federal Highway Trust Fund. Because of their importance, data used to compute AADT in the HPMS undergo a robust QA process examining the methodology in which AADT values are computed and ensures unusual volume trends are supported by valid data.

Unfortunately, obtaining annual HPMS data files takes considerable effort and coordination, and identifying the appropriate HPMS traffic section from which to obtain AADT values is also complex.

The process developed under this study to link LTPP test sites to HPMS sections uses geographic information system (GIS) functionality, which matches the latitude and longitude of the LTPP test site to the GIS road network for HPMS.(18)

This process is as follows:

1. The LTPP test location was linked to the HPMS segment, using the ArcGIS "Near" command to calculate which specific segment of the HPMS national coverage was associated with a specific LTPP site (represented as a point). The Near command gives the distance and the ArcGIS internal unique identifier (Object ID) to the nearest feature of interest (i.e., roadway segment). The search can be improved by also including the Route Number obtained from the LTPP INV_ID table.
2. The table of the HPMS dataset was then "Joined" to the LTPP points using this common unique identifier (Object ID).
3. LTPP sites within 50 ft of an HPMS line segment for the correct Route ID were assigned to that segment.
4. Beginning and ending mileposts for that HPMS segment were then determined from the HPMS database along with the route name, as these end points identify the HPMS segment and are used to extract data from the HPMS dataset and identify the same HPMS road segment from earlier years of HPMS data.
5. If no segment was identified, the dataset was queried for sites farther than 50 ft from the closest HPMS line segment because these LTPP sites do not directly associate with the HPMS GIS "road geometry" due to differences in the GIS line work for HPMS and the latitude/longitude values associated with the LTPP test section.

One issue with the above process is that the current HPMS GIS shape file is nondirectional. Thus, when a roadway has separate alignments for opposite directions of travel, the HPMS shape file only shows segments in one direction. In many cases, the LTPP site is located on the alignment not used in the HPMS shape file (i.e., in the opposite direction of travel).

The initial automated process failed to locate 330 sites because the LTPP location point was farther than 50 ft from the HPMS segment GIS line. These 330 sites were visually inspected on a GIS map, as illustrated in figure 4, and assigned to specific HPMS roadway sections. Visual inspection allows for easy detection of when the HPMS line segment follows one side of a divided roadway, but the LTPP study site is on the other side of that divided roadway.

Screen capture performed by University of Washington from ArcGIS software produced by ESRI and used under license. Photomap layer source credited within that product to: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopt, and the GIS User Community. Additional HPMS and LTPP layer data obtained from FHWA and incorporated using ArcGIS.

Figure 4. Photo. Example of an LTPP test section located on a divided roadway where that side of the roadway is not used in the HPMS shape file.

LTPP sites were flagged if they appeared not to be associated with an HPMS segment. Nine sites were flagged. These all had LTPP identifiers of “0800” or “A800” and were not found in the InfoPave database. These nine sites were SPS-8 LTPP environmental test sections not subject to traffic loads that only experience deterioration due to environmental effects. Therefore, they were not likely to be located on roads included in the HPMS road network. An example of one of these SPS-8 locations is shown in figure 5.

Screen capture performed by University of Washington from ArcGIS software produced by ESRI and used under license. Photomap layer source credited within that product to: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopt, and the GIS User Community. Additional HPMS and LTPP layer data obtained from FHWA and incorporated using ArcGIS.

Figure 5. Photo. Example of an SPS-8 site location relative to the nearest HPMS roadway segment.

Sites were also flagged if visual inspection showed the LTPP site was associated with an incorrect HPMS segment due to the LTPP point feature being closer to an HPMS segment on which it is not located. This was done by cross-checking the route name with the InfoPave database. Seven sites fell into this category. These seven sites were joined by their unique identifier to the correct HPMS segment, as determined through visual inspection.

Once these steps were performed, it was possible to extract AADT values from the HPMS database for all sites. If additional years of HPMS data were needed to examine how the State reported changes in traffic volume levels over time on a given HPMS segment, additional years of HPMS data need to be obtained from FHWA HPMS databases created for these years. These data are available dating back to the 1970s. Data were retrieved from those additional HPMS files based on the HPMS segment end points and route name taken from the GIS database.

Other Options

The other option for obtaining information on AADT is to contact each State agency and request access to their archived AADT data. Although this is possible, it is time-consuming and places considerable burden on State highway agencies. In addition, many States maintain only a limited number of years of traffic data online. Obtaining AADT estimates from State agencies for years prior to the 1990s could easily entail retrieving and transcribing data from hardcopies of old reports. This option is not recommended.

AADTT

AADTT is used to categorize the level of truck traffic on a roadway, which is one way of quickly determining the type of pavement needed for that roadway. AADTT is also used for many traditional pavement analyses as a way to quickly compute approximate ESAL loading values. AADTT is a key truck volume input used by AASHTOWare Pavement ME Design software to estimate the number of axle loads. Due to its multiple uses, AADTT is of high importance to the LTPP program. Fortunately, the majority of LTPP sites have multiple years of AADTT values from traffic monitoring performed specifically for the LTPP program or supplied by State highway agencies. Only about 3 percent of site-years of AADTT values are missing from the LTPP database for those years during which the LTPP sites are part of the LTPP experiment.

Best Alternative Data Source

If a review of AADTT data in the LTPP database indicates that the data present are of questionable accuracy, or if additional data are required to determine AADTT for missing years for some sites at LTPP test sections, the best data source for this statistic is the HPMS dataset. The HPMS dataset includes both AADT and a percent truck variable. When combined, these two variables compute AADTT for two-way traffic.

By following the steps described in the AADT section for linking LTPP test site locations to specific HPMS roadway sections, and by retrieving annual HPMS samples from FHWA, it is possible to compute AADTT for any year required. To compute the AADTT value for the LTPP lane, the roadway AADTT needs to be adjusted based on direction and lane distribution of truck traffic.

Other Options

The other option for obtaining information on AADTT is to contact each State agency and request access to their archived AADTT data. Unlike AADT, the majority of AADTT values are present in the LTPP database. Consequently, it may be easier and faster to use existing data to estimate most of the missing AADTT values.

Roughly 85 LTPP traffic sites are missing AADTT values, but only 20 of those sites are missing more than 3 yr of data, and only 12 sites are missing more than 5 yr. Several of the sites with multiple missing years of data are from the same State. Many States have no LTPP sites missing years of AADTT data, and those States would not need to be contacted. This would limit the time required to obtain data in this manner.

It may be easier (for those few sites requiring data from outside of the LTPP database to estimate missing AADTT data) to contact State highway agencies instead of obtaining and working through HPMS datasets. However, if HPMS datasets were already downloaded and processed, the HPMS process is the best approach, as the difficult and time-consuming tasks would already be completed.

TRUCK VOLUMES BY FHWA VEHICLE CLASSIFICATION

Annual truck volumes by vehicle classification are used with axle weight distribution factors to compute pavement loads for traffic design. Most LTPP sites have some vehicle classification data collected as part of the LTPP traffic data collection effort. These data are the best source of truck volume distributions. However, if QA and data consistency reviews indicate that LTPP data are of suspect quality, it will be necessary to examine alternative data sources to confirm the applicability of those data and/or to develop reliable default values.

Annual truck volumes by vehicle classification data are needed for computing a number of different truck volume parameters, including average annual daily truck volume, total truck volume by class for each year for the life of a pavement, monthly truck volume needed to measure seasonal traffic loads, and time of day (hourly) distributions of truck volume.

Best Alternative Data Source

There are two important alternative sources of data describing truck volume by vehicle classification on specific roadway sections. Both alternative datasets are necessary if missing data are estimated because both datasets have different characteristics meeting different LTPP needs.

The HPMS is the best available alternative data source for examining the total number of trucks using roadways included in the LTPP program. However, the HPMS does not include sufficient detail on travel by time of day or on the distribution of travel between different classes of trucks. For that information, the FHWA Travel Monitoring Analysis System (TMAS) database is the best alternative data source.

HPMS Applicability

The HPMS dataset includes the State highway agency’s best estimate of total traffic volume (AADT) and the percentage of that traffic consisting of trucks on the road segment containing the LTPP test section. (Estimates of truck use are of limited accuracy prior to the 1990s, as many States did relatively little truck counting prior to that time; HPMS truck volume estimates become increasingly more reliable around 2000.)

The current HPMS dataset structure also divides truck percentage into single-unit and combination trucks. Having estimates of both single-unit and combination trucks gives further insight into the expected mix of trucks, as measured by the State highway agency. The HPMS does not provide truck volume for each FHWA vehicle class, nor does it describe the time of day (hourly) distribution of truck volumes.

TMAS Applicability

To gain better insight into the distribution of trucks between different FHWA truck vehicle classes, it is necessary to look at more detailed data than those submitted to the HPMS. The best national data source for providing additional detailed truck volume insight is the TMAS. FHWA encourages States to routinely upload permanent count data for volume, vehicle classification, and truck weight to FHWA's TMAS database, which provides a mechanism for QA testing as well as analyzing and sharing data.

From TMAS, it is relatively easy to obtain vehicle class distributions for all sites submitted by a State. These distributions can then be analyzed for statewide trends in classification that can be used to evaluate the reasonableness of data submitted to the LTPP database. For example, TMAS data can be used to determine whether major changes in classification distributions are occurring at other sites in the State or if such changes are observed only at the LTPP site, which would likely be caused by sensor or software issues at that test site.

If necessary, TMAS data can also be used to develop default vehicle classifications. Although TMAS is not a preferred source of data for these defaults, it may be needed for States that have submitted relatively little volume by classification data as part of their routine monitoring program. TMAS can also examine classification data and patterns across State lines.

MONTHLY TRUCK VOLUMES BY FHWA VEHICLE CLASS

Monthly truck volumes by vehicle classification are used with axle weight distributions to compute differences in seasonal pavement loading for pavement performance analysis and design. Given its narrow analysis application, this parameter is moderately important.

As part of the LTPP program, each State placed a permanent, continuously operating vehicle classifier near the LTPP test site. Data from these classifiers can be used to directly measure monthly truck volumes by class.

Where continuous data are not available, it is necessary to compute monthly adjustment factors for each class of trucks and multiply those factors by the AADTT values available for each year. The best source of monthly adjustment factors is from a site-specific counter at the LTPP site. It is possible to use 1 yr (or more) of data to compute a constant monthly adjustment factor, which can be applied against AADTT when actual monthly truck volume data are not available. This process is used within AASHTOWare Pavement ME Design software to estimate monthly truck volume by vehicle classification. Where site-specific data are not available in the LTPP database (the DD_CL_CT table), the recommended approach is to use data from other LTPP sites within that State—or data from a nearby counter on that same road but in a different State—to determine the likely monthly truck volume pattern by vehicle class. If a nearby source of monthly truck volume data is not available and other LTPP data for that State and region exhibit strong truck travel patterns, an average statewide monthly pattern is computed and made available for use at the site without site-specific data with appropriate metadata describing the limitations of those adjustments.

Best Alternative Data Source

The only national data source that can support the computation of monthly truck volume factors is FHWA's TMAS. TMAS has a reporting function that produces truck volume reports by month and vehicle class, from which monthly truck volume factors can be computed. Because TMAS contains multiple years of data, it is also possible to use TMAS to analyze changes in monthly factors over time, and thus compute composite multiyear monthly factors (i.e., one set of monthly adjustment factors that can be entered into AASHTOWare Pavement ME Design software).

The difficulties of using TMAS are gaining access to the system and determining which TMAS reporting site(s) should be associated with a given LTPP test site. The latter difficulty is a function of where geographically TMAS data are available versus where the LTPP site needing the application of monthly adjustment factors is located. TMAS data may be available from a data collection point on the same road that is too far away to be considered a site-specific or site-related to the LTPP data collection site (i.e., located on the same road but away from the test site). Where such a site-related location is not present in TMAS, data from multiple TMAS sites can be averaged and used to estimate monthly patterns for the LTPP site.

A significant part of the work of developing monthly factors is correctly grouping sites that can be averaged to create a monthly pattern to apply at an LTPP site not directly associated to the sites in that group (i.e., the LTPP site does not carry the same traffic stream). The best group of TMAS sites predicting monthly truck volume patterns is likely to be created differently for different LTPP sites. Groups can be formed using sites from the same route or geographic region, or for sites in the same geographic region but only for the same functional roadway classification. When grouping sites, the research team looked at both the variation in the monthly adjustment factor between sites within a defined group and the ability to affectively assign an LTPP site to that group.

Secondary Data Source

If the number of sites for which TMAS monthly volume data are needed is small, it is worthwhile to contact individual State highway agencies for those sites and ask either their traffic monitoring group or their freight planning group to describe the types of truck patterns using the LTPP route. This information (e.g., agricultural, mineral extraction, or long-haul intercity trucking movement) can be used to design a specific set of TMAS sites that carry similar trucking movements. Monthly truck volume factors for those sites can be averaged to create desired default monthly distribution tables.

HOURLY TRUCK VOLUME DISTRIBUTIONS

The hourly distribution of truck volumes is needed for some concrete pavement analyses investigating the combined effect of truck loads and slab curling or warping due to time-of-day temperature changes. Because most LTPP sites have traffic monitoring data that include truck volumes by vehicle class for at least several years, the best data source for developing an hourly truck volume distribution is the LTPP HH_CL_CT database table.

The HH_CL_CT table can be used to directly compute hourly truck volume patterns. Even when only a few days of truck volume by class data are present, the HH_CL_CT table provides the data needed to compute site-specific, time-of-day (e.g., hourly) truck volume patterns.

Where no data are available for a given LTPP site, the second-best data source is LTPP monitoring data for other LTPP sites within the same State located on the roads serving similar trucking needs as the LTPP site in question.

Best Alternative Data Source

For sites where available LTPP data are not sufficient to compute an average hourly truck distribution, it is possible to obtain similar data from FHWA's TMAS database. TMAS has an existing report function that produces traffic volume by class and by hour statistics.

The only limitation with TMAS hourly distribution data is that they do not apply directly to the LTPP test section. However, TMAS offers an additional set of sites that might contain a counter producing a more accurate time-of-day distribution value than simply using the average of such estimates from the other LTPP test sites.

ANNUAL TRUCK (AXLE) WEIGHT DISTRIBUTIONS

Normalized truck axle weight distribution or NALS are one of the primary loading statistics used for the majority of load-related pavement analyses. Historically, NALS were used to estimate an ESAL-per-truck statistic, which was multiplied by truck volume to estimate total pavement loading. In more modern and sophisticated pavement analyses, truck volumes by vehicle class are multiplied directly by the NALS to estimate the number of axle loads, by load range, applied to a pavement study section.

Best Alternative Data Source

Where site-specific NALS data are not present for a given LTPP test section, either because no WIM data were collected at a test site or because WIM data collected are unreliable, it is necessary to obtain NALS from alternative sources. The best of these alternative sources are SPS TPF-5(004) site-specific data, which are already in the LTPP database, and axle loading default NALS developed based on SPS TPF-5(004) data. The default NALS are summarized in LTPP PLUG report and available for use in the PLUG database.(10)

The only difficulty in using LTPP PLUG data is that a user must still select a specific default NALS to use in an analysis. For example, PLUG defaults are specifically designed to allow a user to select "heavy" NALS distributions if the user knows a site contains heavy vehicle loads or "light" NALS distributions if the user knows a site serves a truck population that carries light cargo (e.g., computer parts) or where a significant percentage of trucks are unloaded and returning to their loading docks.

Similarly, some States have unique loading characteristics for some types of vehicles. This occurs when State regulations encourage the use of specific types of truck configurations to efficiently haul loads that the State legislature has decided are particularly important to the State's economy. In these cases, a pavement analyst would want to select State-specific NALS for those vehicle types. But, to select these State default distributions or compute State-specific distributions not observed at SPS TPF-5(004) sites, data from outside the current LTPP SDR database are needed.

There are two nationally available sources of truck axle weight data that help identify the proper default NALS to select for a given LTPP site or compute new State-specific loading patterns not observed in the SPS TPF-5(004) study. The first source is data submitted to the LTPP program that failed the LTPP QA or data rationality tests. The second source is truck weight data stored in

TMAS. Analysts have reservations about using both data sources. LTPP data that did not pass quality or rationality tests came from poorly calibrated and/or poorly functioning WIM equipment. TMAS axle weight data came from WIM equipment with unknown calibration and are therefore of unknown quality.

First Option: LTPP Data

This is the recommended initial step for obtaining site-specific NALS.

It is possible to extract previously submitted but unused axle weight data from the LTPP LTAS database. Typically, these data would have been identified by LTPP data processing and QC software as levels A through D[(292)] and not released to public or used in computation of traffic loading summary statistics. The data needed are in LTAS YY_AX, MM_AX, and DD_AX tables and can be identified by their record status (A to D) as not having passed all data quality steps. These can be data from the TRF* series of tables that did not pass data rationality checks described in this report. On a case-by-case basis, it is often possible to determine the basic shape of the loading curve from these data. When the problem that kept WIM data at less than record status E is a simple calibration issue, it is possible to use the shape of the NALS curves, even though they are poorly calibrated, to identify the best default load spectra to select. Thus, the actual NALS come from the PLUG database and take advantage of high-quality calibrated WIM data from the SPS TPF-5(004) study, but the NALS selection is aided by the NALS shapes determined using data from the poorly calibrated but site-specific WIM site. Basically, poorly calibrated data can provide a good estimate of the fraction of loaded versus empty trucks within each vehicle class (FHWA Classes 4–13). This allows an analyst to select the appropriate PLUG default.

This process is slow and requires manual review, but it takes advantage of data collected at the LTPP site, provides site-specific insight into the loading patterns at sites for which WIM data were collected, even when data came from poorly calibrated equipment, and significantly improves the accuracy of assigning default loading estimates at each LTPP site.

Second Option: Use of TMAS Data

There are LTPP sites for which no loading data were collected or where WIM equipment operated so poorly due to poor pavement conditions that no usable data exist in the LTPP database. In these cases, the best option for assigning default NALS to an LTPP site is to examine available data for that State and/or roadway (when valid WIM data exist for the same route at a different location).

Some States have insufficient valid WIM data in the LTPP database. In these cases, WIM data from the TMAS database can provide insight into the truck-loading patterns found with that State or geographic region.

Relying on TMAS data is not as good as having site-specific insight because truck-loading conditions can differ substantially from site to site within a State, as trucking characteristics often change from one road to another. For example, one interstate freeway can carry a large amount of long-haul truck traffic, while another interstate can carry almost exclusively local truck traffic. The former has a much heavier weight distribution than the latter. Thus, data from TMAS are helpful, but they are the secondary choice to having site-specific data.

Another major limitation of using TMAS data is that they are stored in a format different from the LTPP or MEPDG formats. Future versions of TMAS will eliminate this problem, but until MEPDG-compatible data become available in TMAS, its usability may be limited.

Third Option: TMAS Subset Data Used in Other Studies

There is a third option, which is a subset of the TMAS option. FHWA previously shared TMAS data with outside researchers who built visualization tools with TMAS WIM data. The research team did not explore the availability of these data summaries.

One potential benefit from analyzing TMAS data is that TMAS may be able to produce new default NALS for use within PLUG. NALS from these sources need to be evaluated using the LTPP NALS rationality procedure described in chapter 8 of this report for the location of loaded and unloaded peaks in NALS. Where these data pass rationality tests and do not fit an existing PLUG loading pattern, they can be added as additional default loading patterns to the PLUG database, which allows them to be selected in conjunction with the first option (LTPP data) (i.e., TMAS data may provide a valid load spectrum not observed in SPS TPF-5(004) data but that appear to match load spectra patterns seen in poorly calibrated LTPP data). This would be particularly useful for vehicle classes other than Class 9 where traffic loading patterns might vary more substantially from one State to another.

MONTHLY TRUCK (AXLE) WEIGHT DISTRIBUTIONS

The options described for the annual NALS are applicable for monthly NALS. Most LTPP test sites do not have WIM data of sufficient quality and quantity to estimate monthly changes in NALS. It is expected that only significant shifts in loads will be captured using non-site-specific or poorly calibrated WIM data. For example, it may be possible to observe shifts in loading patterns due to major seasonal load restrictions, but it is unlikely that more modest shifts in loading patterns can be observed. Consequently, LTPP sites with limited site-specific data that miss axle load distributions for most of the month will be assigned a constant NALS for each month without site-specific data because there is no data source of sufficient quality and quantity to estimate monthly changes for the majority of LTPP test sites.

CHAPTER 5. ANALYSIS-READY TRAFFIC PARAMETERS SELECTED FOR THIS STUDYAND GENERAL APPROACH FOR PARAMETER COMPUTATION AND DELIVERY TO USERS

ANALYSIS-READY TRAFFIC PARAMETERS SELECTED FOR THIS STUDY

At the conclusion of Phase I of this study, a list of analysis-ready traffic parameters was approved by FHWA for development in the subsequent phases. The parameters can be summarized into three categories based on their use in pavement analyses, as follows:

- Parameters supporting analyses using a complete time history of changes in a selected traffic parameter.
- Parameters supporting analyses using a representative or an average value of a selected traffic parameter (i.e., summary statistics).
- Parameters supporting analyses based on the MEPDG method and AASHTOWare Pavement ME Design software (See appendix A of this report for the AASHTOWare Pavement ME Design software graphic user interface (GUI) used to enter traffic inputs).

Table 17 contains a list of analysis-ready traffic parameters approved by FHWA for development in subsequent phases of this project. These parameters are expected to be used by researchers for analyses supporting multiple LTPP strategic data analysis objectives. These parameters represent a subset of parameters recommended earlier in table 16.

Table 17. Analysis-ready traffic parameters approved by FHWA.

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective
MEPDG truck traffic growth function by vehicle class (AASHTOWare Pavement ME Design software input)	Either a linear or compound growth function that best describes changes in truck volume by vehicle class over the pavement's service life from the year the pavement was first opened to traffic to the end of the experiment or to the last year with data (if still in the experiment) or, where applicable, from each year where major structural pavement rehabilitation took place to the end of that experiment or to the last year with data (if still in the experiment).	Use in all LTPP pavement performance analyses based on the MEPDG method and analyses for enhancing, developing, and calibrating MEPDG models. Use in all LTPP analyses requiring estimates of truck volumes by year or CTVs over an analysis period.	1, 5, 6, 7, 8

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective
MEPDG truck traffic growth rate by vehicle class (AASHTOWare Pavement ME Design software input)	Annual growth rate (percent) for each truck class (FHWA Classes 4–13) from the year the pavement was first opened to traffic to the end of the experiment or to the last year with data (if still in the experiment) and, where applicable, from each year where major structural pavement rehabilitation took place to the end of that experiment or to the last year with data (if still in the experiment).	Use in all LTPP pavement performance analyses based on the MEPDG method and for enhancing, developing, and calibrating of MEPDG models. Use in all LTPP analyses requiring estimates of truck volumes by year or CTVs over an analysis period.	1, 5, 6, 7, 8
MEPDG base (first) year AADTT LTPP Lane (AASHTOWare Pavement ME Design software input)	AADTT for the first full year the pavement was open to traffic and for each year where major structural pavement rehabilitation events took place.	Use in all LTPP pavement performance analyses using the MEPDG method and analyses for enhancing, developing, and calibrating MEPDG models. Use in all LTPP analyses requiring time history of truck volumes or CTV values.	1, 5, 6, 7, 8
MEPDG vehicle class volume distribution (AASHTOWare Pavement ME Design software input)	One normalized distribution of vehicles in FHWA Classes 4–13 is used to represent the expected vehicle class distribution for the base design/analysis year. The sum for all truck classes is 100. Data used for computation are screened to remove outliers and discrepancies before computing the representative distribution.	Use in all LTPP pavement performance analyses based on the MEPDG method and analyses for enhancing, developing, and calibrating MEPDG models. Use in LTPP analyses where truck type and configuration effect pavement response and performance.	1, 5, 6, 7, 8

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective
MEPDG ALDF (AASHTOWare Pavement ME Design software input)	One representative normalized axle loading distribution (i.e., axle load spectrum) for each vehicle class (FHWA Classes 4–13), axle group type (i.e., single, tandem, tridem, quad), and calendar month of year (January - December) to represent loads for a typical day of each calendar month for a base design/analysis year for each LTPP site.	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models. Use to compute ESAL and other summary loading statistics. Use to assess how heavy truck loads are for a given LTPP sites. Use for load-related pavement response and performance analysis.	1, 5, 6, 7, 8
MEPDG number of axles per truck (AASHTOWare Pavement ME Design software input)	One set of representative values describing the number of axles (i.e., single, tandem, tridem, quad) per truck for each of the 10 vehicle classes (FHWA Classes 4–13) typical for each LTPP site.	Use in all LTPP pavement performance analyses based on the MEPDG method and in analyses for enhancing, developing, and calibrating MEPDG models.	1, 5, 6, 7, 8
AADTT for each truck class (FHWA Classes and 4–13) for each year	Estimate of vehicle class-specific AADTT for the LTPP test lane for each in-service year, up to the end of a site's participation in the LTPP experiment, with missing years estimated, and any data discrepancies resolved.	Use in LTPP empirical analyses where truck volume for specific truck classes is important, analyses where truck volume needs to be aggregated to simpler truck classes (e.g., single-unit, combination unit, multiunit), and analyses where truck volume is used as a secondary traffic input parameter.	1, 5, 6

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective
AADTT (vehicles in FHWA Classes 4–13 combined), estimated annually	Estimate of AADTT for the LTPP test lane since opening to traffic, reported for each in-service year up to the end of the site's participation in the LTPP experiment.	Use in empirical analyses of effects of traffic on nonstructural pavement distresses. Use as a supplemental input in analyses of effects of traffic on structural pavement response and performance.	1, 5, 6
Annual total truck volume (vehicles in FHWA Classes 4–13 combined), estimated annually	Estimate of total annual truck volume for the LTPP test lane since opening to traffic, reported for each in-service year up to the end of site's participation in the LTPP experiment.	Use in empirical analyses of effects of traffic on nonstructural pavement distresses. Use as a supplemental input in analyses of effects of traffic on structural pavement response and performance.	1, 5, 6
Cumulative volume of heavy trucks (vehicles in FHWA Classes 4 and 6–13 combined), estimated annually	Estimate of cumulative heavy truck volume for vehicles in FHWA Classes 4 and 6–13 combined, for the LTPP test lane since opening to traffic, reported for each in-service year up to the end of site's participation in the LTPP experiment.	Use in empirical analyses of effects of traffic on nonstructural pavement distresses. Use as a supplemental input in analyses of effects of traffic on structural pavement response and performance.	1, 5, 6
Cumulative volume of FHWA Class 9 trucks, estimated annually	Estimate of cumulative volume of FHWA Class 9 trucks for the LTPP test lane since opening to traffic, reported for each in-service year up to the end of site's participation in the LTPP experiment.	Use in empirical analyses of effects of traffic on nonstructural pavement distresses. Use as a supplemental input in analyses of effects of traffic on structural pavement response and performance.	1, 5, 6

Parameter	Description	LTPP Analysis Use	LTPP Strategic Analysis Objective
Annual ESAL, estimated annually	Based on measured or estimated axle loading data in the LTPP lane for FHWA Classes 4–13 combined and information about pavement structure and pavement serviceability, this value is computed for each year the pavement site was in service up to the end of the site's participation in the LTPP experiment.	Use in LTPP empirical analyses where a single-value traffic loading statistic is desired and for quantifying and comparing traffic loads between sites. Use to compute cumulative ESAL for the pavement design method described in the 1993 version of the *AASHTO Guide for Design of Pavement Structures*.	1, 5, 6, 7
Annual GESAL, estimated annually	Based on measured or estimated axle loading data in the LTPP lane for FHWA Classes 4–13 combined, this value is computed for each year the pavement site was in service up to the end of the site's participation in the LTPP experiment.	Use in LTPP empirical analyses where a single-value traffic loading statistic is desired and for quantifying and comparing traffic loads between sites.	1, 5, 6, 7
Annual total GVW of all trucks (FHWA Classes 4–13), estimated annually	Based on measured or estimated GVW data in the LTPP Lane for FHWA Classes 4–13 combined, this value is computed for each year the pavement site was in service up to the end of the site's participation in the LTPP experiment.	Use in LTPP empirical analyses where a single-value traffic loading statistic is desired and for quantifying and comparing traffic loads between sites.	1, 5, 6, 7
Codes describing traffic data and method used for parameter estimation	Codes to be included in CPTs providing information about the quantity and quality of traffic data or alternative data sources or default values used to develop specific analysis-ready traffic parameters.	Use to help users make informed decisions about the applicability of each computed parameter for specific analysis applications.	1, 5, 6, 7, 8

GENERAL APPROACH FOR PARAMETER COMPUTATION

Challenges Using Available Traffic Data

Estimating the parameters presented in table 17 posed several challenges that were addressed in the computational methodology. First, it was important to define approaches for how to handle missing data. Data might have been missing for several years of the pavement service life or for the entire pavement service life (i.e., limited availability of traffic loading data). Second, it was important to develop approaches for how to address low or unknown accuracy of traffic loading data. Third, it was important to address situations where available data showed a high degree of variability over time. High variability can occur because of variations in local economic activity but can also occur because of data collection errors. Procedures were required to deal with these conditions when supporting information did not indicate whether the high range of values or atypical/unexpected values should have been included when developing computed parameters.

Addressing Missing or Questionable Traffic Data

Different procedures were developed to account for missing or questionable traffic data for different traffic parameters, as described in the ensuing chapters. The majority of the effort was spent accounting for unreliable data and identifying trusted data against other comparable site-specific data. Outlier values (i.e., values significantly different from other observations of the same kind for the same site) were identified, and ancillary data, when available, were used to identify possible reasons for observed outliers (e.g., small data samples used in parameter computation, data collected by equipment with unknown calibration, or historical data reported for a segment rather than an LTPP lane). Based on information gathered, case-by-case decisions were made about whether to keep or remove outliers from representative or annual value computations.

For missing data, accessible datasets that identified truck volumes and/or loads on the same road near the LTPP test site were used as the basis for LTPP CPT values. Data sources, such as the HPMS and FHWA's TMAS, were considered, but in the majority of cases, available LTPP truck traffic volume data were sufficient for these purposes.

For situations where no alternative data sources were available, sites were assigned default values. Traffic loading defaults developed by the LTPP program based on trusted data collected as part of TPF-5(004) were recommended.

Estimating Traffic Changes over Time

Significant effort was on developing methodologies to characterize changes in traffic over time, such as growth rates or annual estimates of truck traffic volume for years where no data were available or data from different sources gathered over the years were not in agreement.

Because different factors contribute to differences in truck volume, vehicle class distribution, and axle weight, varying approaches for estimating traffic data were established to best suit the type of data being estimated. Estimating techniques depended on the types of errors observed during data assessment. For errors occurring only sporadically, simple manual data review procedures were developed. For errors occurring commonly (e.g., poorly calibrated WIM scales), the research team developed heuristic rules that could be automated. Detailed descriptions of procedures and algorithms for estimating analysis-ready traffic parameters are provided in chapters 6 through 11 of this report.

For sites where some site-specific traffic data, such as truck volume, were available for some but not all years the site was in service, a traffic-projection methodology was developed and applied to estimate traffic volume changes over time. One of the approaches used to accomplish this task was to identify traffic and/or truck volume growth rates producing the smallest errors when AADT and AADTT computed based on these growth rates were compared with available site-specific AADT and AADTT estimates. Additional constraints were developed to limit minimum and maximum expected traffic and/or truck volumes. As part of this work, the research team also referenced existing LTPP metadata describing State responses to QA/QC checks performed by the LTPP program's regional support contractors.

Development of Representative Traffic Values

The parameters representing typical truck traffic volume, vehicle classification, and axle weight characteristics were developed for each LTPP site with site-specific traffic data. Based on the availability and quality of supporting data, different approaches were employed to develop these parameters, including the following:

- Data for LTPP sites with site-specific data were reviewed for accuracy when information quantifying data accuracy was available or reasonableness when supporting information to infer data accuracy was limited or not available.
- All site-specific values collected as part of the LTPP traffic monitoring data collection program were identified as accurate or reasonable and incorporated in the analysis to compute representative values for each site.
- There were cases when specific, valid discontinuities in traffic trends were observed, such as when a major change in truck volume or composition occurred. In these cases, discontinuities were noted in the CPT and the computation of representative values accounted for whether these discontinuities were due to temporary or permanent changes in traffic patterns.
- Site-specific traffic loading data identified through review as being of limited accuracy were used, to the extent feasible, to assign qualitative characteristics to LTPP sites describing loading patterns for dominant heavy truck classes. These characteristics can be used to assign default values.
- LTPP sites with no usable site-specific vehicle classification data (due to quality issues identified through data review) had representative values developed using values from nearby similar sites, where possible. The method used for assignment is noted for each LTPP site and each parameter in the CPT.
- LTPP sites with no usable site-specific detailed axle loading characterization data (due to quality issues or lack of data collection) were identified and reported to the LTPP program. These sites required default assignments outside of this study.

Development of Input Values for AASHTOWare Pavement ME Design software

Several key traffic parameters necessary to support LTPP analyses using AASHTOWare Pavement ME Design software were developed in this study, including the following:

- MEPDG base (first) year AADTT.
- MEPDG vehicle class distribution factors.
- MEPDG vehicle class growth rate and growth type (e.g., linear or compound).
- MEPDG ALDF.
- MEPDG number of axles per vehicle (i.e., truck) class.

All parameter definitions and formats were based on descriptions provided in AASHTOWare Pavement ME Design software help files. Computational procedures and tools were developed to store computed parameters in database tables in tabular format providing maximum compatibility with the software's traffic input requirements (i.e., to allow a cut-and-paste operation between the LTPP table and the GUI of AASHTOWare Pavement ME Design software). In addition, a tool based on the LTPP PLUG database application was developed to create ALDF files in XML format for direct upload to AASHTOWare Pavement ME Design software, including ALDF based on unique monthly loading data.

DELIVERY OF COMPUTED PARAMETERS TO LTPP USERS

CPTs

LTPP uses the term "computed parameter" to identify certain parameters developed or computed based on data available in the LTPP database. Computed parameters are designed to drastically reduce the time required to prepare datasets for analysis. Computed parameters are stored in CPTs in the LTPP database.

Use InfoPave to Access New CPTs

The LTPP program's preferred way for users to access or download CPTs is the online through the InfoPave website.[19]

User Guide for Selecting and Using LTPP Traffic Data

The *Guide* was developed in this study and provided as a standalone publication to help LTPP users identify traffic data and parameters necessary for their analysis needs, including analysis-ready traffic tables and traffic data–usability indices.

CHAPTER 6. ESTIMATING PARAMETERS DESCRIBING TRUCK VOLUMES AND TRUCK VOLUME CHANGES OVER TIME

Truck volume parameters are used as primary or supplemental inputs in virtually all pavement performance and management analyses. Parameters described in this chapter include the following:

- AADTT for the test lane for each in-service year, all truck classes (FHWA Classes 4–13) combined.
- AADTT for the test lane for each in-service year for each truck class (FHWA Classes 4–13).
- Total annual truck volume for the test lane for each in-service year, all truck classes (FHWA Classes 4–13) combined.
- Total annual truck volume for the test lane for each in-service year for each truck class (FHWA Classes 4–13).
- CTV for the test lane for vehicles in FHWA Classes 4–13 combined, estimated and compounded annually.
- CTV for the test lane for each truck in FHWA Classes 4–13, estimated and compounded annually.
- MEPDG truck traffic growth for the test lane for each truck in FHWA Classes 4–13, including growth rate and type of growth function (e.g., linear or compound).
- MEPDG base year AADTT for the LTPP lane for all truck classes (FHWA Classes 4–13) combined (first in-service year).
- MEPDG percentile vehicle class distribution for the LTPP lane for all truck classes (FHWA Classes 4–13) (for use with the first in-service year MEPDG base year AADTT parameter).

AADTT FOR EACH IN-SERVICE YEAR, ALL TRUCKS COMBINED

Computed Parameter Description

AADTT in the LTPP test lane describes the total number of trucks (FHWA Classes 4–13) traveling across the LTPP test pavement on a typical day of the year. This statistic averages out seasonal and day of week (DOW) variation present at the site as well as any growth occurring at the site during the year. As a traffic statistic, AADTT is the most common value chosen to represent truck traffic at a site, and it is a common choice for a simple data input for pavement performance models and analysis.

AADTT for each in-service year, all trucks combined, is developed for each year a given LTPP test section is open to traffic until the end of the test section's participation in the LTPP experiment. AADTT for each year may be computed based on monitoring data, estimated by a State agency, or estimated by an LTPP contractor based on available monitored and State-provided data.

Data Sources Used for Parameter Computation

AADTT values are available for some years, in some form, for almost all LTPP test sites within the LTPP database. The majority of LTPP test sites have data on AADTT for the LTPP lane in one of two pavement performance database tables available through the LTPP annual SDR. The first is the traffic monitoring table (TRF_MONITOR_LTPP_LN), which presents the AADTT value computed from traffic monitoring data submitted by State/Provincial highway agencies to LTPP program. If data pass LTPP QA tests, an AADTT value is present in the variable AADTT within that table. These records can come from an automatic classifier (TRF_DATA_TYPE is 4), a WIM system (TRF_DATA_TYPE is 7), or have a record type (TRF_DATA_TYPE is 0) indicating that both sources were used. Record status "E" results, regardless of record type, are selected over record type "D" results. Given the initial outcome, TRF_DATA_TYPE is 4 results are used to estimate LTPP test site truck volumes.

The second source for AADTT for each in-service year, all trucks combined, is a custom table provided by the LTPP CSSC which contains estimates of truck and total volume submitted by State highway agencies. These annual estimates may be based on counts near the LTPP test site. This table includes a value for AADTT in the LTPP test lane (AADT_TRUCK_COMBO_EST). It also includes AADT for the total roadway for all lanes in both directions (AADT_ALL_VEHIC_EST) as well as a value for the percentage of AADT that are trucks in the LTPP lane (PERCENT_TRUCKS_LTPP_LN_EST). The AADT_VALUES table was computed by combining data from SDR tables TRF_MON_EST_ESAL for traffic estimates from 1990 and TRF_HIST_EST_ESAL for traffic volume estimates prior to 1990.

If additional information is desired, several other tables in the LTPP database contain data that can be analyzed to see if details on truck volumes were collected as part of the traffic monitoring effort or were submitted by State highway agencies. SDR table TRF_HST_CLASS_DATA contains truck volumes by vehicle classification (not always FHWA Class) submitted by State highway agencies. These class-specific volumes can be summed to provide an estimate of total truck volume for specific sites and specific time periods. Variables of interest are stored in the NO_VEH_LTPP_LN field, where the specific class of trucks for that record is identified in the VEHICLE_CLASS_DESCRIPTION field. Summing the volumes across vehicle classes 4 to 13 produces an ADTT value for the LTPP lane. A summary of these data is available in the TRF_HST_CLASS_MASTER table. The fields CLASS_COUNT_BEGIN_TIME, CLASS_COUNT_DURATION_HOUR, and CLASS_NO_TRUCKS_LTPP_LN can be used to compute daily truck volume in the LTPP test lane. Finally, the AADT_TRUCK_COMBO field in the TRF_HIST_EST_ESAL table provides a truck volume estimate for the LTPP lane.

If many years are missing from the LTPP database, or if an independent check of reported volumes in the LTPP database is desired, there are two useful data sources that can be examined. The first source is data at nearby LTPP sites on the same roadway for which data were collected. The second source, if no data supplied by a State highway agency are present, is the State's annual HPMS submittal. These data are not uniformly available, and they are only stored for some road sections back to 1982. (Data prior to that are not readily available.) In addition, the HPMS submittal contains truck volume estimates primarily using a simplified classification scheme of single-unit trucks, combination trucks, and multitrailer trucks. Note that truck volume data may be unavailable for early service years for some old pavements in the LTPP experiment.

Pavements built prior to the mid to late 1980s were built during a time when little truck volume data was collected. In these cases, it is necessary to mathematically estimate volumes using the historical growth rates computed from data that are present.

Methodology for Parameter Computing or Estimating

The purpose of AADTT for each in-service year, all trucks combined, is to give LTPP users a means of estimating total truck traffic volume each LTPP experiment site was exposed to from opening to traffic through the end of the site's participation in the LTPP experiment. To do that, any gaps in AADTT estimates available to LTPP data users need filling. To construct a continuous set of AADTT values, monitoring data collected as part of the LTPP experiment and State-supplied AADTT estimates are combined and used to develop mathematical projections using linear or compound growth functions to estimate years for which no AADTT estimate exists. The projection providing the best fit with available AADTT estimates is used to compute AADTT for the missing years. These computed estimates are combined with available AADTT estimates to develop the complete time history of AADTT changes over each LTPP site's life. To differentiate between sources of data used to develop estimates, codes are assigned to each annual estimate: "M" indicates an estimate based on monitoring data, "S" indicates a State-provided estimate, and "E" indicates an estimate based on a mathematical projection using available monitored and State-provided data. A quality or rationality check of data is performed to determine if the computed parameters need revising to account for unusual conditions.

Computational Procedure or Algorithm

The initial step in the AADTT computational procedure (for each in-service year, vehicles in FHWA Classes 4-13 combined) is to set up the basic working table allowing for the creation of the CPT. The basic working table structure consists of a row for all calendar years for an LTPP traffic site, with secondary tables computed for all LTPP experimental sections using that traffic site's data. This table structure is then filled with available monitoring and State-supplied traffic estimates. Summary statistics are computed and used as necessary, and missing years of data are estimated and incorporated into the table. The specific steps for this procedure are as follows:

1. For each LTPP traffic site, determine the first year for which traffic data are available. This value is extracted from the Microsoft Excel® spreadsheet Traffic_site_experiment_links.xlsx which was provided by the LTPP CSSC. The SHRP_INFO tab within the spreadsheet is used. The first year for which data are available is found in the column START_DATE. The end date for that traffic site is then extracted from the column END_DATE from that same Excel file and tab. The date 31-Dec-50 denotes that a traffic site is still collecting data.

2. The table for that site is sized for one row for each year from the start date to the end date. The table has the following column headers (and the same associated variable names: *CalendarYear*, *Age*, *AADTT*, *Source*, $AADTT_4$, $AADTT_5$, $AADTT_6$, $AADTT_7$, $AADTT_8$, $AADTT_9$, $AADTT_{10}$, $AADTT_{11}$, $AADTT_{12}$, $AADTT_{13}$, Per_4, Per_5, Per_6, Per_7, Per_8, Per_9, Per_{10}, Per_{11}, Per_{12}, Per_{13}, *ClassCountDays*, *HistClassCountHours*, *QAflag*, *CountType*.

3. A second working table is constructed for every LTPP pavement site. For each site, the year the site opened to traffic is obtained from the LTPP Inventory database file in the TRAFFIC_OPEN_DATE table. For SPS sites, the SPS_ID table is extracted from LTPP database Standard Data Release (SDR 30 was used at the time of this study) data set. The date the site opened to traffic is taken from the DATE_OPEN_TRAFFIC column. This date is kept as a value to be used later. The year from that date is placed in the YEAR field in the first row of this working table. The number of days into the year represented by that date (e.g., January 10 would be 10 d into the year) is computed and retained.

4. The end date for the site is extracted from the DEASSIGN_DATE column in the EXPERIMENT_SECTION table of the SDR 30 data set. The year extracted from the DEASSIGN_DATE column (assigned as 2016 if the column is blank, meaning the site is still active) is used to size this working table. The table is sized to include one row for each year from the year the site opened to traffic to the year identified in the deassignment date.

5. For GPS sites, a similar process is followed, but different tables are used to build the second working table. The INV_AGE column is used from within the INVENTORY table to select the date the site opened to traffic. For SPS sites that transition to GPS sites, the open to traffic date for the new experiment is understood to be the ASSIGN_DATE.

6. The end date for the site is extracted from the DEASSIGN_DATE column in the EXPERIMENT_SECTION table of the SDR 30 data set. The year extracted from the DEASSIGN_DATE column (assigned as 2016 if the column is blank, meaning the site is still active) is used to size this working table. The table is sized to include one row for each year from the year the site opened to traffic date to the year identified in the deassignment date.

7. The second working table has the same structure as the initial working table. The table has the following column headers (and the same associated variable names): *CalendarYear*, *Age*, *AADTT*, *Source*, $AADTT_4$, $AADTT_5$, $AADTT_6$, $AADTT_7$, $AADTT_8$, $AADTT_9$, $AADTT_{10}$, $AADTT_{11}$, $AADTT_{12}$, $AADTT_{13}$, Per_4, Per_5, Per_6, Per_7, Per_8, Per_9, Per_{10}, Per_{11}, Per_{12}, Per_{13}, *ClassCountDays*, *HistClassCountHours*, *QAflag*, *CountType*.

    a. The first row of the table is given the *CalendarYear* equal to the year the section opened to traffic.

    b. *CalendarYear* in the last row of the table is set equal to the value in the DEASSIGN_DATE column.

    c. The *CalendarYear* value is incremented by 1 yr for each row in the table, ending with the last row where *CalendarYear* should equal the year in the DEASSIGN_DATE column.

    d. The value for *Age* for the first row of the table is set to "0" (i.e., there is no age of the pavement in the first year).

e. *Age* is computed for each succeeding row by adding “1.” If the site opened to traffic in 1990, *Age* for the row containing *CalendarYear* of 1990 is “0.” *Age* for the row containing *CalendarYear* of 2000 is “10.”

8. For the LTPP traffic site, use the TRF_MONITOR_LTPP_LN table in SDR 30 to extract the *AADTT* estimate (from the TRUCKS_LTPP_LN field) for each year and place that value in the appropriate row of the new table. Then, set the *Source* value of “M” for that row as containing monitoring data.

   Note: if “extra” years of monitoring data are present in the TRF_MONITOR_LTPP_LN table after the traffic site leaves the LTPP experiment, those years will be added to the traffic working table. Those years may be included in future analyses when manual review of data at that site results in a decision that adding data from those years will result in better computed parameters. For these additional rows, the variable *QAflag* will be set to “2” to indicate that extra years of data are present and should be reviewed for inclusion in the analysis. The criteria behind the decision to use or ignore these extra years is flexible, as it is not clear without examination whether those data should be used. In general, it is good to have more data. However, trends may have changed in the last few years due to economic changes or local events, making new data less beneficial for use in predicting historical AADTT values. In general, external years of data are used when little data internal to the LTPP study exist and are excluded from the equation fitting when the majority of years in the LTPP life of the pavement have monitoring or State-supplied AADT values.

9. If an *AADTT* value is not present for a given year in the TRF_MONITOR_LTPP_LN table, search the AADT_TRUCK_COMBO_EST column in the AADT_VALUES table, extract any annual values for that site for years where no monitoring data are present, and fill the *AADTT* column with this data and set the *Source* value on the same row as “S” (“S” means containing State-submitted estimates).

10. If an *AADTT* value is not in either TRF_MONITOR_LTPP_LN or AADT_TRUCK_COMBO_EST tables, search the AADT_TRUCK_COMBO column in the TRF_HIST_EST_ESAL table for values for that site and year. The AADT_TRUCK_COMBO column in the TRF_HIST_EST_ESAL table contains historical estimates (pre 1990) of LTPP lane truck travel provided by State highway agencies and set the *Source* value on the same row as “S” for containing State-submitted estimates.

11. If no data are available for a site for any year from the TRF_MONITOR_LTPP_LN or TRF_HIST_EST_ESAL tables, set the *Source* value to “D” for default required. This will be used to stop processing for this site. A default set of *AADTT* values is supplied manually by the analyst using the process described in steps 13 through 20.
12. A quality or rationality check of the data is performed based on year-to-year differences in truck volume. The data rationality check determines if either *AADTT* values change by more than 25 percent from year to year and if the change in volume is larger than 50 trucks. If a site has such a change, it is flagged for further review with *QAFlag* is “1.”

Note that a 25 percent change in truck volume at a low-volume LTPP test site is a reasonable change in traffic loading and accepted as valid because traffic data in SDR 30 were already reviewed by the LTPP program. It is also possible that the site will be flagged to indicate that two or more distinct traffic patterns are present due to changes in traffic characteristics caused by changes in the economy. The manual review process may determine that, given other available information, some submitted *AADTT* estimates are not reasonable for use in the CPT.

13. If there are still years for which there are no *AADTT* estimates, the remaining *AADTT* estimates are estimated using a linear or compound growth function.

14. Assuming only one growth equation is developed, available *AADTT* values are used to compute two regression equations, one using a linear growth rate and the other using a compound growth rate. Regression is computed using the *AADTT* and *Age* columns of the traffic site working table and only uses rows for which a valid *AADTT* statistic is present.

15. Unless one of the growth equations predicts a negative *AADTT* value for a year in which the LTPP site was open for traffic or for the year 2030, the formula with the best R-squared value is used to estimate any missing *AADTT* values. If a negative value occurs, the other growth equation is selected, even if it has a lower R-squared value. (i.e., if the negative value appears in the linear equation, use the compound equation and vise versa.) If a negative value is determined for the second growth equation as well, the first growth equation is used until the year when a negative *AADTT* is first computed. For this (first negative AADTT year) and all the following years, AADTT value from the last year with positive AADTT value is used. If this occurs, set the *QAflag* to "6."

16. For any years for which *AADTT* values are estimated with the regression equation, set the *Source* value for that row as "E" for containing a computed estimate.

17. If the manual review shows major discontinuities exist in truck trends (e.g., one LTPP site is significantly affected by a construction road closure changing truck travel patterns for several years), a different forecast process is used for the duration of the construction event versus those years when no closure was present. The same process noted in steps 6–8 is followed for developing the regression equations, but the years of data used are restricted to those years when a given pattern is present. This process is done manually, with data manually inserted into the CPT table being created.

18. When manual adjustments are made to the automated process, such as described in step 17, the *QAflag* variable for all years included in the manually adjusted years of data is set to "9."

19. Upon completion of traffic site statistics, LTPP experimental sites are constructed. A crosswalk between individual LTPP experiment sites and traffic sites is found in the Excel spreadsheet Traffic_sites_experiment_links.xlsx. In general, the experimental site is listed in table fields with the headings STATE_CODE and SHRP_ID. The traffic count site used for classification data is found in the CLASS_SITE column. The one exception to this is that all SPS experimental sections are automatically assigned to their parent

traffic site. For example, SPS sites 040113, 040115, 040122, and 040163 are all assigned to LTPP traffic site 040100. Some manual revision of these rules was required where some SPS sections were on different sides of the road from other test sections for that SPS site. These were hand-coded to be exceptions to the assignment of the specific experimental sites to the traffic data collection location for the parent site. (That is, the sections on the north side of the road have been manually assigned to a traffic location on the north side, while the sections on the south side of that road are assigned to the parent site, which is also on the south side of the road.)

20. The experimental site working tables are filled with the *AADTT* for those years in the table from the appropriate traffic site.

Examples of Parameter Estimating

AADTT Estimation for LTPP Traffic Site 040100, Case of Complete Dataset with Large Truck Volume Variations

The first example of the AADTT estimation process is for LTPP traffic site 040100. This traffic site is used for many SPS test sections (040113–040124 and 040160–040163.) The site opened to traffic on June 1, 1993 and left the experiment June 1, 2006.

The site has traffic monitoring data for two distinct periods. From 1994 to 2001, monitoring data are present. After a brief loss of data, starting in 2003, traffic monitoring data were again available; the site continues to provide data even though the site left the LTPP experiment in 2006. The site also has State-submitted AADTT data for 1993–1995, 2001, and 2002 (table 18). State-submitted estimates are only used for 1993 and 2002. Data for the years beyond 2006 are shown in table 18 because this allows continuing trends to be observed. Data from 2006 onward can be used in the computation of the CPT but would not be included in the table, which covers only the years during which the test site was part of the LTPP experiment.

Table 18. AADTT estimates for LTPP traffic site 040100.

Year	AADTT	Monitoring (M) or State Estimate (S)
1993	400	S
1994	629	M
1995	657	M
1996	714	M
1997	770	M
1998	835	M
1999	875	M
2000	950	M
2001	1,006	M
2002	1,085	S
2003	214	M
2004	221	M
2005	220	M
2006	219	M

Year	AADTT	Monitoring (M) or State Estimate (S)
2007	413	M
2008	237	M
2009	286	M
2010	379	M
2011	942	M
2012	1,031	M
2013	1,186	M
2014	1,334	M

As can be seen in the table, truck volumes dropped by approximately a factor of four from 2003–2010. Discussions with the LTPP program's regional support contractor indicated that traffic volumes using this road changed due to a major road construction project altering traffic patterns during this period. (There were truck restrictions imposed on this route after September 11, 2001, that were in place for several years prior to the construction project.) This creates a difficult problem for developing computed parameters for this site, in that truck volumes experience a major discontinuity during the period of the LTPP experiment. There are really two truck volume patterns, the pattern from 1993–2003, which resumes part way through 2011 when the construction project ends and traffic is restored to its previous patterns, and from 2003–2010 when much lower truck volumes cross this test site.

Another observation is that the truck volume reported in 1993 is only about two-thirds of what might be expected in a trend line formed from 1994–2001. This is doubly surprising when a casual comparison of State-supplied and monitoring truck volumes for 1994 and 1995 shows State-supplied volumes for those 2 yr significantly overestimate truck volumes collected as part of the LTPP monitoring program. However, because it is not possible to guess whether traffic ramped up on the pavement at this LTPP traffic site, State-supplied values for AADTT are used for 1993.

Lower truck volumes observed in the LTPP database starting in 2003 fail the consistency test used for QA purposes—that is, they demonstrate greater-than-30-percent changes in AADTT from one year to the next, and the percent of truck travel by FHWA Class 9 trucks also changes by more than 20 percent. These data were manually reviewed and ultimately left in the dataset as valid because they were accurate representations of actual traffic loads experienced by the LTPP traffic site. They are simply a symptom of the impacts of construction traffic changes on the truck traffic volumes experienced by the LTPP site.

The effects of this 9.5-yr discontinuity are discussed in later examples in this chapter.

AADTT Estimation for LTPP Traffic Site 320100, Case of Partial Dataset with Moderate Truck Volume Variations and No Growth

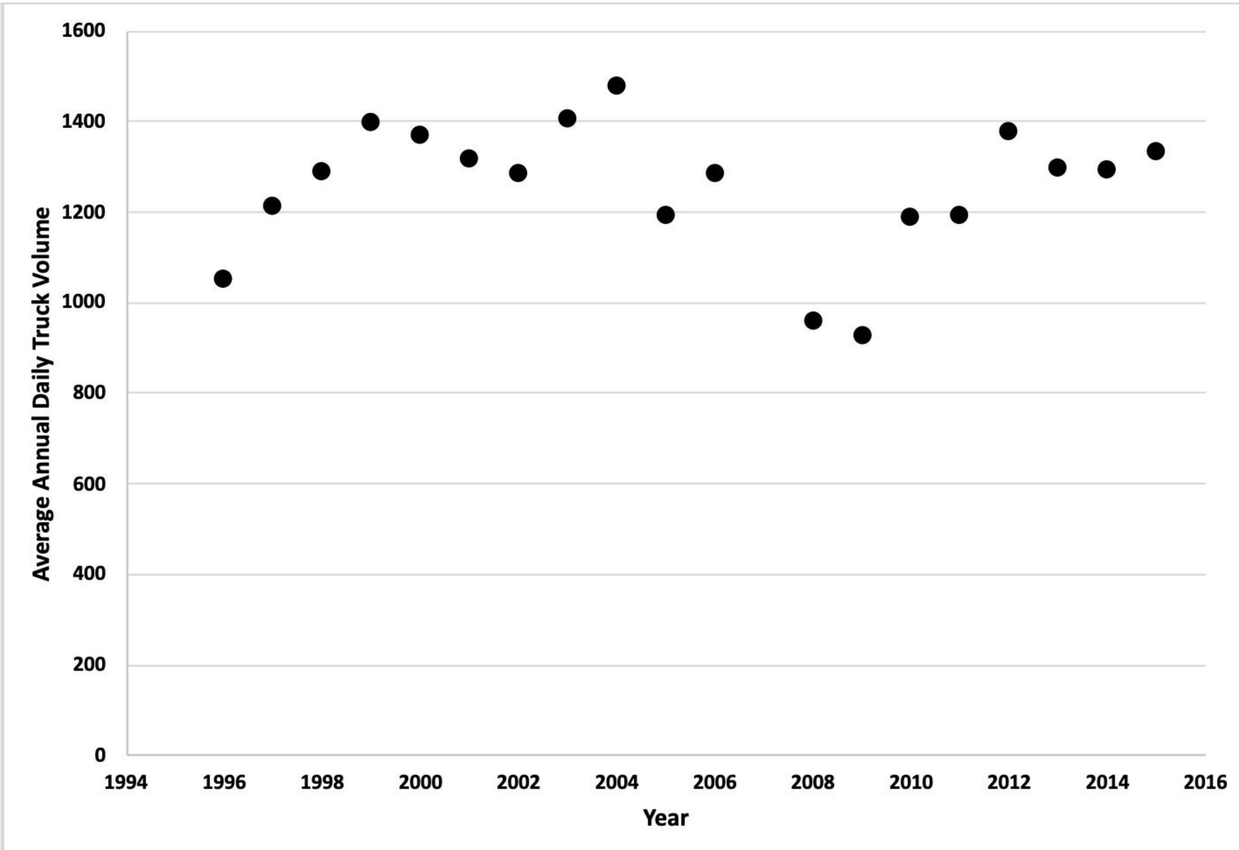
The second example of the AADTT estimation process is for LTPP traffic site 320100. This traffic site is used for 12 different SPS test sections (320101–320112). The site was assigned to the LTPP experiment in 1993, opened to traffic on September 1, 1995, and left the experiment July 1, 2009. Data collection continued at the site after leaving the LTPP experiment. AADTT estimates based on monitored data at the site are present in the LTPP database through 2015 and are shown in table 19.

Table 19. AADTT estimates for LTPP traffic site 320100.

Year	AADTT	Monitoring (M), State Estimate (S), or Regression Estimate (E)
1995	1,261	E
1996	1,050	M
1997	1,212	M
1998	1,287	M
1999	1,396	M
2000	1,369	M
2001	1,316	M
2002	1,285	M
2003	1,404	M
2004	1,479	M
2005	1,193	M
2006	1,285	M
2007	1,244	E
2008	961	M
2009	926	M
2010	1,190	M
2011	1,191	M
2012	1,376	M
2013	1,298	M
2014	1,294	M
2015	1,334	M

At this site, traffic monitoring data are present for all years except 1995 and 2007. No State-submitted data are available. To develop estimates for missing years, it was necessary to compute best fit regression curves to available data and use the best of these two curves to estimate AADTT for 1995 and 2007.

Linear and compound regression equations were fit through the traffic monitoring data, with the year the site opened to traffic as the independent variable. Neither curve provides an especially good fit because AADTT values do not closely follow either a linear or compound growth pattern. Figure 6 is a graph of monitored AADTT values from 1996 to 2015, which shows a significant drop in trucking activity at this site in 2008 and 2009, during the heart of the Great Recession. However, even outside of the recession, truck volumes at this site were volatile, showing no clear growth trend, often increasing for several years and then decreasing for several years.



Source: FHWA.

Figure 6. Graph. Monitored AADTT by year at LTPP traffic site 320100.

Even without the drop in truck volumes during heart of the Great Recession, there is no clear growth pattern at this site. The best fit of the two growth equations is the compound equation, but its R-squared value is 0.0029 when using all years through 2015. The linear regression equation's R-squared value is 0.0028. Actual AADTT values computed using the two equations are not significantly different from each other. Both equations place predicted AADTT values for missing years in the middle of the range of AADTT values illustrated in figure 6.

If instead of using all years for which data are present, only data from 1996–2009 are used (the period when the site was part of the LTPP experiment), and the R-squared value goes up considerably for both the linear and compound equations. If only data through 2009 are used, the R-squared values for the two regression curves are 0.138 for the compound equation and 0.117 for the linear equation. Both the linear and compound regression equations predict slightly decreasing truck volumes at this site regardless of whether data from 1996–2006 (prior to the recession), through 2009, or through 2015 are used in equation development.

Given the fluctuation in truck volumes over time, equations that use only the data through 2009 are considered better for predicting missing AADTT values during the LTPP experiment, as it is not possible to predict fluctuating volumes with a high degree of precision. However, if AADTT values for later years are predicted, equations based on the fully available traffic monitoring dataset (i.e., through 2015) should be used despite the lower R-squared value, as additional years of traffic monitoring data reflect changes occurring at the site (i.e., the continuing rebound in truck traffic after the Great Recession).

AADTT Estimation for LTPP Traffic Site 321020, Case of Partial Dataset with Consistent Truck Volume Growth Trend

The third example of the AADTT estimation process is for LTPP traffic site 321020. This traffic site was initially part of the GPS-1 experiment. The pavement was opened to traffic on June 1, 1984, and left the LTPP experiment in September 2000. At that time, the LTPP test site became part of the GPS-6 experiment, and it continues to be part of that experiment today.

Monitoring traffic data exist for parts of 8 different years, beginning in 1991 and ending in 2003. In addition, the Nevada DOT supplied estimates of AADTT for 1984–2000. These data are summarized in table 20. Years 2001–2015 are covered by the ongoing GPS-6 experiment.

Table 20. AADTT estimates for LTPP traffic site 321020.

Year	AADTT	Monitoring (M), State Estimate (S), or Regression Estimate (E)
1984	117	S
1985	109	S
1986	109	S
1987	144	S
1988	183	S
1989	183	S
1990	168	S
1991	165	M
1992	176	M
1993	194	M
1994	230	S
1995	293	S
1996	271	M
1997	270	M
1998	240	S
1999	390	S
2000	329	M
2001	334	E
2002	342	M
2003	276	M
2004	402	E
2005	427	E

Year	AADTT	Monitoring (M), State Estimate (S), or Regression Estimate (E)
2006	454	E
2007	483	E
2008	513	E
2009	546	E
2010	580	E
2011	617	E
2012	656	E
2013	697	E
2014	742	E
2015	788	E

To supply missing AADTT values for which there are neither traffic monitoring data nor State-supplied estimates, the regression technique was used. Both linear and compound regression equations were tested against the combined State-supplied and traffic monitoring data. The R-squared value for the compound equation was slightly better than the linear equation (0.85 versus 0.81, respectively). Consequently, the compound equation was used to estimate missing AADTT values.

AADTT FOR EACH TRUCK CLASS AND EACH IN-SERVICE YEAR

Computed Parameter Description

This computed parameter describes the number of trucks that travel across the LTPP test pavement on a typical day of the year, with values provided for each in-service year since the LTPP site opened to traffic until the end of LTPP site's participation in the experiment. This computed parameter disaggregates total AADTT volumes into AADTT volumes for individual FHWA vehicle Classes 4 through 13 so changes in the mix of trucks occurring over time can be incorporated into pavement loading calculations.

AADTT for each truck class and each in-service year averages out seasonal and DOW variations present at the site as well as any growth occurring at the site during the year. It is the best simple traffic volume statistic for characterizing annual changes in the truck traffic mix.

Data Sources used for Parameter Computation

The primary source for truck volumes by vehicle classification are traffic-monitoring traffic monitoring data submitted by State highway agencies stored in the TRF_MONITOR_LTPP_LN table in the LTPP database. This table includes the LTPP program's best estimate of annual truck volume by vehicle class (FHWA Classes 4–13). Where counts have been made across multiple years of data, trend lines can be developed with these data. Variability of the percentage of travel across various truck classes (FHWA Classes 4–13) can also be examined.

If additional data are required as part of the manual review of available data, LTAS monthly traffic tables can be accessed. These tables are found in SDR releases and start with "MM_CT." LTAS monthly tables provide more detailed truck volume data collected by State highway agencies specifically for the LTPP program by class of truck, year, month, lane, and DOW. Should they be needed as part of a manual data quality review, these data allow the direct computation of truck volumes by FHWA vehicle class in the LTPP test lane as well as comparison of LTPP lane volumes versus truck volumes counted in other lanes on that roadway.

Where no monitoring data were collected by a State highway agency at a specific LTPP test site, there are three useful data sources that can be examined. The first is estimates of annual volume traffic data for the site supplied by a State highway agency. These data are stored in the TRF_HIST_CLASS_DATA table of SDR 30. The data include estimates of vehicle volumes by class of vehicle and typically include car volumes and truck volumes. The TRF_HIST_CLASS_MASTER table includes a description of these counts, including the duration of any counts submitted. In some cases, these data are submitted using a vehicle classification scheme that is somewhat different than FHWA's 13-bin vehicle classification table. Using these data requires manual review because of the potential variability in data reported.

Computed AADTT parameters (combined for all trucks) described in the previous section of this document provide annual control totals for truck volumes at a site. These can be used with data on the distribution of trucks within each class to estimate AADTT by truck class when traffic monitoring data are not available.

If no data supplied by State highway agencies are present, then to gain insight into the likely percentage of travel by each FHWA vehicle class, it is possible to examine: data at other LTPP sites on the same roadway located nearby geographically; sites elsewhere in the State; sites on similar roads that are not physically close to the site being examined; and a State's HPMS submittal for the roadway being examined to understand the State's expectations for the size and basic composition (e.g., single versus combination units) of truck volumes at a given site. The HPMS submittal contains an estimate of truck volume by class. Most, but not all, roads used in the LTPP experiment have data available in the HPMS. There are two major limitations in the data available through the HPMS: limited or no truck volume data exist at most sites prior to the 1990s because most State agencies did relatively little truck volume counting; and most truck volume data in the HPMS are limited to simplified truck categories (e.g., single and combination unit volumes) as opposed to more detailed FHWA vehicle classification categories.

Consequently, wherever possible, the computed parameter development process relies on submitted LTPP traffic monitoring data and State highway agency submittals.

Methodology for Parameter Computing or Estimating

The methodology for parameter computing or estimating begins with the completion of the previously computed base computational table used for developing an AADTT value for all truck classes combined for all years. At the conclusion of that task, an AADTT value is available for all years for which each test site is open to traffic. These values are used in combination with the parameters described in the following sections.

Extraction of Annual Truck Percentage Data by Vehicle Classification

The next step is to extract all detailed annual truck volume data by vehicle classification from the LTPP database that have passed at least through Level D of the LTPP QA checks. For traffic monitoring data, these come from the TRF_MONITOR_LTPP_LN table; for historical data, these come from the TRF_HIST_CLASS_DATA table.

Both datasets are examined to determine the number of days of data present in each yearly estimate. Data come from the *COUNT_DAYS* variable in the TRF_MONITOR_LTPP_LN table and from the *CLASS_COUNT_DURATION_HOUR* variable in the TRF_HIST_CLASS_MASTER table for pre-LTPP traffic monitoring data collection counts submitted by State highway agencies. These data are used to make a manual reliability judgement for producing annual estimates of truck travel by FHWA vehicle classes 4 through 13. This is important only when percentages of truck travel by class of trucks from these counts are significantly different from other values obtained from monitoring counts, which include a larger number of days.

Next, if historical volume data are not collected and submitted using FHWA truck classes, adjustments are manually made to convert data to FHWA classes, as needed.

Available data are converted to estimates of annual average daily truck volumes for each of FHWA's truck classes. In the case of data taken from the TRF_MON_LTPP_LN table, the annual truck volume estimate for each class is divided by the number of days in the year (365 or 366). Daily volume estimates by class of vehicles are also converted into a percentage of total truck volume. This is done for each year for which data are present. For historical data supplied by State highway agencies, this computation may be for a short duration count, not for an average annual condition.

Test Reasonableness of the Available Data

Where data exist, the percentage distribution of truck volumes across FHWA truck classes is computed. Large changes in FHWA Class 5, 8, and 9 truck volumes indicate a manual QA review of the reliability of these counts is required. Otherwise, data are used as collected.

This QA review is performed because, when errors in data collection occur in the field, major changes in the percentage of vehicles in specific truck classes can occur. FHWA Class 5 or 8 trucks are particularly susceptible to classification errors. Shifts between FHWA Classes 5 and 8 also occur when new classification equipment and/or algorithms are put in place. When these errors occur, total truck volumes also typically rise or fall significantly as pick-up trucks and light-duty vehicles pulling trailers are classified as heavy trucks in FHWA Classes 5 and 8, or are no longer classified in those categories, respectively. The difficulty with confirming errors in counts associated with these vehicle classes is that, without other information, it is hard to identify which class assignments are correct and which are incorrect or whether other factors actually caused observed changes in traffic characteristics, such as the traffic pattern shift described earlier for LTPP traffic site 040100.

To look for these classification errors, a two-stage process was proposed. The process uses annual LTPP traffic monitoring data where at least 8 of the 10 FHWA vehicle classes have annual traffic volume estimates with a record status of "E" resulting from the LTPP QA process.[1] The first stage of the QA review includes the following three steps:

1. For each LTPP site, determine the maximum and minimum annual percentage of all trucks within each vehicle class for all years of data present in the database (e.g., Class 4 volume/total truck volume).
2. Where the percentage of Class 9 trucks changes by more than 20 percent (i.e., maximum percentage minus minimum percentage), a detailed manual review of that site's vehicle classification data is performed.
3. Where the absolute percentage of the maximum percentage minus the minimum percentage changes by more than 15 percent for any other truck class, a detailed review of that site's vehicle classification data is performed.

For sites that fail this initial review, the second review stage is performed. In this stage, detailed monthly and, if necessary, daily truck volumes by vehicle classification data are examined to determine if specific bad datasets are causing these fluctuations (i.e., determining if a small number of counts are causing these errors). In addition, review available metadata to determine if data collection equipment changes are implicated in some of the data variation observed in the truck volumes by vehicle classification. Where metadata exist, they are stored in the TRF_CALIBRATION_AVC table and, in some cases, the TRF_EQUIPMENT_MASTER table in SDR 30.

After extracting detailed classification data and supporting metadata, a manual review is performed to determine if observed data are a result of a data collection error or poor device calibration. An example of such a finding might occur if data at a site were initially obtained with a portable counter and the computed percentage of trucks by class changed significantly when a permanent counter was put in place. In such cases, data from the permanent counter (if it exhibits consistent data quality) are accepted for use in computing vehicle classification percentages used in the CPT. A flag will also be placed in the database stating that a change in equipment caused a change in classification. Similarly, if the annual estimate of truck traffic is based on a short-duration count that is very different from the majority of other available counts, the accuracy of that annual estimate is discounted in the estimation of annual volumes.

The second stage of the QA review includes the following three steps:

1. Check if estimates from short portable counts are significantly different than data collected from permanently mounted sensors (e.g., check if year-to-year volumes of FHWA Classes 5, 8, or 9 change by more than 30 percent). Where those changes are larger than 50 vehicles per day, does the percentage of truck traffic falling within any of these three vehicle classes change by more than 10 percent? Permanent count data showing consistent patterns are accepted over portable counts. Where this occurs, set *QAflag* variable value to "7."

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[1]For some sites, data for most classes are at record status E, but one class may be at record status D. These data are assumed to be valid for computed parameter development.

2. Check if data are collected via calibrated WIM equipment[2] versus uncalibrated equipment and/or portable vehicle classifiers. If the shift in classification percentage occurs with a change in equipment, choose calibrated WIM data over other sources. The choice between other data sources is a function of the consistency of collected data, where consistency is computed as a change in monthly classification percentages of other data sources. The more consistent data source is selected. Where this occurs, set *QAflag* variable value to "8."

3. Compare the total volume of trucks counted per day to the change in percentage in each truck class. If the change in Class 9 percentage is primarily due to a significant change in the volume of Class 5 or 8 trucks, this is likely due to errors in the classification data collection process (e.g., overcounting Class 5 and 8 vehicles). Unusual traffic volume patterns are flagged and described in a note. Those findings are also used when selecting representative truck percentages, where the high percentage of Class 5 and 8 trucks is generally discounted. When large changes in the percentage of Class 5 or 8 volumes occur, it is frequently (but not always) a sign of poor vehicle classification system performance. Where this occurs, set *QAflag* variable value to "8."

Note that equipment changes are not always reported to the LTPP program and are therefore not always noted in the LTPP database. However, the basic comparison of total truck volumes versus percentage of Class 5, 8, and 9 trucks can be used on a monthly or even weekly basis to detect changes in equipment performance, even when no specific notification of equipment change occurred. The change may be the result of site maintenance, equipment failure, or a change in a State highway agency's vehicle classification algorithm.

Finally, note that some major changes in both truck volumes and percentages are correct. An example of this is the LTPP traffic site 040100, which experienced major changes in traffic volume due to a construction project.

Approach for Parameter Computation

After completing the QA review, available traffic monitoring data are used to compute AADTT for each vehicle class (FHWA Classes 4–13) for each year a pavement at an LTPP site was open to traffic and for which data are present using the following approach:

1. From the TRUCKS_LTPP_LN column of the TRF_MONITOR_LTPP_LN table in SDR 30, extract the estimate of annual truck volume by vehicle by class, by year. These data are available (when submitted by States) from roughly 1990 through the present day. Compute the percentage of truck traffic in each class of trucks.

2. If the traffic site was open to traffic prior to 1990, extract and summarize historical data from the TRF_HIST_CLASS_DATA table in SDR 30. Convert these estimates to a percentage of truck traffic in each class of trucks.

[2]The LTAS database contains information on equipment types used to collect traffic monitoring data. These data, while not always present, may explain the reason for changes in vehicle class distribution data. They do not directly confirm which data are correct, but they can explain why changes occur.

3. Where traffic monitoring data are not available for specific years, the classification-specific annual average daily truck volume is computed by multiplying the AADTT value in the CPT by either the historical percentage of truck traffic in each FHWA classification (where those data exist) or the mean percentage of trucks in each truck category for all years for which monitoring data passing quality checks are available.

4. If a significant change in truck volume distributions occurs, and the resulting manual review determines from other metadata that different patterns apply to different years, the mean value for just the years that follow the correct pattern is applied to AADTT values in the CPT for missing years.

5. Where no monitoring data are available for a site, a manual search for an alternative data source is performed. Data on the percentage of truck travel by vehicle classification (FHWA Classes 4–13) are obtained from one of three sources. The first source for which data are found is used. The search for an alternative data source is performed in the following order:

    a. Estimates of annual truck volume by vehicle classification (FHWA Classes 4–13) data for the site supplied by State highway agencies.

    b. Percentage of LTPP data existing at test sites that are geographically nearby (e.g., <50 mi) on the same roadway, provided those estimates are based on continuous count locations.

    c. An average of annual truck volume by vehicle classification (FHWA Classes 4–13) estimates for the roads in the same road functional classification and serving similar trucks or goods movement in that State.

6. AADTT for each class of trucks is computed for each year for which a traffic monitoring estimate is not available by multiplying the AADTT value for all trucks combined from the CPT by the percentage of truck traffic in each class of vehicles.

Computational Procedure or Algorithm

The specific computational procedure for the development of AADTT by FHWA vehicle classification (FHWA Classes 4–13) parameters is performed in the following three steps:

1. Use the working table created to develop the computed parameter called AADTT by year (presented earlier in this report), which already contains AADTT values from monitoring, State-supplied, and estimated sources for each year of pavement service life.

2. Where data exist for a traffic site, extract the estimated annual truck volume (by class and by year) from the TRUCKS_LTPP_LN column of the TRF_MONITOR_LTPP_LN table from SDR 30. Divide that value by the number of days in that calendar year and store the outcome in the appropriate variable for that class (e.g., $AADTT_4$ for FHWA Class 4). Also extract the highest value for that year (across all vehicle classes) from the column and place it in the variable *ClassCountDays* in the working table.

3. Compute the percentage trucks in each classification from monitoring counts using the following formula:

$$Per_{ij} = AADTT_{ij}/(\sum_{j=4}^{13} AADT_{ij}) * 100 \tag{1}$$

Where:

Per_{ij} = percent of annual truck traffic occurring in FHWA vehicle class j during year i.

$AADTT_{ij}$ = AADTT in truck class j during year i.

j = the specific class of trucks for which the percentage is being computed (FHWA Classes 4–13)

4. Extract historical truck volume data from the TRF_HIST_CLASS_DATA table in SDR 30 with the following tasks:

   a. Create a new working table including one row for each historical data collection session for a given site and columns for each of the 10 FHWA truck classes (FHWA Classes–13), plus columns for the year of the count, count duration, and whether the count is for just the LTPP test lane or multiple lanes and/or directions.

   b. Create a row in the table for each unique date for that site, found in the CLASS_COUNT_BEGIN_DATE column.

   c. Extract the year for that count from the date value in the CLASS_COUNT_BEGIN_DATE column and place that value in the year column of the working table.

   d. Fill the columns in the working table with the count data from the NO_VEH_LTPP_LN column where data exist in that column. Also set the type of count to "9," meaning the count is just for the LTPP lane.

   e. If no data exist in the NO_VEH_LTPP_LN column, but data do exist in the NO_VEH_LTPP_DIR column, use those data to fill the count columns in the working table, but set the count type to "8," meaning directional count.

   f. If no data exist in the NO_VEH_LTPP_DIR column, but data do exist in the NO_VEH_2WAY column, use those data to fill the count columns in the working table, but set the count type to "7," meaning traffic data was submitted for both directions.

   g. Extract the value from the CLASS_COUNT_DURATION_HOUR column of the TRF_HST_CLASS_MASTER table in SDR 30 and place it in the working table in the variable *HistClassCountHours*.

5. Compute the percentage trucks in each classification from historical counts with the following tasks:

a. For each year of historical data present in the working table, select all rows for that year. If only one row of data is present for each year, compute the percentage of truck traffic in each vehicle class from that row's values and enter those data in the CPT working table in the appropriate column (e.g., Per_4 holds the percentage of truck traffic occurring in FHWA Class 4). Use the following equation:

$$Per_{ij} = Volume\_Class_{ij}/(\sum_{j=4}^{13} Volume\_Class_{ij}) * 100 \tag{2}$$

Where:

$Volume\_Class_{ij}$ = annual volume of vehicles in FHWA vehicle class j during year i.

j = the specific class of trucks for which the volume is being computed (FHWA vehicle Classes 4 to 13)

Also retrieve from the historical data working table and store the hourly duration value in the *HistClassCountHours* column of the CPT working table. Finally, store the *CountType* variable in the CountType column of the CPT working table.

b. If more than one row of data exists in the historical count working table for a given year, and all rows in a given year are for the same type of count (i.e., they are all for the LTPP lane, or all for both directions combined), add the classification volumes in each column together, and then compute the percentage of truck volume for the combined volumes that falls within each FHWA vehicle class 4 through 13. Place this percentage in the CPT working table. Sum the count duration hours in the multiple records for that year, and place that total in the CPT working table. Finally, place the count type value in the CountType column.

c. If more than one type of count is performed in any given year for a site (that is, at least two different counts were made, and they have different start dates and were of different count types), choose only those records which are the most associated with the LTPP lane (so choose data with a CountType of "9" over data with a CountType of "8" or "7," but choose a CountType of "8" over a CountType of "7"). Compute the appropriate statistics as defined in step 5a or 5b depending on the number of rows of data available for that year or that count type. The only difference is that CountType should be set equal to 6, to indicate that multiple types of data were present. This will be used as a manual review flag to determine if manual intervention is needed to take better advantage of the available historical classification count data.

6. The CPT working table already has AADTT values (all truck classes combined) for all years the traffic site was part of the LTPP experiment. It also has truck percentages for all years for which data were submitted, either traffic monitoring data collected as part of the LTPP experiment or State-submitted historical counts. These data are used in the data QA/ reasonableness review to find shifts and/or outliers in vehicle classification

percentages using data from multiple years. The following steps are used to perform that review:

a. Process the CPT working table to see if, during any year-to-year comparison, the percentage of truck volume assigned to any given vehicle class changes by more than 15 percent (e.g., if in 2006, Class 9 trucks account for 50 percent of truck travel, and in 2007, Class 9 trucks account for 65.2 percent of truck travel, this site's vehicle classification data would be flagged for manual review). Where this occurs, set *QAflag* variable value to "3."

b. If these large changes are found, perform a manual review of data. The review will look at whether volumes at the site are very small (so small that minor changes in truck volumes result in large percentage changes); whether there were changes in data collection equipment (and if one set of data should be considered less accurate); and if some data should be ignored because their collection represents a small sample size (e.g., only a few hours of data were collected) and are therefore subject to potential bias as an annual estimate of conditions relative to other data available at the site.

7. Based on the review, the reviewer will select which years to use to compute the mean condition for the site. This may mean one set of years is used to predict use for all years for which previously submitted data are not present. Alternatively, the manual review might indicate the need to use more than one vehicle pattern to represent traffic characteristics over the life of the LTPP test site. For example, in the case of the LTPP traffic site 040100, two different periods are identified in the manual review. One vehicle classification pattern was used for the period when construction affected the site, and a second was used for the period when construction did not affect the site. Historical data were included in these computations if data passed the data QA/reasonableness review performed in step 6.

8. The mean value of the percentage of truck traffic occurring in each truck class j ($MeanPercentClass_j$) is computed using all years for which data are available and of acceptable quality. This is computed for each class using the following formula:

$$MeanPercentClass_j = \sum_i^n Per_j \;/\; N \qquad (3)$$

Where:
Per_j = percent of annual truck traffic occurring in FHWA vehicle class j.
n = total number of years (not necessarily consecutive) for which valid traffic monitoring data are available at this site.
i = in-service year.
N = number of years for which valid traffic monitoring data exist at this site.

9. These values will be assigned to all years for which traffic monitoring data are not present and any years for which historical data are considered unreliable by the manual review process.

10. If more than one (confirmed) vehicle classification pattern is observed in the data, the calculation in step 9 is repeated for each verified classification pattern. Specific years of data included within each pattern will be determined as part of the manual review.

11. In this step, it must be confirmed that the sum of the mean percentage values computed in steps 9 and 10 equals 100 percent. If the sum of these values across all 10 truck classes is not equal to 100 percent, normalize the values so that they equal 100 percent.

12. Compute AADTT for each FHWA vehicle class j (j= 4 to 13) for all years for which traffic monitoring data are not available by multiplying the mean truck percentage $MeanPercentClass_j$ by the total AADTT (FHWA Classes 4–13 combined) for that year i. This is expressed in the following equation:

$$AADT_{ij} = MeanPercentClass_j \times AADTT_{i\_total} \quad (4)$$

Where:
$AADTT_{i\_total}$ = AADTT in year i for all truck classes combined.

Although other methods for estimating volumes for individual truck classes are possible, lower volume truck classes are often volatile. For low-volume classes, changes can be modest in absolute size but represent significant percentage changes (e.g., a change from a count of two to three represents a 50 percent increase in truck volume). A review of collected data shows that many of these low-count values follow relatively little pattern. It was determined that a consistent replacement—the mean of all valid data—provided a more transparent and potentially more reliable replacement value than trying to directly interpolate between available data points, particularly given multiple gap sizes and no knowledge of underlying factors affecting truck traffic at the LTPP test sites.

13. The LTPP traffic site now has a complete set of $AADTT_{ij}$ values. Populate the CPT with $AADTT_{ij}$ values from the CPT working table, along with other required ancillary data, such as the data source values in the "Source" column. The data source value will be set as "M," meaning data are from monitored data; "S," meaning data are from historically collected count data; "E," meaning data are estimated from a combination of State-supplied volume estimates and average vehicle distributions; or "D," meaning data external to the LTPP program or borrowed from other LTPP test sites must be used to estimate the distribution of trucks across the 10 FHWA vehicle classes.

Examples of Parameter Estimating

AADTT by Vehicle Class Estimation for LTPP Traffic Site 040100, Case of Significant Change in Vehicle Classification Due to a Construction Event

The first example of the process for computing $AADTT_{ij}$ for each vehicle classification (FHWA Classes 4–13) is for LTPP traffic site 040100. As described above for the development of the computed parameter for the AADTT value for each year ($AADTT_i$) for all truck classes combined, this site has traffic monitoring data for 1994–2001, and from 2003 to the current year. It has State-submitted AADTT estimates for 1993–1995, and 2001. The CPT for total $AADTT_i$

was shown in table 18. Table 21 shows the $AADTT_{ij}$ by vehicle classification (FHWA Classes 4–13) for each year for which monitoring data were submitted for this site.

Table 21. $AADTT_{ij}$ for each vehicle class for LTPP traffic site 040100.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
1994	9	109	18	0	53	384	3	43	9	0
1995	9	113	16	1	55	413	3	37	9	1
1996	9	112	18	0	58	459	4	42	8	1
1997	11	159	24	0	43	477	5	41	8	1
1998	10	182	22	0	47	518	4	43	8	1
1999	14	182	22	0	44	549	4	49	9	1
2000	20	221	25	1	49	571	5	46	9	1
2001	20	223	24	1	57	617	6	49	9	1
2002	—	—	—	—	—	—	—	—	—	—
2003	6	131	9	0	22	45	0	0	0	0
2004	6	119	8	0	27	58	0	1	0	0
2005	9	118	9	0	24	58	0	0	0	1
2006	5	175	5	0	7	25	0	0	0	1

— = No data.

Table 22 shows the percentile distribution of trucks in each FHWA vehicle class 4 through 13 for each year for which traffic monitoring data are available. Table 22 also shows the mean percentile values at the bottom of the table for all years for which classification counts were submitted as part of the traffic monitoring process.

Table 22. Percentage of trucks in each vehicle class for LTPP traffic site 040100.

Year	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
1993	—	—	—	—	—	—	—	—	—	—
1994	1.4	17.4	2.9	0.0	8.4	61.1	0.5	6.8	1.5	0.0
1995	1.4	17.2	2.5	0.1	8.4	62.9	0.5	5.6	1.3	0.1
1996	1.3	15.7	2.6	0.0	8.1	64.4	0.6	5.9	1.2	0.1
1997	1.4	20.7	3.2	0.0	5.6	62.0	0.6	5.3	1.0	0.1
1998	1.2	21.8	2.6	0.0	5.6	62.1	0.5	5.2	1.0	0.1
1999	1.6	20.9	2.5	0.1	5.0	62.8	0.5	5.6	1.1	0.1
2000	2.1	23.3	2.6	0.1	5.2	60.3	0.5	4.9	1.0	0.1
2001	2.0	22.1	2.4	0.1	5.7	61.4	0.6	4.8	0.9	0.1
2002	—	—	—	—	—	—	—	—	—	—
2003	3.0	61.5	4.1	0.1	10.1	20.9	0.2	0.1	0.0	0.1
2004	2.9	53.9	3.8	0.1	12.2	26.3	0.2	0.4	0.0	0.1
2005	4.0	53.7	4.1	0.2	11.0	26.5	0.2	0.1	0.0	0.2
2006	2.2	79.9	2.3	0.0	3.4	11.6	0.2	0.0	0.0	0.3
Mean	2.0	34.0	3.0	0.1	7.4	48.5	0.4	3.7	0.7	0.1

— = No data.

As can be seen in Table 22, years 1993 and 2002 don't have traffic monitoring data. Table 22 shows that truck percentages changed dramatically in 2003 when construction events changed the nature of truck traffic using this road. Thus, the shift observable in the data is valid. What is unclear is exactly when in 2002 the traffic pattern changes. In cases where no additional information is available, the mean percentage of truck traffic by class of vehicles is used to estimate these percentages. At LTPP traffic site 040100, the dramatic change in traffic volume between 2002 and 2003 signals a major change in the truck traffic composition. Because the State highway agency understands when this change occurred and submitted an AADTT value (for all truck classes combined) that mimics the preconstruction traffic pattern, it is assumed that the preconstruction pattern applies to 2002. Thus, the average of only pre-2002 yr are used to estimate the truck traffic distribution pattern. Table 23 shows both the percentage values used for estimation and the estimated 1993–2002 AADTT values for each class of trucks, which are computed by multiplying the 1993 or 2002 AADTT value for all truck classes combined by the percentage of traffic by class.

Table 23. Computed truck volumes and percentages by truck class for LTPP traffic site 040100 in 2002 and 1993.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
Mean, pre-2002 percent by class	1.5 percent	19.9 percent	2.7 percent	0.0 percent	6.5 percent	62.1 percent	0.5 percent	5.5 percent	1.1 percent	0.1 percent
2002 AADTT by class	17	216	29	1	71	674	6	60	12	1
1993 AADTT by class	6	80	11	0	26	248	2	22	4	0

The estimated 1993 and 2002 AADTT values by FHWA vehicle classification are then used to fill in missing 1993–2002 values in the CPT.

AADTT by Vehicle Class Estimation for LTPP Traffic Site 321020, a Case of a Dataset with Gap Years and a Short-Duration Change in Vehicle Classification

The second example of the $AADTT_{ij}$ estimation process is for LTPP traffic site 321020. The section was opened to traffic on June 1, 1984, and left the LTPP GPS-1 experiment in September 2000. At that time, the LTPP test site entered the GPS-6 experiment, and it continues to be part of that experiment today. As shown in table 20, traffic monitoring data exist for parts of 8 different years beginning in 1991 and ending in 2003. Counts for these years provided data from between 16 and 295 d of the year. In addition, the Nevada DOT supplied estimates of AADTT (total for all truck classes) for 1984–2000. AADTT values were displayed in table 20. In addition, two short-duration vehicle classification counts, both lasting less than 24 h, were performed in 1985 and 1988. Table 24 shows $AADTT_{ij}$ values for the years during which traffic monitoring data were submitted. Table 25 shows these values converted to a percentage of average annual truck volume. Also, table 25 contains the historical percentages from the 1985 and 1988 short-duration vehicle classification counts, shown on the first two rows.

Table 24. $AADTT_{ij}$ by FHWA truck class at LTPP traffic site 321020.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13	Total Truck Volume
1991	2	25	3	1	6	102	3	9	4	9	165
1992	2	24	3	2	5	110	2	9	5	14	176
1993	2	22	4	1	8	122	2	15	5	12	194
1996	2	36	10	0	5	148	8	11	7	45	271
1997	3	17	7	2	7	157	14	18	10	35	270
2000	2	13	4	1	8	135	23	37	26	81	329
2002	5	24	3	0	4	260	3	15	6	21	342
2003	3	24	6	1	10	204	3	8	6	14	276

Table 25. Percent of $AADTT_{ij}$ by FHWA truck class by year at LTPP traffic site 321020.

Year	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
1985	1.1	21.1	7.4	3.2	0.0	54.7	0.0	4.2	1.1	7.4
1988	0.6	14.3	2.5	0.0	3.1	55.9	0.0	1.9	6.2	15.5
1991	1.1	15.2	1.9	0.8	3.6	62.2	1.8	5.6	2.4	5.4
1992	1.1	13.4	1.7	0.9	2.9	62.6	1.1	5.4	2.6	8.2
1993	1.2	11.6	2.0	0.6	4.3	62.7	1.1	7.8	2.6	6.2
1996	0.8	13.2	3.6	0.0	1.7	54.4	2.8	4.0	2.7	16.6
1997	1.0	6.4	2.7	0.6	2.6	58.1	5.2	6.5	3.8	13.1
2000	0.6	4.0	1.1	0.4	2.5	41.1	6.8	11.1	7.8	24.6
2002	1.4	7.0	0.9	0.0	1.1	76.1	1.0	4.5	1.8	6.3
2003	1.2	8.6	2.0	0.2	3.4	73.6	1.1	2.8	2.1	5.0

The data QA/reasonableness review found two periods when large changes in vehicle percentages and volumes occurred. This resulted in a manual review of available LTPP data. A decrease of greater than 15 percent occurs in FHWA Class 9 trucks in 2000 when compared to the previous record (1997); this is followed by an increase in 2002 (the next year of data). In 2000, there is also a significant increase in the volume of FHWA Class 13 vehicles, a lesser increase in other combination truck classes, and a decrease in FHWA Class 9 vehicles. These increased volumes go away in 2002 when volumes return to a more typical pattern, although FHWA Class 9 volume continues to be higher than in previous years.

An examination of equipment replacement and calibration records in the LTPP database provides no information on the equipment. An examination of the data in the LTAS database shows changes in traffic volume patterns. It is possible that some vehicle misclassification occurred in 2000. However, it is also possible that changes in local traffic patterns due to non-LTPP-related road construction activity caused these volume changes.

The analysis of data in tables 25 and 26 indicate that truck volumes and percentages tend to vary substantially over time at this site, yet the basic pattern of the percentage of travel by each truck class is reasonably consistent. That is, FHWA Class 9 trucks are by far the largest category of trucks. Only in 2000 does FHWA Class 9 drop below 50 percent of the truck traffic, and during 2000, the major reason for the decline in FHWA Class 9 percentage was a unique growth in FHWA Class 11 and 13 truck volumes rather than a significant decline in FHWA Class 9 volumes. Such growth—without a commensurate increase in FHWA Class 5 or 8 truck volumes—is not a common classification error; it is likely the result of temporary construction activity placing heavy truck loads on this road section.

The manual review of historical records available in LTPP database concluded nothing in these historical data suggest that taking the mean value of the percentage of travel by vehicle classification from traffic monitoring data would lead to a poor estimate of truck travel by classification. This was done, and these percentages were applied to $AADTT_i$ values found in the previously developed CPT whenever actual traffic monitoring data were not available. (Note that these mean values were also used to create the CPT describing the representative percentages of travel by vehicle classification.) Table 26 is the resulting new CPT. The exception to this was that historical short-count data were used for the percentage of truck travel in the two years where those data were collected.

Table 26 shows the final table of $AADTT_{ij}$ for LTPP traffic site 321020 from the year it first opened to traffic until the end of 2015. Table 26 was used to extract the two CPTs for LTPP traffic site 321020, one for the GPS-1 experiment (July 1984–September 2000) and the other for the GPS-6 experiment (September 2000 to present).

Table 26. CPT for *AADTT$_{ij}$* by FHWA vehicle classification for FHWA Classes 4–13 at LTPP traffic site 321020.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13	Source
1984	1	12	2	1	3	72	3	7	4	13	S
1985	1	23	8	3	0	60	0	5	1	8	S
1986	1	11	2	0	3	67	3	6	3	12	S
1987	1	14	3	1	4	88	4	9	5	15	S
1988	1	26	5	0	6	102	0	3	11	28	S
1989	2	18	4	1	5	112	5	11	6	20	S
1990	2	17	3	1	5	103	4	10	5	18	S
1991	2	25	3	1	6	102	3	9	4	9	M
1992	2	24	3	2	5	110	2	9	5	14	M
1993	2	22	4	1	8	122	2	15	5	12	M
1994	2	23	5	1	6	141	6	14	7	25	S
1995	3	29	6	1	8	180	8	17	9	31	S
1996	2	36	10	0	5	148	8	11	7	45	M
1997	3	17	7	2	7	157	14	18	10	35	M
1998	2	24	5	1	7	147	6	14	8	26	S
1999	4	39	8	2	11	239	10	23	13	42	S
2000	2	13	4	1	8	135	23	37	26	81	M
2001	3	33	7	1	9	205	9	20	11	36	E
2002	5	24	3	0	4	260	3	15	6	21	M
2003	3	24	6	1	10	204	3	8	6	14	M
2004	4	40	8	2	11	246	11	24	13	43	E
2005	4	42	9	2	12	262	11	25	14	46	E
2006	5	45	9	2	13	279	12	27	15	49	E
2007	5	48	10	2	13	296	13	29	15	52	E
2008	5	51	10	2	14	315	13	31	16	55	E
2009	6	54	11	2	15	335	14	33	18	58	E
2010	6	58	12	3	16	356	15	35	19	62	E
2011	6	61	12	3	17	379	16	37	20	66	E

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13	Source
2012	7	65	13	3	18	403	17	39	21	70	E
2013	7	69	14	3	19	428	18	42	22	75	E
2014	8	73	15	3	21	455	19	44	24	79	E
2015	8	78	16	3	22	484	21	47	25	84	E

AADTT by Vehicle Class Estimation for LTPP Traffic Site 320100, Case of Dataset with Gap Years and No Significant Changes in Vehicle Classification over the Years

The third example of the $AADTT_{ij}$ estimation process is for LTPP traffic site 32-0100. This site joined the LTPP experiment in 1993, opened to traffic on September 1, 1995, and left the experiment July 1, 2009. Table 27 shows the $AADTT_i$ for each of the 10 FHWA truck classes for each year for which traffic monitoring data are available through 2009, when the site left the LTPP experiment.

Table 27. *AADTT_{ij}* for each vehicle class for LTPP traffic site 320100.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
1996	15	64	15	0	17	798	22	18	18	82
1997	17	165	15	0	17	828	25	18	14	113
1998	17	154	17	0	17	880	27	19	12	143
1999	16	175	14	0	19	980	23	22	10	137
2000	16	154	13	0	19	934	20	23	10	181
2001	16	152	14	0	17	922	22	25	12	136
2002	16	153	12	0	17	914	19	19	11	123
2003	19	182	13	0	19	993	17	19	11	132
2004	21	215	16	0	21	1013	18	22	13	141
2005	8	86	14	1	22	959	24	22	14	61
2006	25	25	28	0	82	898	38	24	16	147
2007	—	—	—	—	—	—	—	—	—	—
2008	23	23	23	1	34	705	22	26	16	84
2009	23	19	19	1	25	702	20	22	17	80

— = No data.

These values were used in the CPT. However, annual statistics were also needed for 1995 and 2007. These values were computed by taking the mean percentage of truck traffic across all years and multiplying that by AADTT for all truck classes combined (See computation results in Table 29).

Table 28 shows the percentage of trucks in each FHWA vehicle classes 4 through 13 for each year for which traffic monitoring data are available. Analysis of these data shows no major changes in classification percentages during the LTPP experiment. Thus, the mean value of these conditions is assumed to be the best estimator of truck percentages during the years when no traffic monitoring data are available. The mean value of these annual statistics is shown at the base of the table.

Table 28. Percent of AADTT by FHWA truck class at LTPP traffic site 320100.

Year	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
1996	1.5	6.1	1.4	0.0	1.6	76.0	2.1	1.7	1.7	7.8
1997	1.4	13.6	1.2	0.0	1.4	68.3	2.0	1.4	1.2	9.3
1998	1.3	12.0	1.4	0.0	1.4	68.3	2.1	1.5	0.9	11.1
1999	1.1	12.5	1.0	0.0	1.4	70.2	1.6	1.6	0.7	9.8
2000	1.1	11.2	1.0	0.0	1.4	68.2	1.4	1.7	0.8	13.2
2001	1.2	11.5	1.0	0.0	1.3	70.1	1.7	1.9	0.9	10.4
2002	1.3	11.9	1.0	0.0	1.3	71.1	1.5	1.5	0.8	9.6
2003	1.4	12.9	0.9	0.0	1.3	70.7	1.2	1.3	0.8	9.4
2004	1.4	14.5	1.1	0.0	1.4	68.5	1.2	1.5	0.9	9.5

Year	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
2005	0.7	7.1	1.1	0.1	1.9	79.2	2.0	1.8	1.2	5.1
2006	2.0	2.0	2.2	0.0	6.4	69.9	3.0	1.9	1.2	11.5
2007	—	—	—	—	—	—	—	—	—	—
2008	2.4	2.4	2.4	0.1	3.6	73.6	2.3	2.8	1.7	8.8
2009	2.5	2.1	2.1	0.1	2.7	75.6	2.1	2.4	1.8	8.6
Mean value	2.1	8.5	1.5	0.0	2.0	71.7	1.8	1.6	1.2	9.6

— = No data.

Using these percentages and the AADTT values from table 19, the computed parameters for the 2 yr during which no traffic monitoring data were collected are computed and shown in table 29.

Table 29. Computed $AADTT_{ij}$ values by FHWA truck class for missing years at LTPP traffic site 320100.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
1995	26	107	19	0	25	904	23	20	16	121
2007	26	106	19	0	25	891	23	19	15	119

These values were included with traffic monitoring data shown previously in table 27 to produce the required CPT. The mean percentage values are also used to create the CPT for representative percentage of travel by each vehicle class (FHWA Classes 4–13).

TOTAL ANNUAL TRUCK VOLUME

Computed Parameter Description

Total annual truck volume ($Total\ Annual\ Truck\ Volume_i$) is a parameter derived from AADTT. $Total\ Annual\ Truck\ Volume_i$ is the sum of all truck traffic for each day, while AADTT is the average daily value. $Total\ Annual\ Truck\ Volume_i$ is computed for each in-service year i and characterizes total annual volume of vehicles in FHWA Classes 4–13.

Data Sources used for Parameter Computation

Total annual truck volume is based on the $AADTT_i$ computed parameter statistic described in previous sections. It relies on no additional data other than the dates when the LTPP test lane was open to traffic for each year, which are used to determine the number of days included in years where the LTPP site was open for only a portion of the year.

Methodology and Computational Procedure for Parameter Computing or Estimating

$Total\ Annual\ Truck\ Volume_i$ is computed for each in-service year the pavement was part of the LTPP experiment using a simple computational formula shown in the following equation:

$$Total\ Annual\ Truck\ Volume_i = AADTT_i \times (number\ of\ days\ open\ to\ traffic\ in\ year\ i) \quad (5)$$

Where:

number of days open to traffic in year i = number of days the roadway was open to traffic in year *i*.

Examples of Parameter Estimating

Because this computation is simple, only one example is given. Table 30 shows how total annual truck volume is computed for LTPP traffic site 040100. This road opened to traffic on June 1, 1993, and left the LTPP experiment on June 1, 2006.[1] Thus, the first year of traffic is a partial year. In addition, the computation needs to account for the extra day in leap years (1996, 2000, 2004). Note that, if the LTPP test section leaves the experiment partway through the last calendar year, the last year of traffic can also be expressed as a partial year.

Table 30. Total annual truck volume estimates for LTPP traffic site 040100.

Year	AADTT	Number of Days Open to Traffic	Total Annual Truck Volume
1993	400	184	73,600
1994	629	365	229,585
1995	657	365	239,805
1996	714	366	261,324
1997	770	365	281,050
1998	835	365	304,775
1999	875	365	319,375
2000	950	366	347,700
2001	1,006	365	367,190
2002	1,085	365	396,025
2003	214	365	78,110
2004	221	366	80,886
2005	220	365	80,300
2006	219	151	33,069

TOTAL ANNUAL TRUCK VOLUME FOR EACH TRUCK CLASS (FHWA VEHICLE CLASSES 4–13)

Computed Parameter Description

Total annual truck volume for each truck class ($Total\ Annual\ Volume\ Truck\ Class_{ij}$) is related to the computed parameter $AADTT_{ij}$ described previously. $Total\ Annual\ Volume\ Truck\ Class_{ij}$ is the product of $AADTT_{ij}$ by the number of days in a given year the LTPP site was open to traffic. This

[1]The annual total volume for 2006 is low because it is assumed that the last day of traffic for the LTPP experiment was May 31, 2006.

statistic is computed for each in-service year (i) and each truck class (j) (i.e., FHWA Classes 4–13).

Data Sources used for Parameter Computation

Total Annual Volume Truck Class$_{ij}$ is based on the computed parameter AADTT by FHWA vehicle class. It relies on no additional data other than the dates the LTPP test lane was open to traffic for each year.

Methodology and Computational Procedure for Parameter Computing

The procedure for computing *Total Annual Volume Truck Class$_{ij}$* for each FHWA vehicle class j (j changes from 4 to 13) and year i is shown in the following equation:

$$Total\ Annual\ Volume\ Truck\ Class_{ij} = AADTT_{ij} \text{ x } (number\ of\ days\ open\ to\ traffic\ in\ year\ i) \quad (6)$$

If the LTPP test section leaves the experiment partway through the last calendar year, the number of days in the last year of traffic will be less than a full year.

Examples of Parameter Estimating

Because this computation is simple, only one example is given. Table 31 shows how *Total Annual Truck Volume$_i$* is computed for FHWA Class 9 vehicles for LTPP traffic site 040100. This same computation is performed for each of the 10 FHWA vehicle classes, and the multiplier is the same for each vehicle class. This road opened to traffic on June 1,1993 and left the LTPP experiment on June 1, 2006. Thus, both the first and last year of traffic are partial years. In addition, the computation needs to account for the extra day in leap years (1996, 2000, 2004).

Table 31. Total annual truck volume estimates for FHWA Class 9 for LTPP traffic site 040100.

Year	AADTT for FHWA Class 9	Number of Days Open to Traffic	Total Annual Volume for FHWA Class 9
1993	248	184	45,632
1994	384	365	140,160
1995	413	365	150,745
1996	459	366	167,994
1997	477	365	174,105
1998	518	365	189,070
1999	549	365	200,385
2000	571	366	208,986
2001	617	365	225,205
2002	674	365	246,010
2003	45	365	16,425
2004	58	366	21,228
2005	58	365	21,170
2006	25	151	3,775

CUMULATIVE TOTAL TRUCK VOLUME FOR VEHICLES IN FHWA CLASSES 4–13 COMBINED, ESTIMATED AND COMPOUNDED ANNUALLY

Computed Parameter Description

Cumulative total truck volume for vehicles in FHWA Classes 4–13 combined (*Cumulative Total Truck Volume*) is defined as the total number of trucks that passed over the LTPP test section at a defined point in time, typically the end of a given calendar year. A separate value is computed for each year an LTPP site is open to traffic, considering traffic from all previous years. This process continues until the site leaves the LTPP experiment. For LTPP sites at which traffic data are being collected and where those traffic volumes apply to more than one LTPP experiment, these computations are made for each experiment and are performed for each traffic site until the last LTPP experiment using that site's traffic data leaves the LTPP experiment.

Data Sources used for Parameter Computation

Cumulative Total Truck Volume is based on the computed parameter *Total Annual Truck Volume$_i$*. It relies on no additional data other than the dates the LTPP traffic site was open to traffic for each year and decommissioned from LTPP experiment.

Methodology and Computational Procedure for Parameter Computing

Cumulative Total Truck Volume$_i$ is the sum of all *Total Annual Truck Volume$_i$* statistics for each year from the date an LTPP site opened to traffic to the end of the year (*i*) for which cumulative truck traffic was computed. Thus, if a roadway opened to traffic on July 1, 1985, and the year for which cumulative traffic was provided is 1990, the reported value would be the sum of the *Total Annual Truck Volume$_i$* for 1985–1990, and where the value of *Total Annual Truck Volume$_i$* for 1985 represents only 6 mo of traffic. The basic procedure is represented mathematically in the following equation:

$$Cumulative\ Total\ Truck\ Volume_i = \sum_{Opening\ Date}^{Date\ of\ Interest} Total\ Annual\ Truck\ Volume_i \qquad (7)$$

Where:

Opening Date = date when pavement was first opened to traffic.

Date of Interest = last date in the accumulating period or the date when the site was deassigned from the LTPP experiment.

Note that, in both the first and last years of this computation, *Total Annual Truck Volume$_i$* is based on the total period during the year the site was part of the LTPP experiment. If the LTPP traffic site leaves the experiment partway through the last calendar year, the *Total Annual Truck Volume$_i$* for the last year of traffic will represent a partial year.

Examples of Parameter Estimating

Because this computation is simple, only two examples are given.

Cumulative Total Truck Volume Estimation for LTPP Traffic Site 040100

Table 32 shows how *Cumulative Total Truck Volume$_i$* is computed at LTPP traffic site 040100. This road was opened to traffic on June 1,1993, and left the LTPP experiment on June 1, 2006. Thus, the first and last years of traffic are partial years.

Table 32. Cumulative total truck volume for LTPP traffic site 040100.

Year	AADTT	Number of Days Open to Traffic	Total Annual Truck Volume	Cumulative Total Truck Volume
1993	400	184	73,600	73,600
1994	629	365	229,585	303,185
1995	657	365	239,805	542,990
1996	714	366	261,324	804,314
1997	770	365	281,050	1,085,364
1998	835	365	304,775	1,390,139
1999	875	365	319,375	1,709,514
2000	950	366	347,700	2,057,214
2001	1,006	365	367,190	2,424,404
2002	1,085	365	396,025	2,820,429
2003	214	365	78,110	2,898,539
2004	221	366	80,886	2,979,425
2005	220	365	80,300	3,059,725
2006	219	151	33,069	3,092,794

Cumulative Total Truck Volume Estimation for LTPP Traffic Site 321020, Case of Two LTPP Experiments Using a Single Data Source

The second example uses LTPP traffic site 321020 because it serves two different LTPP experiments. The first experiment, a GPS-1 project, experienced traffic from June 1, 1984, until September 11, 2000. These cumulative totals are shown in table 33. After de-assignment from GPS-1 project, this site joined the GPS-6 experiment and continues to be part of that experiment today. CTVs restart at “0” when a site enters a new experiment. Computed parameters are developed through 2015 for the GPS-6 experiment. These values are shown in table 34.

Table 33. Cumulative total truck volume for LTPP traffic site 321020: GPS-1 experiment.

Year	AADTT	Number of Days Open to Traffic	Total Annual Truck Volume	Cumulative Total Truck Volume
1984	117	151	17,667	17,667
1985	109	365	39,785	57,452
1986	109	365	39,785	97,237
1987	144	365	52,560	149,797
1988	183	366	66,978	216,775
1989	183	365	66,795	283,570
1990	168	365	61,320	344,890
1991	165	366	60,390	405,280
1992	176	365	64,240	469,520

Year	AADTT	Number of Days Open to Traffic	Total Annual Truck Volume	Cumulative Total Truck Volume
1993	194	365	70,810	540,330
1994	230	365	83,950	624,280
1995	293	366	107,238	731,518
1996	271	365	98,915	830,433
1997	270	365	98,550	928,983
1998	240	365	87,600	1,016,583
1999	390	366	142,740	1,159,323
2000	329	254	83,566	1,242,889

Table 34. Cumulative total truck volume for LTPP traffic site 321020: GPS-6 experiment.

Year	AADTT	Number of Days Open to Traffic	Total Annual Truck Volume	Cumulative Total Truck Volume
2000	329	112	36,848	36,848
2001	334	365	121,910	158,758
2002	342	365	124,830	283,588
2003	276	365	100,740	384,328
2004	402	366	147,132	531,460
2005	427	365	155,855	687,315
2006	454	365	165,710	853,025
2007	483	365	176,295	1,029,320
2008	513	366	187,758	1,217,078
2009	546	365	199,290	1,416,368
2010	580	365	211,700	1,628,068
2011	617	365	225,205	1,853,273
2012	656	366	240,096	2,093,369
2013	697	365	254,405	2,347,774
2014	742	365	270,830	2,618,604
2015	788	365	287,620	2,906,224

CUMULATIVE TRUCK VOLUME FOR EACH VEHICLE CLASS (FHWA CLASSES 4–13), ESTIMATED AND COMPOUNDED ANNUALLY

Computed Parameter Description

Cumulative truck volume by vehicle class ($Cumulative\ Volume\ Truck\ Class_{ij}$) is defined as the total number of trucks passing over the LTPP test section at a defined point in time. A separate value is computed for each class of trucks (*j*) for each year (*i*) an LTPP site is open to traffic. This process continues until the site leaves the LTPP experiment. For LTPP sites at which traffic data are collected and where those traffic volumes apply to more than one LTPP experiment, these computations are made for each experiment and performed for each traffic site until the last LTPP experiment using that site's data leaves the LTPP experiment.

Data Sources used for Parameter Computation

Cumulative Volume Truck Class$_{ij}$ is based on the *Total Annual Volume Truck Class*$_{ij}$ parameter described previously in this chapter. It relies on no additional data other than the dates the LTPP test lane was open to traffic for each year and when the LTPP site left the experiment.

Methodology and Computational Procedure for Parameter Computing

Cumulative Volume Truck Class$_{ij}$ value is the sum of all *Total Annual Volume Truck Class*$_{ij}$ statistics for each year from the date a site opened to traffic to the last year (*i)* for which cumulative traffic was computed. Thus, if a roadway opened to traffic July 1, 1985, and the year for which cumulative traffic was provided is the end of 1990, the reported value would be the sum of the *Total Annual Volume Truck Class*$_{ij}$ for 1985–1990, where *Total Annual Volume Truck Class*$_{ij}$ for 1985 represents only 6 mo of traffic. This is represented mathematically in the following equation:

$$Cumulative\ Volume\ Truck\ Class_{ij} = \sum_{Opening\ Date}^{Date\ of\ Interest} Total\ Annual\ Volume\ Truck\ Class_{ij} \tag{8}$$

From these cumulative statistics, one additional traffic parameter is computed: *Cumulative Heavy Truck Volume*$_i$ for each year (*i*), which is the sum of all *Cumulative Volume Truck Class*$_{ij}$ values across all FHWA Classes 4–13, except FHWA Class 5 for that year.

Examples of Parameter Estimating

Because this computation is simple, only one example is given. Table 35 shows how *Cumulative Volume Truck Class*$_{ij}$ is computed for FHWA Class 9 for LTPP traffic site 040100. The only difference between this process and what is shown in table 32 is that the computation is performed for each vehicle class *j* (*j*=9 in this example) starting from the CPT *Total Annual Volume Truck Class*$_{ij}$ rather than starting from *Total Annual Truck Volume*$_i$ (for all truck classes combined). This same computation is performed for each of the 10 vehicle classes. LTPP traffic site 040100 opened to traffic June 1, 1993, and left the LTPP experiment June 1, 2006. Thus, both the first and last year of traffic are partial years.

Table 35. Cumulative total truck volume for FHWA Class 9 trucks for LTPP traffic site 040100.

Year	AADTT for FHWA Class 9	Number of Days Open to Traffic	Total Annual Truck Volume for FHWA Class 9	Cumulative Total Truck Volume for FHWA Class 9
1993	248	184	45,632	45,632
1994	384	365	140,160	185,792
1995	413	365	150,745	336,537
1996	459	366	167,994	504,531
1997	477	365	174,105	678,636
1998	518	365	189,070	867,706

Year	AADTT for FHWA Class 9	Number of Days Open to Traffic	Total Annual Truck Volume for FHWA Class 9	Cumulative Total Truck Volume for FHWA Class 9
1999	549	365	200,385	1,068,091
2000	571	366	208,986	1,277,077
2001	617	365	225,205	1,502,282
2002	674	365	246,010	1,748,292
2003	45	365	16,425	1,764,717
2004	58	366	21,228	1,785,945
2005	58	365	21,170	1,807,115
2006	25	151	3,775	1,810,890

Producing the TRF_TREND CPT

The TRF_TREND CPT, was developed by the research team to include traffic parameters described in the previous sections of this chapter for each LTPP traffic site. The methodologies described in the previous sections of this chapter were used for parameter extraction from the available LTPP traffic data sources or for parameter estimation. For each LTPP traffic site, one row in the TRF_TREND table is present for each calendar year a site was open to traffic until the site leaves the LTPP experiment.

MEPDG TRUCK VOLUME GROWTH PARAMETERS

Computed Parameter Description

For analyses using AASHTOWare Pavement ME Design software, there is no option for direct entry of annual truck volume statistics for each year of pavement analysis. Instead, the software requires the user to enter truck volume growth parameters: an initial (i.e., base year) AADTT value, percentile vehicle class distribution for FHWA Classes 4–13, growth function, and growth rate. These parameters are used within AASHTOWare Pavement ME Design software to provide truck volume estimates over the course of the pavement analysis. These parameters include the following:

- AADTT_FIRST_YEAR_LTPP_LANE, which represents base year AADTT used in pavement analysis with AASHTOWare Pavement ME Design software.
- $VEH\_CLASS\_DISTRIBUTION\_PERCENT_i$, which is the percent of the base year AADTT related to a specific FHWA vehicle class (i) provided for each of the 10 truck classes (FHWA Classes 4–13).
- $VEH\_CLASS\_GROWTH\_FUNCTION_i$, which defines whether the MEPDG will use a linear or compound growth function to estimate volumes for vehicle class (i) for years after the base year.
- $VEH\_CLASS\_GROWTH\_RATE_i$, which is the rate of growth applied to vehicle class (i) in the equation type specified using $VEH\_CLASS\_GROWTH\_FUNCTION_i$.

A separate growth function and growth rate is provided for each FHWA vehicle Class 4 to 13. Only one usability rating, describing how well computed parameters represent traffic at the site, is provided for the site.

Data Sources Used for Parameter Computation

Data for developing MEPDG truck volume growth parameters come from the computed parameters tables described in previous sections. Growth parameter computations are based on the values of the parameter $AADTT_{ij}$ provided for each in-service year for each truck class. Because they are computed parameters, these data are present for all years an LTPP site was open to traffic. In a few cases, additional data are present at the traffic count site for years after the site left the LTPP experiment. These data are available for computing AADTT values and developing growth rates.

Methodology and Computational Procedure for Parameter Computing

An important aspect of developing the MEPDG truck volume growth parameters is that the $AADTT_{ij}$ estimates produced using these parameters may not be identical to the the $AADTT_{ij}$ estimates provided in the TRF_TREND table. This is because AASHTOWare Pavement ME Design software allows input of only one growth function and growth rate per vehicle class for the entire analysis period and one base year AADTT value (for FHWA Classes 4–13 combined). Base year AADTT is converted into base year $AADTT_i$ within the software using the $VEH\_CLASS\_DISTRIBUTION\_PERCENT_i$ values. The purpose of the MEPDG truck growth parameters (MEPDG base year AADTT, percent truck distribution by vehicle class, growth function, and growth rate) is to allow AASHTOWare Pavement ME Design software to generate annual truck volumes over the analysis period that provide the best estimates of cumulative truck traffic at a site given the limitation of input options in AASHTOWare Pavement ME Design software (i.e., allowing only one base year AADTT value, one growth function, and one growth rate per each vehicle class).

Truck volumes can be volatile from year to year, and changes in truck volumes year over year do not always follow consistent linear or compound trends. The percentage difference between computed truck volumes based on these growth functions and reported truck volumes based on actual traffic monitoring data may be high for some years, especially for low-volume roads or truck classes where year-to-year variation is high. The methodology for developing computed parameters is intended to select values that minimize differences in the total truck volume by class accumulated over the total analysis period; however, the percentage difference observed during any given year may be substantial.

To compute the MEPDG truck volume growth parameters, $AADTT_{ij}$ values are extracted from the CPT TRF_TREND table for each in-service year for each truck class. These values are used in two different regression models, one linear and one compound in formulation. The equation with the better (i.e., larger) R-squared value is selected as the model for each vehicle class. Growth coefficients and the formulation of that model are extracted and used to populate the CPT housing the MEPDG truck volume growth parameter. The CPT also includes an indicator of which formula is used for that vehicle class's growth curve.

The linear growth function formulation is shown in the following equation:

$$MEPDG\_AADTT_{ij} = (MEPDG\_AADTT_{Base_j} * Age_i * (Growth_{percent}/100)) + MEPDG\_AADTT_{Base_j} \quad (9)$$

Where:

MEPDG_AADTT$_{ij}$ = AADTT value for FHWA Class *j* in year *i* estimated by MEPDG growth function.

MEPDG_AADTT$_{Base\,j}$ = base year AADTT for FHWA Class *j*, which is computed by multiplying the LTPP lane AADTT value for the first year a site opened to traffic (*AADTT_FIRST_YEAR_LTPP_LANE*) by the percentage of vehicles in class *j* (*VEH_CLASS_DISTRIBUTION_PERCENT*$_j$).

Age_i = age of the traffic site in year *i* where the first year of traffic operating over the site is equal to year "0."

$Growth_{percent}$ = linear growth rate, expressed as a percent.

The compound growth function formulation is shown in the following equation:

$$MEPDG\_AADTT_{ij} = MEPDG\_AADTT_{Base_j} * (1 + Growth_{percent}/100)\hat{}Age_i \quad (10)$$

Note that all AADTT values are reported rounded to the nearest integer. Mathematically, for low-volume vehicle classes, *MEPDG_AADTT*$_{Base\text{-}j}$ can be less than 1. In all cases where this occurs and vehicles of class *j* are present, the *MEPDG_AADTT*$_{Base\text{-}j}$ value is rounded up to 1.

The *AADTT_FIRST_YEAR_LTPP_LANE* value in the CPT is computed as shown in the following equation:

$$AADTT\_FIRST\_YEAR\_LTPP\_LANE = \sum_4^{13} MEPDG\_AADTT_{Base_j} \quad (11)$$

Where *AADTT_FIRST_YEAR_LTPP_LANE* is the LTPP lane AADTT value for the first year a site opened to traffic.

The values for the percentage of base year AADTT in each of the vehicle classes (*VEH_CLASS_DISTRIBUTION_PERCENT*$_j$) are computed by dividing *MEPDG_AADTT*$_{Base\,j}$ by *AADTT_FIRST_YEAR_LTPP_LANE* and multiplying the result by 100.

VEH_CLASS_GROWTH_USE_RATING index was developed by the research team to describe how effectively growth functions computed from available data for the site represent estimates of truck traffic volume growth occurring over the life of the pavement. The index is determined by examining a combination of the sources of the $AADTT_i$ and $AADTT_{ij}$ traffic parameters presented in previous sections and the consistency (i.e., uniformity) of truck volume trends at a site. Generally, the more traffic monitoring data present for each LTPP site, the better the rating. But, since the MEPDG requires using a consistent linear or compound growth trend, significant discontinuities or abrupt truck volume changes in those trends detract from the reliability of such a formulation when predicting annual loading values. Thus, even if good, site-specific data are present for creating the growth function, if external factors caused major discontinuities or changes in truck volume trends, the usability rating is lowered to reflect that the trend function may not produce a close approximation of actual traffic loading conditions experienced by the best fit growth function.

Details of the usability rating for the *VEH_CLASS_GROWTH_USE_RATING* parameter are provided in chapter 11 and summarized as follows:

- A "Best" (code 1) rating is given when more than 75 percent of years of data used in computing the growth equation have vehicle class data from the traffic monitoring program and during no year of traffic monitoring data does the year-to-year percentage of truck traffic within one class of trucks change by more than 15 percent (e.g., FHWA Class 9 trucks does not grow from 50 percent to more than 65 percent of total truck traffic).

- A "Better" rating (code 2) is given when more than 50 percent of years of data used in computing the growth equation have vehicle class data from the traffic monitoring program and during no year of monitoring data does the year-to-year percentage of truck traffic within one class of trucks change by more than 15 percent.

- A "Good" (code 3) rating is given when more than 50 percent, but less than 75 percent, of years of data used in computing the growth equation have vehicle class data from the traffic monitoring program and during no year of traffic monitoring data does the year-to-year percentage of truck traffic within one class of trucks change by more than 15 percent.

- A "Fair" (code 4) rating is given if no code has been assigned above, and more than 25 percent of years of data used in computing the growth equation have vehicle class data from the traffic monitoring program.

- A "Poor" (code 5) rating is given if less than 25 percent of years of data used in computing the growth equation have data from the traffic monitoring program, but at least 1 yr of traffic monitoring vehicle classification data is collected during the experiment.

- A rating of "Bad" (code 6) is given if no traffic monitoring data are present for a site.

Examples of Parameter Estimating

Estimation of Truck Volume Growth Parameters for LTPP Traffic Site 040100

The first example describes the computation of growth parameters for LTPP traffic site 040100. Table 36 shows values for the computed parameter $AADTT_{ij}$ extracted from the TRF_TREND table for each in-service year for each truck class for this site. Table 37 shows the R-squared statistics for each growth model formulation. The best fit formulations, as judged by the R-squared value, are identified by "*." The R-squared value is based on comparison between computed parameter $AADTT_{ij}$ values and MEPDG_$AADTT_{ij}$ values predicted by the growth model. Growth rate and AADTT base value are given in Table 37 for the "best fit" equation formulation for each vehicle class (FHWA Classes 4–13), along with an indicator of which formulation was selected for that class.

Table 36. *$AADTT_{ij}$* for each vehicle class for LTPP traffic site 040100.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
1993	6	80	11	0	26	248	2	22	4	0
1994	9	109	18	0	53	384	3	43	9	0
1995	9	113	16	1	55	413	3	37	9	1
1996	9	112	18	0	58	459	4	42	8	1
1997	11	159	24	0	43	477	5	41	8	1
1998	10	182	22	0	47	518	4	43	8	1
1999	14	182	22	0	44	549	4	49	9	1
2000	20	221	25	1	49	571	5	46	9	1
2001	20	223	24	1	57	617	6	49	9	1
2002	17	216	29	1	71	674	6	60	12	1
2003	6	131	9	0	22	45	0	0	0	0
2004	6	119	8	0	27	58	0	1	0	0
2005	9	118	9	0	24	58	0	0	0	1

Table 37. Growth function attributes for each vehicle class for LTPP traffic site 040100.

Parameter	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
Linear R-squared	0.000	0.146	0.114	0.002	0.213	0.199	0.170	0.289	0.332	0.015*
Compound R-squared	0.006*	0.185*	0.221*	0.015*	0.296*	0.428*	0.404*	0.548*	0.556*	0.014
Growth rate, percent	-0.8	3.3	-5.8	-1.7	-7.4	-16.5	-15.6	-35.4	-37.1	-0.8
MEPDG $AADTT_{Base\ j}$	10	118	23	1	61	779	6	165	35	1
Vehicle class distribution, percent	0.83	9.84	1.92	0.08	5.09	64.97	0.50	13.76	2.92	0.08
Equation type	C	C	C	C	C	C	C	C	C	L

*Best fit model.
C = compound growth; L = linear growth.

AADTT_FIRST_YEAR_LTPP_LANE is the sum of base year *$AADTT_{ij}$* values in Table 37, which is 1,199.

Because LTPP traffic site 040100 experiences a major discontinuity in truck travel in 2003, table 36 illustrates the limitations of using a single growth formula for estimating truck travel on roads that do not experience consistent traffic patterns. The resulting R-squared value illustrates how poorly the linear and compound growth functions replicate traffic monitoring volume patterns. But, since these are the only formulas allowed by AASHTOWare Pavement ME Design software, the best of these allowable formulations are computed, as shown in Table 37, and are placed in the computed parameter for MEPDG truck volume growth parameters.

Discontinuity caused the *VEH_CLASS_GROWTH_USE_RATING* for LTPP traffic site 040100 to be set to 4 (Fair). If not for the discontinuity, this site would be rated as 1 (Best).

Estimation of Truck Volume Growth Parameters for LTPP Traffic Site 320100

The second example describes the computation of MEPDG truck volume growth parameters for LTPP traffic site 320100. Table 38 shows the computed parameter $AADTT_{ij}$ values extracted for each in-service year for each truck class for this site. Table 39 shows the R-squared statistics for each model formulation. The best fit formulations, as judged by the R-squared value, are identified by "*." The R-squared value is based on comparison between computed parameter $AADTT_{ij}$ values and $MEPDG\_AADTT_{ij}$ values predicted by the growth model. Growth rate and AADTT base value are given in Table 39 for the "best fit" equation formulation for each vehicle class (FHWA Classes 4–13), along with an indicator of which formulation was selected for that class.

Table 38. $AADTT_{ij}$ for each vehicle class for LTPP traffic site 320100.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
1995	26	107	19	0	25	904	23	20	16	121
1996	15	64	15	0	17	798	22	18	18	82
1997	17	165	15	0	17	828	25	18	14	113
1998	17	154	17	0	17	880	27	19	12	143
1999	16	175	14	0	19	980	23	22	10	137
2000	16	154	13	0	19	934	20	23	10	181
2001	16	152	14	0	17	922	22	25	12	136
2002	16	153	12	0	17	914	19	19	11	123
2003	19	182	13	0	19	993	17	19	11	132
2004	21	215	16	0	21	1013	18	22	13	141
2005	8	86	14	1	22	959	24	22	14	61
2006	25	25	28	0	82	898	38	24	16	147
2007	26	106	19	0	25	891	23	19	15	119
2008	23	23	23	1	34	705	22	26	16	84
2009	23	19	19	1	25	702	20	22	17	80

Table 39. Growth function characteristics for each vehicle class for LTPP traffic site 320100.

Parameter	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
Linear R-squared	0.002	0.116	0.051*	0.300*	0.113	0.054	0.000	0.3029*	0.0019	0.054

Parameter	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
Compound R-squared	0.005*	0.253*	0.034	0.239	0.136*	0.070*	0.003*	0.3029	0.0024*	0.074*
Growth rate, percent	-0.4	-7.3	18.5	2.1	2.8	-0.5	-0.2	28.3	0.2	-1.5
MEPDG $AADTT_{Base\ j}$	20	176	16	1	18	925	23	19	13	131
Vehicle class distribution, percent	1.49	13.11	1.19	0.07	1.34	68.93	1.71	1.42	0.97	9.76
Equation type	C	C	L	L	C	C	C	L	C	L

*Best fit model.
C = compound growth; L = linear growth.

AADTT_FIRST_YEAR_LTPP_LANE is the sum of base year $AADTT_i$ values in table 39, which is 1,342.

The *VEH_CLASS_GROWTH_USE_RATING* for this site is 1 (Best), because more than 75 percent of years (13 of 17) have data collected as part of the LTPP traffic monitoring program, and no major discontinuities are apparent in those data. This means that the majority of data used to produce these formulas are LTPP site-specific and underwent a variety of QC checks, making the estimates reasonable. However, the low R-squared values shown in table 39, indicate these equation formulations may not always provide a highly accurate replication of actual truck volume conditions.

Estimation of Truck Volume Growth Parameters for LTPP Traffic Site 321020

The third example describes the computation of growth equations for LTPP traffic site 321020. Two separate equations are developed for this traffic site because it is used for two separate LTPP experiments. Initially, from June 1984 to September 2000, this site was part of the GPS-1 experiment. Then, after a major maintenance treatment was performed, it became part of the GPS-6 experiment, and it continues to be part of that experiment today. Separate growth equations were produced for both experiments. Table 40 shows computed parameter $AADTT_{ij}$ values extracted for each in-service year for each truck class while in the GPS-1 experiment. Table 42 shows computed parameter $AADTT_{ij}$ values extracted for each in-service year for each truck class while part of the ongoing GPS-6 experiment.

Similar to the two previous examples, table 41 and table 43 show the R-squared statistics for each model formulation, and the resulting values for MEPDG growth rate and base year AADTT values for the “best fit” equations.

Table 40. *$AADTT_{ij}$* for each FHWA truck class for LTPP traffic site 321020, GPS-1 experiment.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
1984	1	12	2	1	3	72	3	7	4	13
1985	1	23	8	3	0	60	0	5	1	8
1986	1	11	2	0	3	67	3	6	3	12
1987	1	14	3	1	4	88	4	9	5	15
1988	2	18	4	1	5	112	5	11	6	20
1989	2	18	4	1	5	112	5	11	6	20
1990	2	17	3	1	5	103	4	10	5	18
1991	2	25	3	1	6	102	3	9	4	9
1992	2	24	3	2	5	110	2	9	5	14
1993	2	22	4	1	8	122	2	15	5	12
1994	2	23	5	1	6	141	6	14	7	25
1995	3	29	6	1	8	180	8	17	9	31
1996	2	36	10	0	5	148	8	11	7	45
1997	3	17	7	2	7	157	14	18	10	35
1998	2	24	5	1	7	147	6	14	8	26
1999	4	39	8	2	11	239	10	23	13	42
2000	2	13	4	1	8	135	23	37	26	81

Table 41. Growth function characteristics for each FHWA truck class for LTPP traffic site 321020, GPS-1 experiment.

Parameter	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
Linear R-squared	0.639	0.220*	0.190	0.004*	0.655	0.726	0.571*	0.664	0.470	0.547
Compound R-squared	0.723*	0.212	0.264*	0.200	0.227*	0.811*	0.303	0.740*	0.580*	0.614*
Growth rate, percent	0.064	0.735	0.046	0.266	0.401	0.067	0.841	0.104	0.107	0.103
MEPDG $AADTT_{Base\ j}$	1	16	3	1	2	69	1	5	3	10
Vehicle class distribution, percent	0.90	14.41	2.70	0.90	1.80	62.16	0.90	4.50	2.70	9.01
Equation type	C	L	C	C	L	C	L	C	C	C

*Best fit model.
C = compound growth; L = linear growth.

For the GPS-1 experiment, the value for *AADTT_FIRST_YEAR_LTPP_LANE* is the sum of base year $AADTT_i$ values in table 40, which is 111.

Based on R-squared values provided in table 41 for the GPS-1 experiment, the compound growth formulation generally performs better than the linear formulation. The *VEH_CLASS_GROWTH_USE_RATING* is 4 (Fair) because only 6 of 17 yr have traffic monitoring data collected by vehicle class.

Table 42. $AADTT_{ij}$ for each FHWA truck class for GPS site 321020.

Year	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
2000	2	13	4	1	8	135	23	37	26	81
2001	3	33	7	1	9	205	9	20	11	36
2002	5	24	3	0	4	260	3	15	6	21
2003	3	24	6	1	10	204	3	8	6	14
2004	4	40	8	2	11	246	11	24	13	43
2005	4	42	9	2	12	262	11	25	14	46
2006	5	45	9	2	13	279	12	27	15	49
2007	5	48	10	2	13	296	13	29	15	52
2008	5	51	10	2	14	315	13	31	16	55
2009	6	54	11	2	15	335	14	33	18	58
2010	6	58	12	3	16	356	15	35	19	62
2011	6	61	12	3	17	379	16	37	20	66
2012	7	65	13	3	18	403	17	39	21	70
2013	7	69	14	3	19	428	18	42	22	75
2014	8	73	15	3	21	455	19	44	24	79
2015	8	78	16	3	22	484	21	47	25	84

Table 43. Growth Function Characteristics for Each FHWA Truck Class for GPS Site 321020.

Parameter	FHWA Class 4	FHWA Class 5	FHWA Class 6	FHWA Class 7	FHWA Class 8	FHWA Class 9	FHWA Class 10	FHWA Class 11	FHWA Class 12	FHWA Class 13
Linear R-squared	0.934*	0.954*	0.945*	0.836*	0.921*	0.960*	0.348*	0.619*	0.413*	0.452*
Compound R-squared	0.839	0.833	0.824	0.439	0.748	0.912	0.341	0.469	0.409	0.397
Growth rate, percent	0.349	3.861	0.770	0.182	0.989	20.144	0.694	1.760	0.831	2.912
MEPDG $AADTT_{Base\ j}$	3	20	4	1	6	165	8	17	11	34
Vehicle class distribution, percent	1.12 percent	7.43 percent	1.49 percent	0.37 percent	2.23 percent	61.34 percent	2.97 percent	6.32 percent	4.09 percent	12.64 percent
Equation type	L	L	L	L	L	L	L	L	L	L

*Best fit model.
L = linear growth.

For the GPS-6 experiment, the value for *AADTT_FIRST_YEAR_LTPP_LANE* is the sum of $AADTT_i$ values in Table 42, which is 269. Note that this is a different base year value than used for the GPS-1 site at the same physical location. The growth equations are also different because the base year for the GPS-6 site is computed from the time the site became a GPS-6 site, which is different from when the site became a GPS-1 site.

For the GPS-6 experiment, unlike the GPS-1 experiment, the linear formulation does a better job of estimating AADTT for all truck classes than the compound formulation. For this experiment, the *VEH_CLASS_GROWTH_USE_RATING* is 5 (Poor) because the majority (13 of 16 yr) of traffic estimates for this experiment are extrapolations of earlier data collection efforts. As a result, the R-squared values are high, only because the growth equation is based on already modeled numbers. In reality the values may not be accurate estimates of actual truck traffic volumes.

CHAPTER 7. ESTIMATING REPRESENTATIVE TRUCK VOLUMES AND TRUCK VOLUME DISTRIBUTIONS BY VEHICLE CLASS

Representative truck volume or vehicle class distributions are used in analyses when one value or one set of values (as in the case of a distribution by vehicle class) is used to characterize truck traffic for an LTPP site. For example, representative AADTT values are used to differentiate between LTPP sites that have high, moderate, or low truck volumes. Representative vehicle class distributions are used to identify LTPP sites exposed predominantly to freight trucks (i.e., a high volume or percentage of FHWA Class 9 trucks compared to other heavy vehicle classes) versus those exposed predominantly to local service trucks (i.e., a high volume or percentage of FHWA Class 5 trucks compared to other heavy vehicle classes).

REPRESENTATIVE AADTT FOR LTPP LANE, FHWA VEHICLE CLASSES 4–13 COMBINED

Computed Parameter Description

Representative AADTT describes the total number of trucks (all vehicles in FHWA Classes 4–13) expected to pass over an LTPP test section in a typical day of a given experiment. It serves as an easily selected statistic when identifying which LTPP test sections should be included in an analysis.

For example, a researcher might want to include only sites with more than 5,000 trucks per day in their analysis. Since truck volumes change over time, the representative AADTT value provides a single, simple representative statistic.

Data Sources used for Parameter Computation

Representative AADTT is computed from the previously developed computed parameter AADTT for each in-service year, all trucks combined. Data sources underlying those statistics are described in chapter 6.

A CPT TRF_TREND was selected as a data source over limited traffic monitoring data because it better accounts for changes in traffic conditions over the life of an experiment and allows for the incorporation of those changes in the representative value. This approach also provides consistency between CPT datasets.

Methodology for Parameter Computing or Estimating

Representative AADTT is computed as the mean of AADTT values for each year from the CPT TRF_TREND containing $AADTT_i$ values for each in-service year, all trucks combined. The mean of AADTT values is selected because some sites show highly variable AADTT values, and thus an alternative approach of taking a specific year might not provide an accurate estimate of truck volume over the duration of that site's involvement in the LTPP experiment. High variability is often found at LTPP sites with lower truck volumes, as changes in economic activity in nearby locations (or at geographic locations generating truck travel on that specific road) can cause large percentage changes in truck volumes. In other cases, construction projects on nearby or parallel routes (or the opening of newly constructed roads) can shift truck traffic onto, or off, the road on which the LTPP site is located. By choosing the mean value rather than the median value, representative AADTT accounts for both high- and low-volume traffic periods in proportion to the time those periods are present.

Note that for roads experiencing significant changes in truck volumes during the LTPP experiment, a single representative traffic statistic is not necessarily a good measure of traffic loading during any specific year.

Computational Procedure or Algorithm

Representative AADTT is computed as the mean value taken from all years of the computed parameter statistic $AADTT_i$ for each in-service year, all trucks combined.

To help LTPP users understand the applicability of this parameter for their studies, a usability rating (REP_AADTT_USE_RATING) is assigned to this value in the TRF_REP CPT table. The usability rating parameter describes how effectively a single number, computed from available data for the site, represents traffic loading typical daily truck volume at an LTPP site. It is determined by examining a combination of the source of individual AADTT statistics and the consistency of travel trends at the site. Generally, the more traffic monitoring data present for each LTPP site, the better the rating. Also, the more consistent the traffic trends, the better the rating. Significant discontinuities in truck volume trends reduce the ability of a single number to represent the traffic loading condition at a site. Even if large amounts of good, site-specific data are present, the usability rating is lowered if external factors caused major discontinuities in truck volume trends, reflecting that one number may not be capable of representing actual traffic loading truck traffic volumes at a site.

The following criteria were developed to define usability ratings:

- A “Best” (code 1) rating is given when more than 75 percent of years of data come from the LTPP traffic monitoring program and no major changes in truck volume trends occurred at the site. A major discontinuity is defined as a year-to-year change in AADTT of more than 25 percent that is also larger than 50 vehicles.

- A “Better” rating (code 2) is given when more than 75 percent of annual AADTT estimates available from a site come from either the LTPP traffic monitoring program or State-supplied estimates and there are no major discontinuities in the truck volume trend line.

- A “Good” (code 3) rating is given when more than 50 percent, but less than 75 percent, of years of data come from the LTPP traffic monitoring program or State-supplied AADT statistics, and the site’s truck volume trend does not contain major year-to-year discontinuity.

- A “Fair” (code 4) rating is given if less than 50 percent, but more than 25 percent, of the years of data come from the LTPP traffic monitoring program or State-supplied AADTT values or major discontinuity in truck volumes occurred during the life of the LTPP experiment.

- A “Poor” (code 5) rating is given if data do not meet the “Fair” standard.

Examples of Parameter Estimating

Estimation of Representative AADTT for LTPP Traffic Site 040100 (LTPP Lane Only)

The first example illustrated is for LTPP traffic site 040100, which is the single traffic data collection site for several SPS-1 sections. The LTPP site opened on June 1, 1993, and left the study in June 2006. As discussed in chapter 6, this site experienced two major shifts in truck volume during its life in the LTPP experiment. Early in the monitored life of the test pavement, the site carried 600 to 1,000 trucks per day, with an upward trend in truck volumes each year. In 2003, AADTT dropped significantly due to a major construction project shifting truck travel patterns in the area. AADTT fell to around 220 trucks per day, with a couple higher volume years of up to about 400 trucks per day. After 2011, truck volumes returned to previous levels, basically following the growth trend line existing prior to the construction activity. However, the site’s participation in the LTPP experiment ended by that time. Table 44 shows the values for a computed parameter $AADTT_i$ for this site.

Table 44. Computed parameter $AADTT_i$ values for LTPP traffic site 040100.

Calendar year	$AADTT_i$
1993	400
1994	629
1995	657
1996	714
1997	770
1998	835
1999	875
2000	950
2001	1,006
2002	1,085
2003	214
2004	221
2005	220
2006	219

Using the adopted definition, representative AADTT value for LTPP traffic site 040100 is computed as a mean of $AADTT_i$ values presented in Table 44, which is 628.

Although this value understates the volume of trucks experienced early in the experiment, it accounts for lower volumes during the later portion of the LTPP experiment, when the site was experiencing low truck traffic volumes. Thus, the value of 628 represents AADTT experienced on average during the experiment.

REP_AADTT_USE_RATING is set to 4 (Fair) because of the large discontinuity in truck volumes occurring because of construction traffic rerouting.

Estimation of Representative AADTT for LTPP Traffic Site 320100 (LTPP Lane Only)

The second example of computing representative AADTT is for LTPP traffic site 320100. This traffic site is used for 12 SPS-1 experimental sections (320101–320112). The site opened to traffic on September 1, 1995, and left the experiment July 1, 2009. These data are shown in table 45.

Table 45. Computed parameter $AADTT_i$ values for LTPP traffic site 320100.

Year	AADTT	Monitoring (M), State Estimate (S), or Regression Estimate (E)
1995	1,261	E
1996	1,050	M
1997	1,212	M
1998	1,287	M
1999	1,396	M
2000	1,369	M
2001	1,316	M
2002	1,285	M
2003	1,404	M
2004	1,479	M
2005	1,193	M
2006	1,285	M
2007	1,244	E
2008	961	M
2009	926	M

As with LTPP traffic site 040100, LTPP traffic site 320100 experienced changes in truck volume from year to year, although these shifts were not as dramatic as those from LTPP traffic site 040100. Most noticeable was the drop in truck volume during the Great Recession in 2008 and 2009. The mean value used for the representative AADTT of 1,247 is a compromise between steady traffic volumes experienced in the 1990s, higher volumes in the early 2000s, and the decline in truck traffic starting in 2005.

REP_AADTT_USE_RATING for this site is set to 1 (Best) because more than 75 percent of years (13 of 17 yr) have data collected as part of the LTPP traffic monitoring program and no major discontinuities are apparent.

Estimation of Representative AADTT for LTPP Traffic Site 321020 (LTPP Lane Only)

The third example of the AADTT estimation process is for LTPP traffic site 321020. This site was initially part of the GPS-1 experiment. The site opened to traffic in June 1984 and left the

LTPP experiment in September 2000. At that time, the LTPP test site entered the GPS-6 experiment, and it continues to be part of that experiment today.

Because this site served two different LTPP experiments, two different representative AADTT values were computed. The first was for the GPS-1 experiment from 1984 to 2000. The second was for the GPS-6 experiment from 2000 to 2015. Table 46 shows the computed parameter $AADTT_i$ values for this site.

Table 46. Computed parameter $AADTT_i$ values for LTPP traffic site 321020.

Year	AADTT	Monitoring (M), State-Supplied (S), or Estimated (E)
1984	117	S
1985	109	S
1986	109	S
1987	144	S
1988	183	S
1989	183	S
1990	168	M
1991	165	M
1992	176	M
1993	194	S
1994	230	S
1995	293	M
1996	271	M
1997	270	S
1998	240	S
1999	390	M
2000	329	E
2001	334	M
2002	342	M
2003	276	E
2004	402	E
2005	427	E
2006	454	E
2007	483	E
2008	513	E
2009	546	E
2010	580	E
2011	617	E
2012	656	E
2013	697	E
2014	742	E
2015	788	S

During the GPS-1 experiment, the pavement experienced consistently growing truck volumes. The representative AADTT value of 210 trucks per day was computed as a mean of $AADTT_i$ values for 1984–2000).

The growth pattern observed during the GPS-1 experiment continued after the site transitioned into the GPS-6 experiment. Consequently, the GPS-6 pavement experienced considerably more truck traffic per day than did the GPS-1 pavement. The lowest year of traffic the GPS-6 pavement experienced was higher than the representative value computed for the GPS-1 experiment. The representative AADTT value for the GPS-6 experiment (i.e., mean value computed using $AADTT_i$ values for 2001–2015) was 524 trucks.

REP_AADTT_USE_RATING for the GPS-1 site (1984–2000) was set to 2 (Better) because more than 75 percent of the years had data either collected under the LTPP traffic monitoring program or as State-supplied estimates. However, because much of the data came from State-supplied estimates and were not collected at the site and did not undergo a QC as part of the LTPP traffic monitoring program, the index is not set to 1. There were no major discontinuities during the life of the GPS-1 experiment.

REP_AADTT_USE_RATING for the GPS-6 site (2001–2015) was set to 5 (Poor) because the majority (13 of 16 yr) of traffic estimates for this experiment were extrapolations of earlier data collection efforts.

REPRESENTATIVE PERCENTILE VEHICLE CLASS DISTRIBUTION FOR FHWA CLASSES 4–13 IN LTPP LANE

Computed Parameter Description

Representative percentile vehicle class distribution for FHWA Classes 4–13 in LTPP lane provides information that can be used with AASHTOWare Pavement ME Design software. The software requires the user to enter a set of 10 values representing a percentile distribution of heavy vehicles by FHWA classification (for vehicles in FHWA Classes 4–13). This set of computed parameters provides the best available set of these values for each LTPP test site.

Data Sources used for Parameter Computation

The dataset used to develop these values is the same one used for developing $AADTT_{ij}$ for each truck class and each in-service year described in chapter 6. Representative percentile vehicle class distribution for FHWA Classes 4–13 in the LTPP lane has the same value as $MeanPercentClass_j$ used to compute $AADTT_{ij}$. To compute the representative percentile vehicle class distribution for FHWA Classes 4–13 in the LTPP lane, it is necessary to compute the mean percentage of trucks in each FHWA Class 4 through 13, which is done using all years of vehicle classification monitoring data, except when data fail the QA review process.

Methodology for Parameter Computation or Estimation

The methodology for computing the representative percentile vehicle class distribution for FHWA Classes 4–13 in the LTPP lane is similar to computing the $MeanPercentClass_j$ values described in chapter 6.

Computational Procedure or Algorithm

1. The following steps describe the process for computing representative percentile vehicle class distributions for FHWA Classes 4–13 in the LTPP lane. Compute $AADTT_{ij}$ by FHWA class (*j*) and year (*i*) and $AADTT_i$ for all truck classes combined using the annual total truck volume estimates reported in the TRF_MONITOR_LTPP_LN table. These estimates are based on monitored vehicle classification data submitted by each State for each year of traffic monitoring. Methodology for $AADTT_{ij}$ and $AADTT_i$ computation was presented in chapter 6.

2. Use the $AADTT_{ij}$ estimates by FHWA class and $AADTT_i$ for all truck classes combined to compute the fraction of that truck traffic occurring in each truck class (*j*) during the year (*i*): $AADTT_{ij} / AADTT_i$.

3. For years traffic monitoring data are present in the TRF_MONITOR_LTPP_LN table and pass basic QA tests, compute the mean percentage of truck traffic occurring in each class across by averaging the results of the previous step over all years of valid data.

4. Normalize these percentage values to ensure the total of the mean percentages equals 100 percent.

5. If no vehicle classification data from the LTPP traffic monitoring program are available for a site, use any historical traffic monitoring data submitted for that site and follow Steps 1-4. Do not use these data to estimate representative values if traffic monitoring data are present in the LTPP database.

6. If neither traffic monitoring data nor detailed historical data are present at the site, first attempt to use data at other LTPP sites nearby on the same roadway. If no such data exist, average the representative vehicle classification data from the other LTPP sites located on similar roadways (i.e., same road functional classification) in the same State to estimate the representative percentage distribution of truck travel within each of the 10 vehicle classes (i.e., FHWA Classes 4–13).

The usability rating index REP_VEH_CLASS_USE_RATING was developed to help LTPP users in selecting the representative percentile vehicle class distributions for FHWA Classes 4–13 in the LTPP lane. This index describes data used in parameter computation and how well the computed parameter represents the percentile distribution of truck volume by vehicle class. Details of the usability rating are provided in chapter 11.

The following criteria were developed to define usability ratings:

- A "Best" (code 1) rating is given when more than 75 percent of the years of data come from the LTPP traffic monitoring program, no major changes in truck volume trends occurred at the site, and no major discontinuities in truck mix are reported. A major discontinuity is defined as a change in truck class percentage of more than 15 percent.

- A "Better" (code 2) rating is given when more than 50 percent of years contain traffic monitoring data.

- A “Good” (code 3) rating is given when more than 50 percent of years contain traffic monitoring data, but the site’s traffic trend contains a moderately large year-to-year discontinuity in AADTT.

- A “Fair” (code 4) rating is given if less than 50 percent, but more than 25 percent, of years have traffic monitoring data or a major change in truck mix (e.g., a shift of more than 15 percent of truck traffic occurring within a single vehicle class) occurs at a site.

- A “Poor” (code 5) rating is given if less than 25 percent of years have traffic monitoring data.

Examples of Parameter Estimating

Example: Develop Representative Percentile Vehicle Class Distribution for LTPP Traffic Site 040100

The first example of estimating representative percentile vehicle class distribution for FHWA Classes 4–13 for LTPP traffic site 040100. This site has traffic monitoring data for 1994–2001 and 2003–present. The percentages of truck traffic in each FHWA truck class (Per_{ij}) from these counts were shown previously in table 22. Table 47 repeats these values and shows the mean value of these statistics. The row containing the mean value was used to report representative percentile vehicle class distribution for FHWA Classes 4–13 in LTPP lane.

Table 47. Percentage of trucks in each vehicle class for LTPP traffic site 040100.

Year	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
1994	1.4	17.4	2.9	0.0	8.4	61.1	0.5	6.8	1.5	0.0
1995	1.4	17.2	2.5	0.1	8.4	62.9	0.5	5.6	1.3	0.1
1996	1.3	15.7	2.6	0.0	8.1	64.4	0.6	5.9	1.2	0.1
1997	1.4	20.7	3.2	0.0	5.6	62.0	0.6	5.3	1.0	0.1
1998	1.2	21.8	2.6	0.0	5.6	62.1	0.5	5.2	1.0	0.1
1999	1.6	20.9	2.5	0.1	5.0	62.8	0.5	5.6	1.1	0.1
2000	2.1	23.3	2.6	0.1	5.2	60.3	0.5	4.9	1.0	0.1
2001	2.0	22.1	2.4	0.1	5.7	61.4	0.6	4.8	0.9	0.1
2002	—	—	—	—	—	—	—	—	—	—
2003	3.0	61.5	4.1	0.1	10.1	20.9	0.2	0.1	0.0	0.1
2004	2.9	53.9	3.8	0.1	12.2	26.3	0.2	0.4	0.0	0.1
2005	4.0	53.7	4.1	0.2	11.0	26.5	0.2	0.1	0.0	0.2
2006	2.2	79.9	2.3	0.0	3.4	11.6	0.2	0.0	0.0	0.3
Mean value	2.0	34.0	3.0	0.1	7.4	48.5	0.4	3.7	0.7	0.1

— = No data.

As noted previously, the difficulty with this statistic is that LTPP traffic site 040100 experiences two entirely different truck traffic patterns during its time in the LTPP experiment. One pattern is present from 1993, when it opened to traffic, until 2001, when construction events elsewhere caused a change in traffic patterns. This pattern reasserts itself in 2006, when the construction project ends. During the construction event (2003–2005) a very different pattern exists in both total truck volume and the fractional distribution of truck types within that total volume.

Because the construction event was identified and reported, the research team concluded that the observed shift was valid. Consequently, using the mean value of all years the site was open to traffic produces a reasonable estimate of overall traffic conditions, even if that value may not represent traffic during any specific year of the road's operation (i.e., because some years experienced a low percentage of heavy truck traffic, while others experienced a high percentage, a representative value for the entire period must be a mix of these two patterns).

Because this site experienced major discontinuity in truck travel in 2003, the REP_VEH_CLASS_USE_RATING index for this site is set to 4 (Fair). If not for the discontinuity, this site would be rated as 1 (Best) due to the sufficient monitoring data available.

Example: Develop Representative Percentile Vehicle Class Distribution for LTPP Traffic Site 321020

Table 48 shows the percentage of annual average daily truck travel observed in LTPP traffic monitoring data collected at site 321020. This site is part of two different LTPP experiments. The pavement opened to traffic in June 1984 as part of the GPS-1 experiment and left that experiment in September 2000. At that time, the LTPP test site entered the GPS-6 experiment, and it continues to be part of that experiment today. Consequently, two separate mean values were computed for the representative percentile vehicle class distribution, as shown in Table 49. The first used traffic monitoring data through 2000. The second used traffic monitoring data collected after 2000. If no traffic monitoring data were collected during one of these periods, the mean value from the other period was used.

Table 48. Percentage of trucks in each vehicle class for LTPP traffic site 321020.

Year	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
1991	1.1	15.2	1.9	0.8	3.6	62.2	1.8	5.6	2.4	5.4
1992	1.1	13.4	1.7	0.9	2.9	62.6	1.1	5.4	2.6	8.2
1993	1.2	11.6	2.0	0.6	4.3	62.7	1.1	7.8	2.6	6.2
1996	0.8	13.2	3.6	0.0	1.7	54.4	2.8	4.0	2.7	16.6
1997	1.0	6.4	2.7	0.6	2.6	58.1	5.2	6.5	3.8	13.1
2000	0.6	4.0	1.1	0.4	2.5	41.1	6.8	11.1	7.8	24.6
2002	1.4	7.0	0.9	0.0	1.1	76.1	1.0	4.5	1.8	6.3
2003	1.2	8.6	2.0	0.2	3.4	73.6	1.1	2.8	2.1	5.0

Table 49. Mean percentage of trucks in each vehicle class for LTPP traffic site 321020.

GPS or SPS and Years	FHWA Class 4 (Percent)	FHWA Class 5 (Percent)	FHWA Class 6 (Percent)	FHWA Class 7 (Percent)	FHWA Class 8 (Percent)	FHWA Class 9 (Percent)	FHWA Class 10 (Percent)	FHWA Class 11 (Percent)	FHWA Class 12 (Percent)	FHWA Class 13 (Percent)
GPS-1 prior to 2000	0.97	10.63	2.17	0.55	2.93	56.85	3.13	6.73	3.65	12.35
GPS-6 post 2000	1.30	7.80	1.45	0.10	2.25	74.85	1.05	3.65	1.95	5.65

For the GPS-1 experiment, *REP_VEH_CLASS_USE_RATING* index is set to 4 (Fair) because only 6 of 17 yr have traffic monitoring data collected by vehicle class.

For the GPS-6 experiment, *REP_VEH_CLASS_USE_RATING* index is 5 (Poor) because the majority (13 of 16 yr) of traffic estimates are extrapolations of earlier data collection efforts and are not based on actual data collected in the field.

CHAPTER 8. ESTIMATING REPRESENTATIVE AXLE LOADING DISTRIBUTION FACTORS BY VEHICLE CLASS AND AXLE GROUP FOR MEPDG USE

COMPUTED PARAMETER DESCRIPTION

ALDF are used to characterize traffic loading for pavement analysis and design based on the MEPDG method. The format and meaning of this parameter is specific to AASHTOWare Pavement ME Design software. ALDF provide the percentile distribution of axle counts by load range (or load bin) for each heavy vehicle class (FHWA Classes 4–13) and axle group (i.e., single, tandem, tridem, and quad+) for a typical year of pavement service life. Each ALDF provides an estimate of the percentage of loads within a specified load range applied to a pavement during a typical day of each of the 12 calendar months of a year (January to December). In the current AASHTOWare Pavement ME Design software, ALDF are defined for each calendar month of the first (base) analysis or design year and remain constant throughout the analysis or design period. Thus, to be used as an input in AASHTOWare Pavement ME Design software, each LTPP site needs one set of ALDF representing an axle loading distribution for a typical year in the pavement's life.

The ALDF parameter has the same meaning as the traffic loading parameter NALS. The latter parameter is generic and not exclusive to AASHTOWare Pavement ME Design software.

DATA SOURCES USED FOR PARAMETER COMPUTATION

Data sources containing information for computing the ALDF parameter include several LTPP tables. Names and descriptions of the LTPP traffic loading tables are as follows:

- DD_AX—contains the number of axles measured in each weight range summarized by site, lane, direction, year, month, day, vehicle class, and axle group. The DD_AX table is created by accumulating axle distributions over all hours by vehicle class in a day. All vehicle classes, including passenger vehicles, may be in this table. Data are in a State/Provincial agency-specified classification method and may not follow the FHWA TMG 13-bin classification table. Data are obtained from WIM equipment installed at or near the LTPP test section.

- MM_AX—contains information about the number of axles measured in each weight range summarized by site, lane, direction, year, month, DOW, vehicle class, and axle group. The MM_AX table is created by summing up the number of days and axle distributions by axle group over the days in a week for a month from the DD_AX table. Only vehicles reported in FHWA TMG 13-bin classification (FHWA Classes 4–13) are included. Any data in an agency-specified classification method are converted into TMG 13-bin classes.

- TRF_MONITOR_AXLE_DISTRIB—contains the number of axles measured in each weight range summarized by site, year, vehicle class, and axle group for the LTPP lane. Data are obtained from WIM equipment installed at or near the LTPP test section. The

WEIGHT_BIN_SIZE field contains sizes of weight bins used to describe weight distribution by axle type. This distribution is for the LTPP lane only.

At the time of this study, two new LTPP traffic loading tables became available: monthly NALS and annual NALS.

Monthly and annual NALS tables were selected as a primary traffic loading data source for developing site-specific ALDF. Both tables were developed by the LTPP program using SDR 30 data for LTPP traffic sites with LTPP WIM data at Levels D and E.

In addition, information about the type and operational characteristics of WIM equipment used to collect axle loading data was used to assess the accuracy of collected loading data and make determinations about whether data are accurate enough to compute site-specific axle loading inputs for pavement analysis and design. To be adequate, data must come from a calibrated WIM device capable of collecting WIM data satisfying the performance parameters of Type I WIM systems per ASTM E1318-09. The following LTPP tables contain information to make this determination:

- TRF_EQUIPMENT_MASTER—contains information about WIM equipment in place during a calibration event and specifies WIM calibration protocol used at some WIM sites.

- TRF_CALIBRATION_WIM—contains statistics quantifying weight measurement accuracy for heavy vehicles and axle groups for each calibration period. This information is available for some, but not all, LTPP WIM sites.

NUMBER OF LTPP SITES REQUIRING PARAMETER ESTIMATION

The number of LTPP sites requiring ALDF information was assessed in collaboration with another LTPP traffic data analysis study. This was done to avoid duplicating the effort of the other LTPP analysis study estimating traffic loading for LTPP sites with no site-specific WIM data. Based on this assessment, 647 LTPP traffic sites were identified as candidates for ALDF development under this study. These sites are listed in appendix B. After reviewing axle loading data, some of these sites were identified as candidates for assigning the default ALDF due to issues with the quality and/or availability of loading data. ALDF for these sites were assigned as part of the outcome from the LTPP traffic data analysis study, *Predicting Truck and Axle Loading Patterns*. As a result, all LTPP sites have ALDF information for use in MEPDG analyses.

METHODOLOGY FOR PARAMETER COMPUTATION OR ESTIMATION

Two approaches were developed for ALDF computation depending on the quality and/or availability of WIM data:

- Computing ALDF for LTPP sites with site-specific WIM data of sufficient quantity and quality.
- Estimating ALDF for LTPP sites with insufficient or poor-quality WIM data.

For the LTPP sites with multiple WIM data collection periods, the methodology for ALDF computation focused on how to select the appropriate dataset for computation. For LTPP sites with insufficient site-specific axle loading data, the methodology focused on selecting ALDF factors from alternative data sources or assigning default values to best represent expected traffic loading patterns.

Hierarchical Approach for WIM Data Selection and Usability Code Assignment Based on Data Quality Considerations

To be successfully used in pavement analysis, ALDF must be computed using accurate axle loading data, especially accurate estimates of heavy axle loads. Ideally, WIM data for ALDF computation should be from a calibrated WIM system satisfying the performance parameters of Type I WIM systems per ASTM E1318-09 during the data collection period (table 1). Reviewing data in TRF_EQUIPMENT_MASTER and TRF_CALIBRATION_WIM tables revealed that only a limited number of the WIM sites contain the information necessary to quantify WIM data quality. The limited available information showed that some LTPP WIM sites satisfied ASTM E1318-09 Type I or Type II WIM system performance requirements.

To overcome this limitation, a hierarchical data assessment methodology and series of data reasonableness checks were developed to evaluate and qualify reasonableness and usability of available axle loading data for ALDF computation. The following hierarchical approach was applied to identify and qualify datasets for computing site-specific ALDF:

1. Axle loading distributions used for ALDF computations (monthly or annual) must be identified as LTPP data QC Level D or E in the LTPP database.

2. If supporting information is available to determine that axle loading data were collected by a WIM system satisfying the performance parameters of Type I WIM systems per ASTM E1318-09 during some data collection periods, use data from these data collection periods to compute the ALDF.

    a. If data from Type I WIM systems are available for at least one instance of each calendar month and are free from error due to WIM sensor temperature sensitivity, use these data to compute a unique ALDF for each calendar month. Computed parameters based on these data have a data–usability code labeled “Best.”

    b. If monthly data are insufficient to compute a unique ALDF for each calendar month, or if a WIM sensor is susceptible to temperature sensitivity (i.e., additional errors due to temperature fluctuation), use annual data summaries for ALDF computation. Computed parameters based on these data have a data–usability code labeled “Better.”

    c. If data collection periods satisfying the performance parameters of Type I WIM systems per ASTM E1318-09 are too short to provide representative values (less than 1 yr of data), data from other data collection periods can be used to compute site-specific ALDF provided these data pass data reasonableness checks (described in the ensuing sections) and show similar loading trends as data from the periods corresponding to Type I WIM performance characteristics. Computed parameters based on these data have a data–usability code labeled “Good.”

3. If no information is available about WIM system performance parameters at the time of data collection or data were collected by a Type II WIM system, apply data reasonableness checks described in the ensuing sections to axle loading distributions.

    a. Identify data periods that do not show signs of low WIM data precision or bias in axle loading distributions. Use data from these periods to compute site-specific ALDF. Computed parameters based on these data have a data–usability code labeled “Good.”

    b. If data assessment shows data are likely affected by low precision or low-to-moderate measurement bias, evaluate if the measurement bias or low precision is likely to have less than 10 percent difference in the percentage of heavy loads for FHWA Class 9 vehicles (estimated based on the axle load-distribution shape).

        i. If the difference is under 10 percent, use these data to compute site-specific ALDF. Computed parameters based on these data have a data–usability code labeled “Fair.”

        ii. If the difference is over 10 percent in the percentage of heavy loads for FHWA Class 9 vehicles. Check if the shape of the axle loading distribution is similar to typical shapes identified for given vehicle classes and axle types. Typical shapes are described in the LTPP PLUG defaults.

            1. If the loading pattern can be identified, assign loading patterns based on similarities of the loading pattern shapes with the LTPP PLUG defaults or other available data sources. Use assigned loading patterns to select site-related or default ALDF. Consider WIM data for this site as “Poor.”

            2. If the loading pattern does not follow any known pattern, assign ALDF default values based on truck volume, vehicle class distribution, and road functional classification. Consider WIM data for this site as “Bad.”

WIM Data Rationality and Data Reasonableness Checks

The majority of axle weight data collected did not have information about WIM equipment accuracy, and if issues with the accuracy of WIM measurements were known, data reasonableness checks were developed to screen and differentiate between WIM records that likely had or had not been affected by WIM equipment accuracy limitations. The purpose of these checks is to identify and classify WIM datasets into the following three categories:

- Suitable to compute site-specific axle loading values based on monthly or annual NALS.
- Not suitable to compute site-specific axle loading values but useful for identifying loading patterns for high-volume heavy truck classes.
- Not suitable to compute site-specific axle loading values or for identifying loading patterns due to poor quality and/or low truck volume.

WIM data reasonableness checks were designed to identify axle loading data with strong measurement bias (due to lack of calibration or calibration drift) and/or very low precision of heavy-weight measurements or possibly a vehicle misclassification. Data reasonableness checks described in this section were applied to monthly and annual NALS for FHWA Class 9 vehicles. FHWA Class 9 NALS were selected because of well-known axle weight-distribution attributes for this category of vehicles. The data reasonableness assessment analyzes tandem NALS for FHWA Class 9 vehicles followed by single NALS for FHWA Class 9 vehicles. Changes in these distributions over time were used to identify data with suspected quality issues.

These checks were applied in a three-step process. In step one of the data reasonableness assessment, the LTPP program applied “tail checks” to identify monthly and annual NALS datasets likely to have been collected by equipment with measurement accuracy issues. These checks were designed to identify high percentages of unusually light or unusually heavy axle loads for FHWA Class 9 vehicles. High percentages of very light loads indicate a likely vehicle misclassification. Very high percentages of loads exceeding the legal load limit on tandem axles indicate a likely calibration drift. NALS with high percentages of both very light and very heavy loads indicate low precision of weight measurements (typically due to temperature sensitivity of the ceramic or polymer piezo sensors). The following criteria were used for the “tail checks” to identify atypical distributions.

“Tail checks” for FHWA Class 9 single axle NALS checks include the following criteria (applies to both U.S. and Canadian LTPP WIM sites):

- 10 percent or more under 5,000 lb.
- 10 percent or more greater than or equal to 21,000 lb.

“Tail checks” for FHWA Class 9 tandem axle NALS checks include the following criteria:

- U.S. sites—10 percent or more under 8,000 lb.
- U.S. sites—20 percent or more greater than or equal to 34,000 lb.
- Canadian sites—10 percent or more under 8,000 lb.
- Canadian sites—20 percent or more greater than or equal to 38,000 lb.

In step two of the data reasonableness assessment, the research team applied additional automated checks to flag monthly and annual NALS for FHWA Class 9 axles with several key axle weight-distribution attributes outside the expected range for FHWA Class 9 vehicles. The following additional checks were applied to monthly and annual NALS.

Checks to identify atypical patterns in FHWA Class 9 single axle NALS include the following:

- Average single axle weight less than 9,000 lb.
- Average single axle weight greater than 12,500 lb.
- Single axles weighing 20,000 lb or more is above 3 percent.

Checks to identify atypical patterns in FHWA Class 9 tandem axle NALS include the following:

- Average weight of loaded tandem axles (computed as average weight of FHWA Class 9 tandem axles weighing 26,000 lb or more) less than 29,000 lb.
- Average weight of loaded tandem axles (computed as average weight of FHWA Class 9 tandem axles weighing 26,000 lb or more) greater than or equal to 34,000 lb.
- Tandem axles weighing 34,000 lb or more above 20 percent.
    - WIM sites located on a road with predominantly empty trucks have overloaded tandems greater than 7 percent.
- Loaded peak location checks (calibration drift checks) meeting the following criteria:
    - When the percent of axles between 30,000 and 35,999 lb is less than the percent of axles between 36,000 and 41,999 lb (overestimation of loads).
    - When the percent of axles between 26,000 and 33,999 lb is less than the percent of axles between 20,000 and 25,999 lb, which applies to sites with less than 30 percent of axles between 10,000 and 15,999 lb (underestimation of loads).
- First loading peak (tandem axles on empty trucks) is not between 10,000 and 15,999 lb.

In step three of the data reasonableness assessment, FHWA Class 9 NALS flagged in the previous two steps were manually reviewed and compared to historical NALS for the same site to identify whether a flagged record represents an expected distribution for a given site or indicates a calibration drift or other event resulting in atypical distribution. The review process used the following guidance:

1. Check the shape of the NALS distribution for consistency between years. If more than one type of WIM sensor was used over the years, put more trust in years with a higher quality sensor (e.g., choose data from quartz sensors over polymer piezo sensors).

2. Trust NALS with the following attributes (typically observed in NALS based on data from calibrated WIM systems):

    a. Repeating shape of distribution.

    b. Loaded tandem peak between 30,000 and 34,000 lb.

    c. Single axle peak between 10,000 and 12,000 lb.

    d. Short axle distribution tail for overloaded tandem axles (typically less than 10 percent of overloads for roads with a balanced loading pattern of FHWA Class 9 trucks or less than 7 percent for roads with mostly empty FHWA Class 9 trucks).

3. Check for calibration drift and favor years with NALS that have the location for loaded tandem peaks and percentages of overloads close to typically expected values for FHWA Class 9 vehicles.

4. Identify annual NALS affected by likely WIM measurement bias through analysis of shifts in peaks of axle loading distributions

5. Identify annual NALS affected by likely low WIM measurement precision through presence of fat, long tail for overloads; high percentage of very light vehicles; and low percentages associated with axle load distribution peak values.

Based on the results of manual review, a decision was made whether to keep or remove atypical monthly or annual NALS from further computations using site-specific WIM data. If FHWA Class 9 monthly or annual NALS were labeled for removal, NALS for all vehicle classes corresponding to the same month or year were removed from the ALDF computation.

WIM Data Availability Criteria

In addition to being accurate, the quantity of WIM data must be sufficient to develop representative ALDF describing average monthly or annual axle loading conditions at a given LTPP site. Therefore, once all monthly or annual axle loading data are considered acceptable for computation, and site-specific ALDF have been identified based on data quality or reasonableness checks, the quantity of data are checked using the following data availability criteria:

- For computing ALDF representing a typical day of each calendar month, the following criteria must be met:
    - Data must be collected by equipment satisfying the performance parameters of Type I WIM systems per ASTM E1318-09 for the entire length of data collection. Due to temperature sensitivity, data collected by piezo-polymer or piezo-ceramic sensors are excluded from this computation because data accuracy cannot be guaranteed over data collection periods lasting many months.
    - Daily axle loading distributions for a given vehicle class and axle group combination (referred as class–axle combination in ALDF discussions) must be available for at least one instance of each DOW for each of the 12 calendar months (e.g., January WIM data should be available for at least one Monday, one Tuesday, one Wednesday) (i.e., at least 7 d, each representing a different DOW, per each of the 12 calendar months).
    - At least 200 axle load applications must be available for each calendar month for a given class–axle combination to compute monthly ALDF. If fewer than 200 axle load applications are available in a month for a given class–axle combination, then the ALDF representing a typical day of the year should be computed for that class–axle combination.
    - ALDF results developed based on data satisfying the preceding criteria are labeled "Best."
- For computing ALDF representing a typical day of the year, all available data, aggregated to the annual level that passed data QC and reasonableness checks discussed in this chapter, are used. Depending on data availability, different letters are assigned to the usability codes as discussed previously.

- No additional letters are assigned at the end of the usability codes, as discussed previously, if one of the following WIM data availability criteria for a given class–axle combination (considering all data collection periods) are satisfied:
    - At least 180 d.
    - At least 6 mo with 7 DOW in each month.
- If the above data availability criteria are not satisfied for a given class–axle combination, "ALS" is assigned at the end of the usability codes, as discussed above, to indicate that particular ALDF may be an atypical axle distribution due to a small data sample size used to compute the ALDF. Using default values may be a better option for cases with small sample sizes. ALDF computed based on limited data should not be used to develop defaults for other LTPP sites.
- If one of the above criteria is satisfied but the count for a particular class–axle combination is very low, atypically low count (ALC) is assigned at the end of the usability codes to indicate that particular ALDF may be atypical due to a low axle count. Using default values may be a better option for cases with low axle counts. ALDF computations based on limited data should not be used to develop defaults for other LTPP sites. A very low count is defined as a total number of axles, considering all data collection periods, of less than 200.

Handling Atypical Axle Groupings

During the data review, the research team discovered that many LTPP WIM sites have a very small percentage of axle loads reported for axle types not typical for assigned vehicle class based on the FHWA vehicle classification scheme. Likely causes are vehicle misclassification, a State-specific vehicle classification algorithm deviating from the FHWA vehicle classification scheme, or an incorrect axle grouping assignment during data processing. For over 95 percent of LTPP WIM sites, the number of misclassified axles was less than 0.5 percent of the total number of axles, and for 98 percent of sites, the number of misclassified axles was less than 1 percent.

Axle counts are used to develop NALS and axles per truck (APT) numbers. APT is computed for each site and vehicle class as a ratio of axle counts reported for each axle grouping to the total number of vehicles in that vehicle class. Because APT is reported in the AASHTOWare Pavement ME Design software to the nearest one-hundredth (X.XX), any ratio less than 0.005 is rounded to 0. Therefore, when the ratio is less than 0.005, ALDF for that axle grouping and vehicle class is not used in MEPDG computations. To avoid confusion with misclassified or atypical ALDF, a decision was made not to report ALDF for atypical axle groupings if the ratio of the number of the atypical axles to the total number of trucks was less than 0.005 for any site, vehicle class, and axle group.

If the ratio of the number of atypical axles to the total number of trucks was greater than 0.005, the research team decided to keep these unexpected ALDF to ensure these axles are accounted for in pavement analyses, including misclassified axle groups. If NALS, APT, and ALDF were computed for atypical axle grouping, an "AA" code was added to the usability codes discussed previously to indicate that data are atypical (most likely due to misclassification) and should not be used for other LTPP sites or defaults.

Method 1—Develop ALDF Based on Site-Specific WIM Data

In AASHTOWare Pavement ME Design software, ALDF are entered for each axle group (i.e., single, tandem, tridem, and quad+), for each heavy vehicle class (FHWA Classes 4–13), and for each calendar month. ALDF represent distribution of traffic loads for a typical analysis or design year. Therefore, to prepare this input using site-specific axle loading data, site-specific axle loading distributions available in the LTPP database from multiple data collection periods must be summarized in a way that provides one representative estimate of axle loading frequency distribution for a typical year of pavement service life.

All ALDF computations are made on the LTPP site, vehicle class, and axle group level. The high-level algorithm for computing site-specific ALDF includes the following operations:

1. Obtain axle loading information and supporting metadata from LTPP database tables:
    a. Monthly and annual NALS from LTPP traffic data tables.
    b. Number of days with WIM data per month and year used in monthly and annual NALS computations from LTPP axle count tables.
    c. Information about WIM sensor types and calibration efforts from LTPP ancillary data tables.
2. Review NALS data availability and identify LTPP sites with data sufficient for ALDF computation.
3. Subject NALS identified in the previous step to automatic data quality/reasonableness checks.
4. Manually review records flagged during automatic checks. If flagged NALS indicate low precision or bias in WIM measurement or vehicle misclassification and/or the extent of the data anomaly is likely to significantly effect MEPDG predictions, remove them from further computations.
5. Select site-specific NALS that passed data availability and data quality/reasonableness criteria for computing site-specific representative ALDF.
6. Select the ALDF computational procedure based on data availability and quality and compute the ALDF.
7. Store the ALDF in the database table in the format compatible with AASHTOWare Pavement ME Design software.

8. Assign a usability code in the ALDF database table specifying the source of the data and the method used for the ALDF computation for each LTPP site, vehicle class, and axle group included in ALDF database table.

Method 2—Estimate ALDF Using Alternative Data Sources or Defaults

For LTPP sites with insufficient WIM data or data with limited accuracy, several estimation approaches were developed based on available information.

All ALDF estimations are made on the LTPP site, vehicle class, and axle group level. The high-level algorithm for estimating ALDF for sites with insufficient site-specific data includes the following operations:

1. If limited or low-quality site-specific NALS are available to draw conclusions about the general loading pattern, assign a loading pattern for each axle group for each dominant heavy vehicle class. Dominant heavy vehicle class is expected to contribute 20 percent or more to the total traffic load at a given LTPP site. When assigning a loading pattern, account for low-precision or high-bias WIM data, if applicable.

2. Use the assigned loading pattern to identify the ALDF or NALS from alternative sources best describing that pattern through the following approaches, listed in the order of preference:

    a. Assign an ALDF developed for a different LTPP site located on the same roadway but at a different location if that location had a similar loading pattern for the selected dominant vehicle class and axle group. Assign ALDF from the same LTPP site for all other nondominant vehicle classes.

    b. Assign an average ALDF computed for roadways in the same State and the same functional classification that had a similar loading pattern for the selected dominant vehicle class and axle group. Assign an average ALDF from the same roadways for all other nondominant vehicle classes.

    c. Assign the LTPP PLUG NALS default best describing available site-specific information about loading patterns for the selected vehicle class and axle group. Assign the LTPP PLUG NALS default for all other nondominant vehicle classes.

3. If available WIM data are insufficient or inconclusive to characterize the axle loading distribution or general loading pattern at an LTPP site, use the following estimation approaches, listed in the order of preference:

    a. Assign the ALDF available for the same roadway but from a different location provided vehicle classification and truck volume is similar between the two locations.

    b. Assign an average ALDF computed for roadways in the same State and the same functional classification with similar vehicle class distribution and truck volume.

c. Assign the LTPP PLUG default based on available site-specific information about dominant truck types, road functional classification, vehicle class distribution, AADTT, and location.

Storing and Using ALDF

ALDF developed for LTPP sites are stored in the MEPDG_AXLE_LOAD_DIST_FACTOR table in a format compatible with AASHTOWare Pavement ME Design software. The ALDF database table was designed in a format that allows copying and pasting information directly into the AASHTOWare Pavement ME Design software GUI screen for axle loading input. A code was provided for each site, vehicle class, and axle group specifying the method used to compute ALDF or assign ALDF from alternative sources.

The research team developed ALDF for all LTPP WIM sites with sufficient data to support ALDF computation Method 1 described above. In addition, ALDF .xml tables compatible with AASHTOWare Pavement ME Design software were developed for each LTPP site that had data to support ALDF computed using Method 1. LTPP sites that required use of the ALDF computation Method 2 were addressed in another LTPP traffic data analysis study.(22)

PROCEDURES FOR ALDF COMPUTATION

This section contains a description of the detailed procedures to compute ALDF, which include the following:

- Review axle loading data availability, accuracy, and rationality and assign the ALDF computation method.
- Identify the loading pattern using annual NALS of limited accuracy.
- Compute ALDF based on site-specific WIM data using Method 1.
- Estimate ALDF for sites with insufficient or no site-specific WIM data using Method 2.

Procedure to Review Axle Loading Data Availability, Accuracy, and Rationality and Assign the ALDF Computation Method

The following procedure describes steps for selecting the ALDF computational method (e.g., Method 1 or Method 2) based on site-specific WIM data quality and availability for each LTPP WIM site.

Step 1. Prepare intermediate database tables to store site-level information about ALDF methods.

1.1. Obtain MM_AX, NALS_MONTHLY_DISTRIB and NALS_ANNUAL_DISTRIB tables from the LTPP database. These tables contain normalized axle load distributions for LTPP traffic sites with WIM equipment. Add these tables to an empty analysis database. Obtain the following additional tables from LTPP database and add them to the analysis database: MM_AX, TRF_CALIBRATION_WIM, TRF_EQUIPMENT_MASTER, and TOTAL_AXLES_YY_TSSC

1.2. Create a new database table called ALDF_ASSIGNMENT_METHOD with fields for STATE_CODE, SHRP_ID, VEHICLE_CLASS, AXLE_GROUP, and ALDF_METHOD.

1.3. Populate the ALDF_ASSIGNMENT_METHOD table with the LTPP traffic site IDs, vehicle classes, and axle group entries included in the NALS_ANNUAL_DISTRIB table. The list of WIM site IDs is included in appendix B of this report. The ALDF_ASSIGNMENT_METHOD table is used to keep track of the assigned ALDF computation or estimation method for each LTPP traffic site ID, vehicle class, and axle group.

1.4. Create a new database table called ALDF_ANNUAL_CANDIDATES with fields for STATE_CODE, SHRP_ID, YEAR, and WIM_TYPE_BY_YEAR. Use the NALS_ANNUAL_DISTRIB table to populate the ALDF_ANNUAL_CANDIDATES table with corresponding WIM site IDs and years.

1.5. Create a new empty database table called ALDF_MONTHLY_CANDIDATES with fields for STATE_CODE, SHRP_ID, MONTH, YEAR, and WIM_TYPE_BY_MONTH.

Step 2. Identify records in monthly NALS tables satisfying minimum data availability criteria.

2.1. Use the NALS_MONTHLY_DISTRIB and MM_AX tables to identify WIM sites (identified by STATE_CODE and SHRP_ID fields), vehicle classes, and axle groups satisfying the following conditions:

- There is at least one occurrence for each of the 12 calendar months at Level E in the NALS_MONTHLY_DISTRIB table for a given WIM site ID.
- Each calendar month has at least one occurrence for each of the 7 DOW (i.e., Sunday–Saturday).
- The total number of axles per month at Level E is 200 or more for a selected vehicle class and axle group.

2.2. Populate the ALDF_MONTHLY_CANDIDATES table with WIM site IDs and all months and years satisfying the data availability criteria described in step 2.1.

Step 3. Identify WIM equipment type and measurement accuracy for each LTPP traffic site.

Perform the following steps for each LTPP WIM site included in ALDF_MONTHLY_CANDIDATES or ALDF_ANNUAL_CANDIDATES tables:

3.1. Match WIM site IDs with the LTPP section IDs in TRF_CALIBRATION_WIM and TRF_EQUIPMENT_MASTER tables and extract information from the WIM_SENSOR field in the TRF_EQUIPMENT_MASTER table.

3.2. Use the TRF_CALIBRATION_WIM table to quantify weight measurement accuracy or bias for each calibration period by using *_DIFF fields and precision by using *DIFF_SD fields and computing the statistical 95 percent confidence interval. Compute the total error as bias ± precision.

3.2.1. If no records are found in the TRF_CALIBRATION_WIM table for a given LTPP WIM site ID or values in DYNAMIC_STAT_SINGLE_AXLE_DIFF, DYNAMIC_STAT_TANDEM_AXLE_DIFF, DYNAMIC_STAT_SINGLE_DIFF_SD, or DYNAMIC_STAT_TANDEM_DIFF_SD fields are missing, identify WIM site ID as "unknown accuracy." Proceed to step 4.

3.2.2. Use values in DYNAMIC_STAT_SINGLE_AXLE_DIFF and DYNAMIC_STAT_TANDEM_AXLE_DIFF fields to assess measurement bias for each WIM site.

3.2.2.1. If bias is over 5 percent in either of these fields, identify the corresponding month and year as "poor or unknown" in the WIM_TYPE_BY_MONTH field. Proceed to step 4.

3.2.2.2. If bias is less than 5 percent for both fields, obtain values from DYNAMIC_STAT_SINGLE_DIFF_SD and DYNAMIC_STAT_TANDEM_DIFF_SD fields, multiply these values by 2, and add to the corresponding bias value from DYNAMIC_STAT_SINGLE_AXLE_DIFF or DYNAMIC_STAT_TANDEM_AXLE_DIFF fields. This is the total measurement error value.

3.2.3. If the total error value is less than 20 percent for single axles and less than 15 percent for tandem axles, identify the corresponding month and year and enter "Type I" in the WIM_TYPE_BY_MONTH field. Proceed to step 4.

3.2.4. If the total error value for single axles is less than 30 percent and less than 20 percent for tandem axles, identify the corresponding month and year and enter "Type II" in the WIM_TYPE_BY_MONTH field. Proceed to step 4.

3.2.5. Identify the traffic site ID and corresponding month and year as "poor or unknown" in the WIM_TYPE_BY_MONTH field. Proceed to step 4.

Step 4. Assign WIM type and select data accuracy assessment option for each LTPP WIM site.

4.1 Using results of step 3, label candidate months and years that likely have data collected by WIM sensors satisfying the performance parameters of Type I WIM systems per ASTM E1318-09 for each LTPP WIM site included in the ALDF_MONTHLY_CANDIDATES table.

4.1.1. If the WIM sensor type is bending plate or load cell and Type I is identified for a given calibration month and year, assign a Type I value for all months following the calibration month for a period of 2 yr after calibration or until any other value is assigned in the WIM_TYPE_BY_MONTH field, whichever comes first.

4.1.2. If the WIM sensor type is piezo quartz and Type I is identified for a given calibration month and year, assign this value for 12 mo following the calibration month or until any other value is assigned in the WIM_TYPE_BY_MONTH field, whichever comes first.

4.1.3. If the WIM sensor type is not bending plate, load cell, or piezo quartz, exclude from WIM Type I monthly assignments (weight changes due to high seasonal temperature sensitivity and lower precision of heavy axle weight measurements between calibrations were observed for these sensors).

4.2. Using results of step 3, label candidate years that likely have data collected by WIM sensors satisfying the performance parameters of Type I or II WIM systems per ASTM E1318-09 for each LTPP WIM site included in the ALDF_ANNUAL_CANDIDATES table.

4.2.1. If Type I is identified in the WIM_TYPE_BY_MONTH field for a given calibration month and year, assign a Type I value for the next year after calibration for all types of piezo sensors and 2 yr for bending plate and load cell sensors in the WIM_TYPE_BY_YEAR field unless any other value is already assigned in the WIM_TYPE_BY_YEAR field for this year(s).

4.2.2. If Type II is identified in the WIM_TYPE_BY_MONTH field for a given calibration month and year, assign a Type II value in WIM_TYPE_BY_YEAR field for the next year after calibration unless any other value is already assigned in the WIM_TYPE_BY_YEAR field for this year(s).

4.2.3. If “poor or unknown” is found in the WIM_TYPE_BY_MONTH field, assign this value in the WIM_TYPE_BY_YEAR field for all following years unless another value is already assigned in the WIM_TYPE_BY_YEAR field.

4.2.4. Assign “unknown accuracy” values in the WIM_TYPE_BY_YEAR field for all remaining months and years with no other values in WIM_TYPE_BY_YEAR fields of ALDF_ANNUAL_CANDIDATES tables.

4.3. Using results of step 4.2, assess WIM data availability based on the values assigned in WIM_TYPE_BY_MONTH and WIM_TYPE_BY_YEAR fields and identify data analysis option, as described in the proceeding steps.

4.3.1. For WIM site IDs with at least one instance for each of the 12 calendar months in the ALDF_MONTHLY_CANDIDATES table with a Type I value in the WIM_TYPE_BY_MONTH field, assign “OPTION 1: WIM Type I accuracy, monthly.” Proceed to step 5.

4.3.2. For WIM site IDs with at least 1 yr in the ALDF_ANNUAL_CANDIDATES table with a Type I value in the WIM_TYPE_BY_YEAR field, assign “OPTION 2: WIM Type I accuracy, annual.” Proceed to step 5.

4.3.3. For WIM site IDs without at least 1 yr in the ALDF_ANNUAL_CANDIDATES table with a Type I value in the WIM_TYPE_BY_YEAR field, but with Type II or “unknown” values, assign “OPTION 3 and 4: WIM Type II or unknown accuracy.” Proceed to step 5.

Step 5. Subject monthly and annual NALS to data quality and reasonableness review and identify NALS for ALDF computation.

Use the following procedure to review quality and rationality of WIM data and identify NALS datasets for ALDF computation:

5.1. For LTPP traffic site ID, months, and years identified as "OPTION 1: WIM Type I accuracy, monthly," perform the following:

5.1.1. Extract monthly NALS for FHWA Class 9 satisfying minimum monthly data availability criteria of at least 7 DOW and 200 axles per month for 12 calendar months.

5.1.2. Subject the monthly NALS for FHWA Class 9 vehicles to the automated reasonableness checks described in section WIM Data Rationality and Data Reasonableness Checks. Flag monthly NALS records failing the checks.

5.1.3. For the sites with flagged FHWA Class 9 NALS, manually review all available FHWA Class 9 NALS for that site (using procedure provided in section WIM Data Rationality and Data Reasonableness Checks) and conclude if the flagged NALS follow the historical loading trend for the site. If the flagged average axle weight for a single axle or for a loaded tandem axle weight deviates from the historical trend (based on reporting periods satisfying the performance parameters of Type I WIM systems per ASTM E1318-09) and this deviation does not represent a repeatable seasonal pattern, consider the flagged monthly NALS a true outlier.

5.1.4. Compile a list of LTPP sites and dates (i.e., month and year) with outlier monthly NALS confirmed during the manual review. Remove records with matching LTPP site IDs, months, and years from the ALDF_MONTHLY_CANDIDATES table.

5.1.5. Check the availability of monthly NALS in ALDF_MONTHLY_CANDIDATES table. For each set of records defined by LTPP traffic site ID, vehicle class, and axle group, check if available NALS have at least one occurrence of each of the 12 calendar months (January to December) with at least 200 axles per month.

5.1.5.1. If the above data availability criteria are not met for a given LTPP site, vehicle class, and axle group, delete the site, vehicle class, and axle group from the ALDF_MONTHLY_CANDIDATES table, then proceed to step 5.2 and check usability of the annual NALS for ALDF computation for that LTPP site, vehicle class, and axle group.

5.1.5.2. If the above data availability criteria are met, populate the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table with "M1MR" values for the corresponding traffic site ID, vehicle class, and axle group. Assignment is completed. Proceed to step 5.4 to check for atypical axle groups and then to the Compute ALDF with Unique Values for Each Calendar Month (Method 1—Monthly) section.

5.2. For annual NALS identified as "OPTION 2: WIM Type I accuracy, annual" in step 4 and LTPP sites initially identified as monthly NALS option 1 that did not pass data reasonableness and/or data availability checks in step 5.1, perform the following:

5.2.1. Extract annual NALS for FHWA Class 9 and apply the automated reasonableness checks described in section WIM Data Rationality and Data Reasonableness Checks. Flag annual NALS records failing the checks.

5.2.2. For sites with FHWA Class 9 NALS flagged during the automated checks, manually review all available FHWA Class 9 NALS (using procedure provided in section WIM Data Rationality and Data Reasonableness Checks) and conclude whether the flagged NALS follow the historical loading trend for the site or shows possible calibration or low precision issues. If the flagged NALS do not follow a pattern typical for FHWA Class 9 NALS and is not consistent with other NALS for a given WIM site, vehicle class, and axle group, consider the flagged NALS an outlier.

5.2.3. Compile the list of LTPP site IDs and years that passed automated and manual QC checks for Type 1 annual NALS. Save the table as ALDF_ANNUAL_OPTION2_FINALISTS.

5.2.4. For each LTPP site ID, vehicle class, and axle group included in the ALDF_ANNUAL_OPTION2_FINALISTS table, check if the corresponding record in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table is empty.

5.2.4.1. If not empty, do not overwrite the previous assignment. Remove site ID, vehicle class, and axle group records from the ALDF_ANNUAL_OPTION2_FINALISTS table.

5.2.5. Check the total number of axles per year in the TOTAL_AXLES_YY_TSSC table for all years reported in the ANNUAL_NALS_OPTION2_FINALISTS table.

5.2.5.1. If 200 or more for each year, add NALS with more than 200 axles per year to the new table called ANNUAL_NALS_OPTION2_FOR_BY_YEAR_COMPUTATION. These records are used to compute ALDF values based on annual averages for sites with Type I WIM data accuracy. Add "M1" values to the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table. Assignment is complete.

5.2.5.2. If fewer than 200 for each year, add NALS to the new table called ANNUAL_NALS_OPTION2_FOR_YEARS_COMBINED_COMPUTATION. These records are used to compute ALDF values based on combined annual axle counts from multiple years marked as option 2 yr. Add "M1YC" values to the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table.

5.2.5.3. For each LTPP traffic site, vehicle class, and axle group included in ANNUAL_NALS_OPTION2_FOR_YEARS_COMBINED_COMPUTATION table, compute the total number of axles for all years combined and save as a new TOTAL_AXLES_OPTION2_FOR_YEARS_COMBINED_ COMPUTATION table. If the total number of axles for all years combined is fewer than 200 but more than 1, add "AL" values to the "M1YC" values in ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table for identified LTPP traffic sites, vehicle classes, and axle groups. Assignment is complete.

5.2.6. Proceed to step 5.4 to check for atypical axle groups and then to the Procedure to Compute ALDF Based on Site-Specific WIM Data Using Method 1 section.

5.3. Proceed with this step after ALDF are computed for option 1 and 2 sites.

5.3.1. Use the ALDF_ASSIGNMENT_METHOD table to create a list of records defined by the LTPP traffic site ID that do not have ALDF_METHOD assignments. These are sites initially identified as "OPTION 3 and 4: WIM Type II or unknown accuracy" and sites initially identified as option 1 or 2 but did not pass the data reasonableness assessment.

5.3.2. Use the list compiled in step 5.3.1 to extract annual NALS for LTPP sites missing ALDF_METHOD assignments. The accuracy of WIM data for these sites is either unknown or of a lesser quality than for Type I sites. The goal of the data reasonableness review for these sites is to identify annual NALS falling into one of the following three categories:

5.3.2.1 Data satisfy data availability and reasonableness criteria for computing site-specific ALDF values.

5.3.2.2 Data quality and/or quantity prevent accurate quantification of loading but are descriptive enough to define a loading pattern for dominant heavy trucks (typically FHWA Class 9 trucks).

5.3.2.3 Data quality and/or quantity is too low to infer meaningful loading information.

5.3.3. Subject annual NALS for FHWA Class 9 vehicles to the automated reasonableness checks described in section WIM Data Rationality and Data Reasonableness Checks. Flag annual NALS records failing the checks.

5.3.4. Manually review LTPP sites with FHWA Class 9 NALS flagged during the automated checks and conclude whether flagged NALS follow the historical loading trend for the site or show possible calibration or low precision issues. For additional guidance, refer to the Procedure to Assess Rationality and Identify Loading Pattern Using Annual NALS of Limited Accuracy section.

5.3.5. Use the results of the manual review to categorize LTPP sites and years using the following criteria:

5.3.5.1 If at least 1 yr with NALS passed automated and manual QC checks, identify these NALS records and label the resulting ALDF for the site as “Good.” Add LTPP sites and year(s) identified “Good” to a new table called OPTION34_S_SITES_YEARS and proceed to step 5.3.6.

5.3.5.2 If all years were flagged, check if any of these years had errors not likely to significantly effect pavement analysis outcomes using the MEPDG method (e.g., FHWA Class 9 NALS with less than 10 percent difference in the expected percentages of heavy loads typical for a given type of road). Identify NALS records for these years and label the resulting ALDF for the site as “Fair.” Add LTPP sites and years identified “Fair” to the OPTION34_S_SITES_YEARS table and proceed to step 5.3.6.

5.3.5.3 If no years passed automated and manual QC checks but typical axle loading pattern can be clearly identified in annual axle load distributions for FHWA Class 9 trucks, add “M2P” values to the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table.

5.3.5.4 If no years passed automated and manual QC checks and no expected loading pattern can be identified in annual axle load distributions for FHWA Class 9 trucks, add “M2NoP” values to the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table.

5.3.6. For each LTPP site ID, vehicle class, axle group, and year included in the OPTION34_S_SITES_YEARS table, check if the total number of axles per year reported in the TOTAL_AXLES_YY_TSSC table at Level E is 200 or more.

5.3.6.1. If 200 axles or more per year, perform the following actions:

5.3.6.1.1. Add NALS for class-axles with more than 200 axles per year to a new table called ANNUAL_NALS_OPTION34_FOR_BY_YEAR_ COMPUTATION. These records are used to compute ALDF values based on annual averages.

5.3.6.1.2. Using the results of the manual review in step 5.3.3, add “M1U-Good” and “M1U-Fair” values to the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table. Assignment is complete.

5.3.6.2. If fewer than 200 axles per year, perform the following actions:

5.3.6.2.1. Add NALS to a new table called ANNUAL_NALS_OPTION34_FOR_YEARS_COMBINED_ COMPUTATION. These records are used to compute ALDF values based on combined annual axle counts from multiple years.

5.3.6.2.2. Using the results of the manual review in step 5.3.5, add "M1UYC," "M1UYC-Good," and "M1UYC-Fair" values to the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table. Assignment is complete.

5.3.6.2.3. For each LTPP site, class, and axle included in the OPTION34_S_SITES_YEARS table, compute the total number of axles for all years. If the total number of axles for all years is fewer than 200 but more than 1 for a given class and axle, identify the record for a given class and axle as "ALC" (for "atypically low count") in the ALDF_ASSIGNMENT_METHOD table.

5.3.7. Proceed to step 5.4 to check for atypical axle groups and then to the Procedure to Compute ALDF Based on Site-Specific WIM Data Using Method 1 section.

5.4. Check for atypical axle groups

5.4.1 Review axle group assignments for each site and vehicle class in the ALDF_ASSIGNMENT_METHOD table and identify records defined by LTPP traffic site ID, vehicle class, and axle group with axle groups extremely unlikely or impossible based on FHWA TMG 13-bin vehicle class definitions (e.g., tridem axle group reported for 2-axle Class 5 vehicle).

5.4.2 For the identified records with atypical axle groups, add the letters "AA" for "atypical axle" to the assigned code in the ALDF_METHOD field. Assignment is complete.

Procedure to Assess Rationality and Identify Loading Pattern Using Annual NALS of Limited Accuracy

Data from Type II WIM systems, systems with unknown accuracy, or data from limited data samples may or may not be applicable for direct use as site-specific traffic loading inputs due to low precision, bias, or a small, nonrepresentative sample size. NALS developed based on calibrated Type II or lower accuracy WIM systems tend to have a shape of loading distribution similar to NALS developed based on Type I WIM data but with wider spread of axle loading distribution, characterized by heavier tails of distribution and lower peaks, as a result of low precision.

These NALS may be used with some caution for developing site-specific ALDF if the effect of the lower precision or bias does not significantly affect the percentage of heavy and overloaded axles (e.g., less than 10 percent difference in the percentage of heavy loads) compared to similarly shaped NALS developed based on research-quality data. If the bias or low precision observed in NALS results in a significant deviation from the expected percentage of heavy and overloaded axles for a given loading pattern, these NALS should not be used for direct computation of ALDF. However, if the general shape of the NALS follows that typically observed for FHWA Class 9 vehicles, the NALS can be used as an aid for selecting the default axle loading distribution developed from research-quality WIM data with a general NALS shape resembling the axle load distribution based on lower quality WIM data.

The following procedures can be used to identify and evaluate axle loading patterns using WIM data of lower quality and aid in selecting default axle loading distribution values:

1. For each WIM site, plot the annual NALS for FHWA Class 9 vehicles on an x–y plot (separately for single and tandem axles). Conduct an initial visual and quantitative assessment of axle load distributions using the criteria listed in step 2 below. Note that sites exhibiting axle weights that deviate from the following criteria may, in fact, represent actual axle weights. However, not knowing specific details about the commodities being transported, it is important to identify and flag the sites with atypical distributions.

2. Flag NALS distributions that do not satisfy the following attributes that identify typical or expected axle load distributions for FHWA Class 9 vehicles:

   For single axles, the following criteria apply:

   - A bell-shaped distribution with a single peak load bin. A secondary heavy loaded peak between 16,000 and 22,000 lb is acceptable (possible when split-tandem axle groups are reported as two single axles).
   - The peak load bin is within the 9,000–11,999 lb range.
   - Less than 3 percent of single axle loads exceed 18,000 lb, and less than 1 percent of single axle loads exceed 20,000 lb.

   For tandem axles, the following criteria apply:

   - A camel-back distribution showing two peaks: one for loaded axles and one for unloaded axles. It is possible, but uncommon, to see only one peak (either loaded or unloaded) at the location of either the first or second peak.
   - First peak load bin is between 10,000 and 15,999 lb (optional check for lightly loaded or empty trucks).
   - Second peak load bin is between 28,000 and 35,999 lb
   - Less than 20 percent of loads exceed the Federal legal limit of 34,000 lb. The majority of sites are expected to have less than 10 percent of axles over the Federal legal limit.
   - Less than 3 percent of loads exceed 40,000 lb.
   - No loads over 60,000 lb are expected. Loads over 60,000 lb should be less than 0.1 percent of all tandem loads for FHWA Class 9 vehicles.

3. If the initial assessment does not indicate anomalies in axle load distribution shape (i.e., the expected shape of distribution with a well-defined bell-shaped distribution of loaded and unloaded axles, values of unloaded and loaded peak loads are within reasonable range, and typical overload values) and no automated checks (described in the WIM Data

Rationality and Data Reasonableness Checks section) are flagged, assume that WIM equipment collects data without significant bias and has adequate precision. NALS passing this assessment can be used to construct site-specific ALDF. ALDF computed based on these NALS should have an ALDF usability code labeled as “Good.” Add the corresponding site IDs and years to the OPTION34_S_SITES_YEARS table and proceed to step 5.3.6 to assess the total number of axles per year and select the ALDF computation procedure.

4. If the initial assessment does not indicate anomalies in axle load distribution shape (i.e., the expected shape of distribution with a well-defined bell-shaped distribution of loaded and unloaded axles, values of unloaded and loaded peak loads are within reasonable range, and typical overload values), but some automated checks described in the WIM Data Rationality and Data Reasonableness Checks section resulted in flagged NALS, WIM equipment likely collected data with some bias or lower precision. Check if these NALS can be used for ALDF computation using the following assessments:

    4.1 Assess the precision of the estimates by comparing the peaks and tails of the distribution and the percentages of overloaded axles with the corresponding values in the default distribution built based on research-quality data with a similar loading shape. Lower precision will result in lower values of both unloaded and loaded peak loads and a wider spread of bell-shaped axle distributions along the x-axis. If the lower precision does not increase the percentage of overloads by an additional 10 percent (e.g., increase in overloads from 7 percent to 17 percent) compared to the expected percentages for a given loading pattern, these values can be used to construct site-specific ALDF. Identify these NALS as SLP (site-specific low precision).

    4.2 Assess the likely value of the bias by reviewing the locations of the loading peaks along the x-axis in comparison with the location of the loading peaks in the default NALS distribution built based on research-quality data with a similar loading shape. If some bias is evidenced by the shifted peak load location for the loaded axles, assess if this shift is likely to result in less than a 10 percent addition or subtraction to/from the percentage of overloads expected for a given loading pattern. If less than a 10-percent change is likely, these NALS can be used to construct site-specific ALDF. Identify these NALS as SNB (site-specific negative bias), or SPB (site-specific positive bias).

    4.3 For NALS identified as SLP, SNB, or SPB, check if a combination of bias and poor precision attributes is likely to increase or decrease the percentage of overloads by over 10 percent. If less than a 10 percent change is likely, these NALS can be used to construct site-specific ALDF. ALDF computed based on these NALS should have an ALDF usability code labeled as “Fair.” Add these corresponding WIM site IDs and years to the OPTION34_S_SITES_YEARS table and proceed to step 5.3.6 to assess the total number of axles per year and select the ALD computation procedure.

5. If the initial assessment does not indicate anomalies in the axle load distribution shape (i.e., the expected shape of distribution with a reasonable peak load location on the x-axis), but the precision is too low to be used as a site-specific loading input value, use table 50 to assign the default axle loading category based on the percentage of heavy loads computed for the FHWA Class 9 tandem NALS. Label FHWA Class 9 tandem NALS using loading category codes shown in table 50. Identify these NALS as "M2P" in the ALDF_ METHOD field in the ALDF_ASSIGNMENT_METHOD table. Note that the labels used to describe loading categories in table 50 are consistent with the labels used by the LTPP PLUG. However, to account for a wider spread of load distributions due to the lower precision of Type II WIM systems compared to distributions based on the LTPP research-quality WIM data, the percentages of heavy load values in table 50 were increased by 5 to 10 percent compared to the percentages used in the LTPP PLUG.

Table 50. Loading category assignment for Type II or low-precision WIM data.

Loading Category	Percent Heavy Loads (>26,000 lb)
Light—L	<20
Moderate—M	20–40
Heavy 1—H1	40–50
Heavy 2—H2	50–60
Very heavy—VH	>60

6. If the initial assessment indicates that NALS under review do not have some or all expected attributes, the following two outcomes are possible:

   - The site location represents unusual loading conditions due to local or regional commodities. If additional information to confirm the observed loading is available and weights are representative of freight being moved, these data may be used as site-specific inputs. In this case, identify the NALS as "M1Special."

   - If no additional information is available or information does not support the observed axle weight distribution, assume the WIM equipment setup, sampling duration, and/or site conditions resulted in an axle load spectrum of limited quality/usability. 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. After this, one of the following two outcomes is possible.

     a. If the tandem axle distribution has the expected shape but location of unloaded and loaded peaks is shifted from expected values, proceed with identifying the loading category based on analyzing the ratio between unloaded and loaded peak axle loads of tandem axle distribution. To do this, find the highest percentage of axle loads corresponding to the first (unloaded) peak (for loads less than 26,000 lb) and the second (loaded) peak (for loads greater than 26,000 lb) and compute the peak load ratio between those peaks (i.e., the percentage of axles corresponding to the unloaded peak load bin divided by the percentage of axles corresponding to the loaded peak load bin). Use table 51 to find the loading category based on the computed peak load ratio. Label FHWA Class 9 tandem

NALS using loading category codes shown in table 51. Identify these NALS as "M2P" in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table. Add LTPP site ID to a new table called OPTION34_P_SITES_YEARS.

Table 51. Unloaded to loaded peak ratios in tandem axle load distributions for different loading categories.

Loading Category	Peak Loads Ratio (Unloaded Peak/Loaded Peak)
Light—L	>6
Moderate—M	≤6 and >2.33
Heavy—H	≤2.33 and >1
Very heavy—VH	≤1

b. If the shape of the distribution is unexpected, stop further analysis. This WIM dataset is unusable for determining the LTPP site's loading condition. These data should not be used as site-specific inputs or to select the defaults. Identify these NALS as "M2NoP" in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table.

Procedure to Compute ALDF Based on Site-Specific WIM Data Using Method 1

Based on available axle loading data, ALDF are computed from either monthly or annual NALS using the ensuing procedures.

Compute ALDF with Unique Values for Each Calendar Month (Method 1—Monthly)

The following procedure describes ALDF computation using monthly NALS records identified as ALDF "M1MR" in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table:

1. For each traffic site ID, vehicle class (FHWA Classes 4–13), axle group, and calendar month, compute average monthly NALS for each calendar month (January to December) by averaging monthly NALS over multiple years included in the ALDF_MONTHLY_CANDIDATES table.

2. Renormalize (i.e., express in percentile form) average monthly NALS so the sum of the percentages across all load bins equals 100 percent.

3. Populate fields of the TRF_MEPDG_ALDF_Method1_Monthly_Results table with the computed percentages for each traffic site ID, vehicle class (FHWA Classes 4–13), axle group, and calendar month.

4. Review the TRF_MEPDG_ALDF_Method1_Monthly_Results table for completeness (i.e., presence of 12 calendar months for each vehicle class [FHWA Classes 4–13] and axle group for each site). Identify any missing records defined by a combination of site ID, vehicle class, axle group, and month. Use the procedure described in the Compute

ALDF Representing a Typical Day of a Year (Method 1–Annual) section to compute missing values.

Compute ALDF Representing a Typical Day of a Year (Method 1—Annual)

The following procedure describes ALDF computation using records identified with “M*” codes (except for the “M1MR” code) in the in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table:

1. Develop representative annual NALS for each LTPP site with codes M1, M1U*, M1_AA, or M1U_AA in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table using the following steps:

    1.1. Average corresponding NALS in ANNUAL_NALS_OPTION2_FOR_BY_YEAR_COMPUTATION or ANNUAL_NALS_OPTION3_4_ FOR_BY_YEAR_COMPUTATION tables over all available years.

    1.2. Renormalize (i.e., express in percentile form) average NALS to ensure the sum of percentages across all load bins equals 100.00 when rounded to the nearest hundredth.

    1.3. Save the results in a new table called ANNUAL_NALS_FOR_ALDF.

2. Develop representative annual NALS for each LTPP site with codes M1YC, M1UYC*, M1YC_AA, or M1UYC_AA in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table using the following steps:

    2.1. Use NALS in the ANNUAL_NALS_OPTION2_YEARS_COMBINED table and the total number of axles per year computed by the LTPP CSSC and reported in the TOTAL_AXLES_YY_TSSC table to compute axle load distributions for years included in the ANNUAL_NALS_OPTION2_YEARS_COMBINED table.

    2.2. Sum axle load distributions for years included in the ANNUAL_NALS_OPTION2_YEARS_COMBINED table.

    2.3. Normalize the resulting axle load distribution (i.e., express in percentile form by dividing the number of axle counts in each load bin by the total number of axle counts in all load bins then multiplying by 100 percent) and save results in the ANNUAL_NALS_FOR_ALDF table.

3. For each traffic site ID, vehicle class (FHWA Classes 4–13), and axle group included in the ANNUAL_NALS_FOR_ALDF table, repeat the same NALS for each of 12 calendar months and save results in a new table called TRF_MEPDG_ALDF_Method1_All_Annual_Results.

4. Identify NALS based either on a small sample due to short count duration (code ALS, meaning fewer than 6 calendar months and fewer than 180 d) or low count of an underrepresented vehicle class or axle type (code ALC, meaning long count duration but low axle volume, fewer than 200 axles total; code APD0, meaning very low number of axles per

day; or code APT0, meaning very low average axle number or no axle group present for a vehicle class).

5. Add identifiers (i.e., flags) of ALS, meaning low sample, or ALC, meaning low axle count, in ALDF_ASSIGNMENT_METHOD tables. These NALS may not be representative of the loading condition due to sample size limitations.

Assemble the TRF_MEPDG_ALDF Table

The TRF_MEPDG_ALDF table is designed to facilitate copy–paste operations between tables in AASHTOWare Pavement ME Design software. See chapter 11 for table design information. Assemble the TRF_MEPDG_ALDF table using the following steps:

1. Add previously computed site-specific ALDF values stored in TRF_MEPDG_ALDF_Method1_Monthly_Results and TRF_MEPDG_ALDF_Method1_All_Annual_Results tables to a new table called TRF_MEPDG_ALDF_Method1_All_Sites.

2. For LTPP sites with monthly and/or annual MEPDG ALDF in TRF_MEPDG_ALDF_Method1_Monthly_Results and TRF_MEPDG_ALDF_Method1_All_Annual_Results tables, identify those vehicle classes and axle types not having site-specific WIM data to compute ALDF (i.e., a particular vehicle class or axle configuration was not observed in data selected for NALS computation) but vehicle classification data were available in the TRF_MEDPG_TRUCK_VOLUME_PARAMETERS table for some other years. For these sites, add missing vehicle classes, axle types, and "0" ALDF values to the TRF_MEPDG_ALDF_Method1_All_Sites table. Add code APT0, meaning no axle group or vehicle class present, to the APD0_FLAG field in the ALDF_ASSIGNMENT_METHOD table.

3. Format site-specific ALDF for tridem- and quad-axle groups to match the 31-bins used in the AASHTOWare Pavement ME Design software by combining percentages reported in load bins 32 and higher and reporting the results in load bin 31.

4. Use entries in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table to assign ALDF usability ratings to the TRF_MEPDG_ALDF_Method1_All_Sites table.

Procedure to Estimate ALDF for Sites with Insufficient or no Site-Specific WIM Data Using Method 2

The task of assigning ALDF for sites with insufficient or no site-specific WIM data was performed outside of this study by a different contractor using a different procedure.

Method 2.1 Estimate ALDF Using Limited Site-Specific Axle Weight Information (Site-Specific Loading Pattern)

1. Apply the following hierarchical process for each LTPP traffic site identified as M2P in the ALDF_ASSIGNMENT_METHOD table, meaning it has a site-specific loading pattern but low-quality axle loading data:

   1.1 Check if another WIM site is available in the LTPP database with the following attributes:

   - Located on the same roadway with the same road functional classification as the site for which ALDF are being estimated.
   - Has similar loading pattern for the dominant heavy vehicle classes as the site for which ALDF are being estimated.
   - Has ALDF computed based on Method 1.

   1.2 If such a Method 1 site is found, assign ALDF from that site to the "M2P" site being estimated.

   1.3 If no suitable Method 1 site is found, check if Method 1 sites are available for the same State and road functional classification with similar loading patterns as the site being evaluated.

   1.3.1 If such sites are available, compute average ALDF for these sites and assign them to the "M2P" site being estimated.

   1.4 If no suitable Method 1 sites are available, assign the LTPP PLUG default that best describes the loading category for the "M2P" site, vehicle class, and axle group being estimated using the ensuing procedure.

   1.4.1 Review available axle load distributions and assign an axle loading category using the following criteria:

   1.4.1.1 If the distribution has a well-defined shape, corresponding to the shape of one of the LTPP PLUG default distributions for a given vehicle class and axle group, assign the loading category using one of the LTPP PLUG default names. Focus on matching the shape of the distribution representing heavy loads. The distribution can be shifted, stretched, or compressed along the x-axis due to calibration issues, but the general shape should be the same.

   1.4.1.2 If the shape is not well-defined (i.e., axle load counts are low and highly variable), loads are atypically high or low (as compared to LTPP defaults), or distribution does not have the expected shape for a given vehicle class and axle group, proceed to step 2.

Method 2.2 Estimate ALDF for Sites with No Usable Site-Specific Axle Weight Information (No Loading Pattern)

The following ALDF estimation procedure is for LTPP traffic sites with no weight data or weight data insufficient or inconclusive to characterize axle loading pattern. Perform the following steps for each LTPP traffic site, vehicle class, and axle group identified as "M2NoP" in the ALDF_ASSIGNMENT_METHOD table:

1. Check if another WIM site is available in the LTPP database with the following attributes:
    - Located on the same roadway as the site for which ALDF are being estimated, no more than 200 mi away.
    - Has the same road functional classification.
    - Has a similar AADTT.
    - Has a similar vehicle class distribution.
    - Has an ALDF computed using Method 1.
2. If such a Method 1 site is found, assign the ALDF from that site to the Method 2 site, vehicle class, and axle group being estimated.
3. If no suitable Method 1 site is found on the same roadway, check if any Method 1 sites are available for the same State and road functional classification with similar AADTT and vehicle class distributions as the site being evaluated.

    3.1 If such sites are available, compute average ALDF and assign them to the "M2NoP" site being estimated.

    3.2 If no suitable Method 1 sites are available, assign the LTPP PLUG default recommended for sites in the same road functional classification that have similar AADTT and vehicle class distribution. For FHWA Class 9 vehicles, assign loading defaults based on road functional use, truck volume, and vehicle class distribution information using table 52.

Table 52. Recommended LTPP default axle loading categories for FHWA Class 9 vehicles based on road functional use, truck volume, and vehicle class distribution information.

LTPP PLUG Default Loading Category	AADTT (LTPP Lane)	Percent FHWA Class 9 (LTPP Lane)	Road Functional Classification	Road Use and Freight Route
Moderate	<1,000 (at least 100 for FHWA Class 9)	<50	Noninterstate roads: urban, rural, other principal and minor arterials.	Local movement of goods away from industrial and multimodal facilities. Not a freight route.

LTPP PLUG Default Loading Category	AADTT (LTPP Lane)	Percent FHWA Class 9 (LTPP Lane)	Road Functional Classification	Road Use and Freight Route
Heavy 1	1,000 to 3,000	50 to 80	Rural and urban interstates and principal arterials.	Combined local distribution and State-to-State freight movements. Mostly noninterstate rural primary arterials, but also urban interstates designated as freight routes.
Heavy 2	>2,000	>80	Rural and urban interstates or rural principal arterials.	Heavy State-to-State freight movements. Also routes serving major industrial and multimodal transportation facilities and warehouses. Main freight routes.

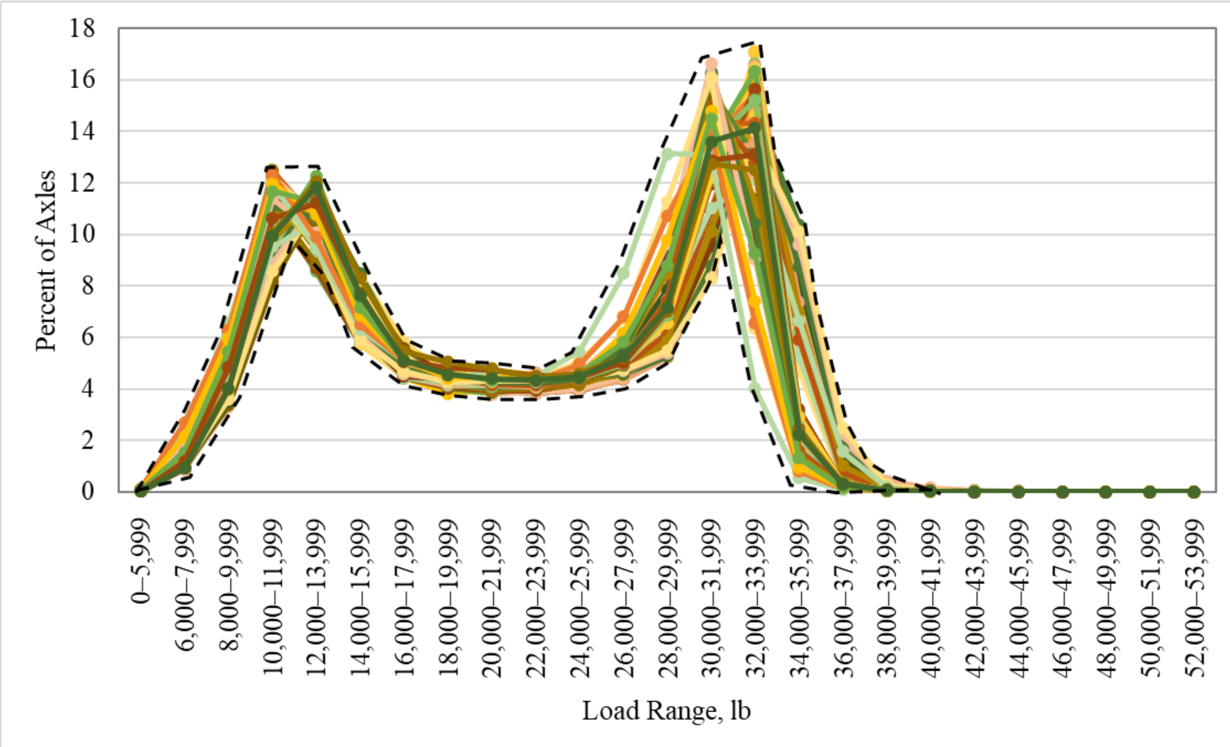
EXAMPLES OF ALDF ESTIMATION

The following examples show ALDF estimation based on different scenarios of NALS quality and availability.

ALDF with Unique Values for Each Calendar Month Based on Site-Specific WIM Data (Method 1—Monthly)

This example demonstrates the ALDF computation for tandem axle group for vehicles in FHWA Class 9 for a site with at least 200 FHWA Class 9 tandem axle counts per month for at least 1 yr. For this example, LTPP traffic site 060200 was selected from a list of sites with sufficient monthly NALS. The same procedure should be used for all other vehicle classes and axle groups that satisfy the aforementioned monthly data availability criterion. ALDF were computed using the following procedure:

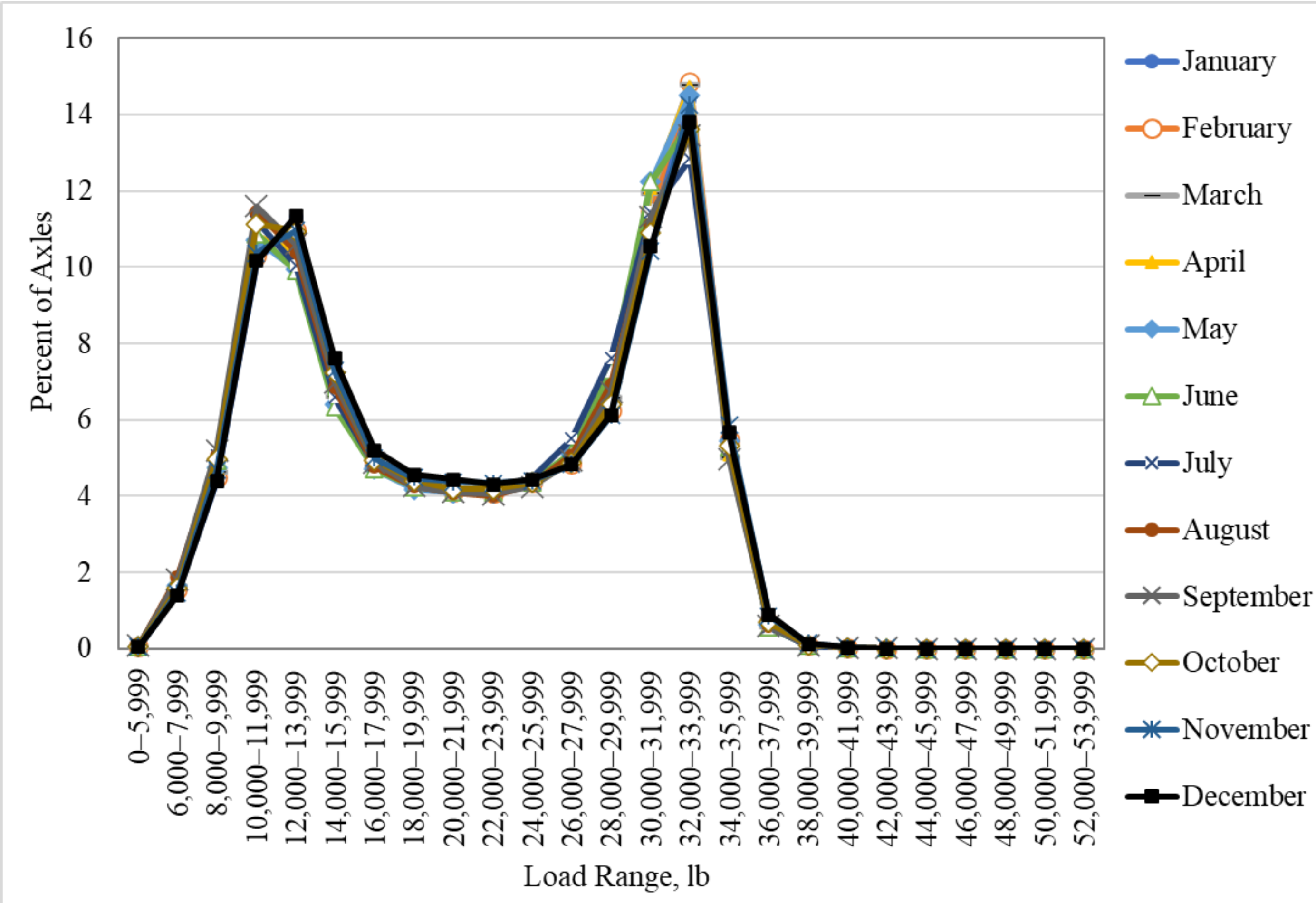
1. For this site, available calibration and validation data indicate WIM data collected from April 2008 to December 2015 satisfying the performance parameters of Type I WIM systems per ASTM E1318-09. These data were used to compute monthly NALS, and figure 7 shows a plot of the available monthly NALS for tandem axle group for FHWA Class 9 vehicles. Each line on the plot corresponds to a specific month–year combination. In addition, dashed lines connect all minimum and maximum values for each load bin observed over the analysis period. This plot shows that, while all months show similar camel-back distribution, some variability between different monthly NALS exist. Specifically, the location of the heavy peak loads ranges between 28,000 and 35,999 lb.



Source: FHWA.

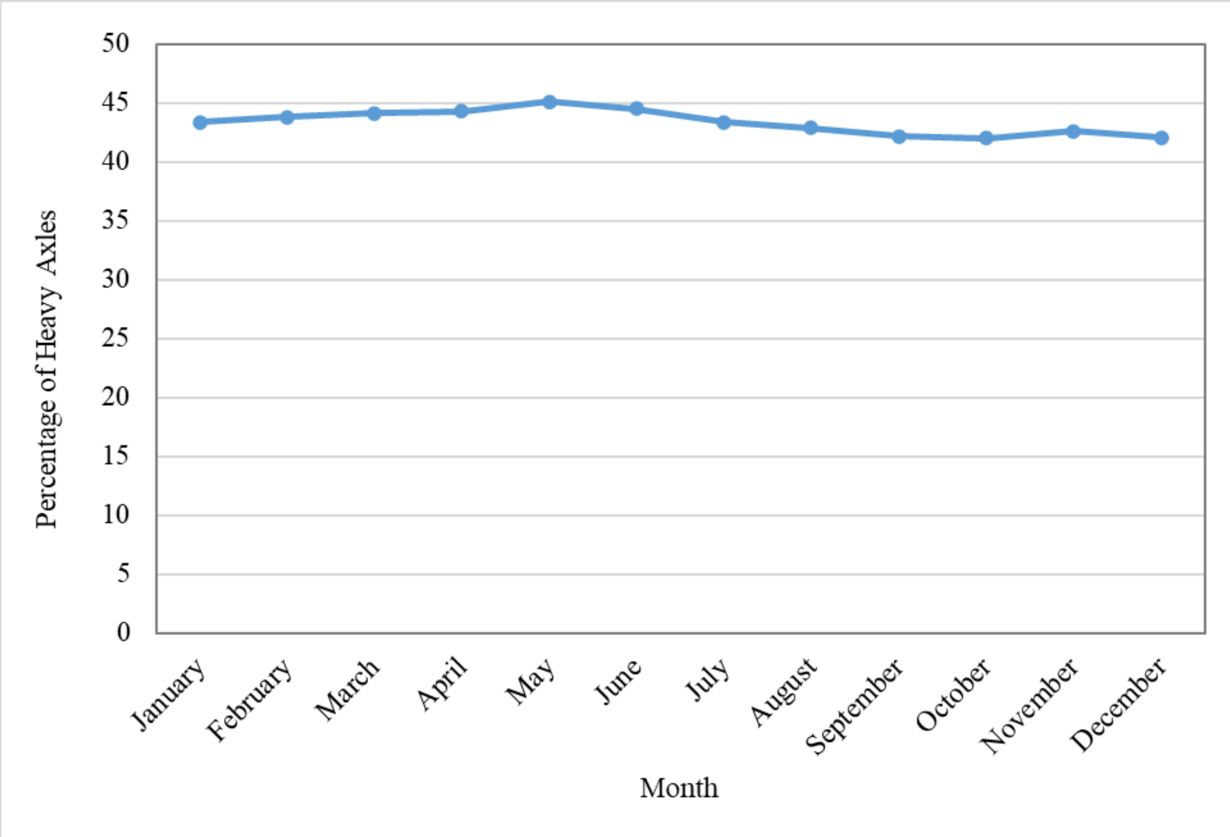
Figure 7. Chart. Monthly NALS for LTPP traffic site 060200 FHWA Class 9 tandem axles from 2008 to 2015.

2. Using the available monthly NALS, average monthly NALS were computed for each calendar month (January to December) by averaging each monthly NALS over multiple years. Figure 8 shows a plot of average monthly NALS for tandem axle group for FHWA Class 9 vehicles. Average monthly NALS indicate the percentage and distribution of heavily loaded trucks (those loaded to 75 percent or more of the Federal legal load limit of 34,000 lb) remains approximately the same during different calendar months. Axle load distributions between different months are almost identical; thus, the variability observed in figure 7 was due to year-to-year (most likely due to calibration adjustment), rather than month-to-month, changes in loading distribution. Figure 9 further demonstrates the distribution of the percentages of heavily loaded FHWA Class 9 tandem axles by month. As can be seen from Figure 8 and Figure 9, this site does not have seasonal changes in loading pattern for FHWA Class 9 tandem loads. For LTPP traffic site 060200, ALDF representing an average day of the month or an average day of the year results in similar pavement performance prediction.



Source: FHWA.

Figure 8. Chart. Average monthly NALS for LTPP traffic site 060200 FHWA Class 9 tandem axles.



Source: FHWA.

Figure 9. Chart. Percentages of heavily loaded FHWA Class 9 tandem axles by month for LTPP traffic site 060200.

3. Computed monthly averages were renormalized to account for rounding errors (i.e., expressed in percentile form) so the sum of percentages across all load bins equals 100 percent. Table 53 shows a sample of computed ALDF factors for tandem axle group for FHWA Class 9 vehicles for LTPP traffic site 060200.

4. The TRF_MEPDG_ALDF table was populated with the computed percentages of axles for each load bin for the selected LTPP traffic site ID (060200), vehicle class (FHWA Class 9), axle group (axle group 2 for tandem), and each calendar month.

Table 53. ALDF table populated with records for FHWA Class 9 tandem axles for LTPP traffic site 060200.

Month	Class	Total	6,000 lb	8,000 lb	10,000 lb	12,000 lb	14,000 lb	16,000 lb	*	82,000 lb
January	9	100	0.0512500	1.4462500	4.3925000	10.1212500	11.3050000	7.3912500	*	0.00000
February	9	100	0.0571429	1.5642857	4.5028571	10.2885714	10.9585714	7.0685714	*	0.00000

Month	Class	Total	6,000 lb	8,000 lb	10,000 lb	12,000 lb	14,000 lb	16,000 lb	*	82,000 lb
March	9	100	0.0600000	1.6700000	4.6428571	10.7128571	10.5042857	6.6400000	*	0.00000
April	9	100	0.0614286	1.6714286	4.7042857	10.8142857	10.4200000	6.5228571	*	0.00000
May	9	100	0.0566667	1.6566667	4.7400000	10.7100000	9.9516667	6.4166667	*	0.00000
June	9	100	0.0683333	1.8083333	4.9450000	10.8850000	9.9133333	6.3333333	*	0.00000
July	9	100	0.0583333	1.7933333	5.0650000	11.2050000	10.0450000	6.5933333	*	0.00000
August	9	100	0.0700000	1.8800000	5.0550000	11.4475000	10.4075000	6.8450000	*	0.00000
September	9	100	0.0787500	1.8250000	5.2037500	11.5975000	10.6025000	6.9812500	*	0.00000
October	9	100	0.0675000	1.5775000	4.9787500	11.1325000	10.9425000	7.2212500	*	0.00000
November	9	100	0.0562500	1.4750000	4.6825000	10.3737500	10.9500000	7.2975000	*	0.00000
December	9	100	0.0537500	1.4025000	4.40000	10.1650000	11.3475000	7.6162500	*	0.00000

*Load bins between 16,000 and 82,000 lb are not shown for space saving.

ALDF Representing a Typical Day of a Year Based on Site-Specific WIM Data (Method 1—Annual)

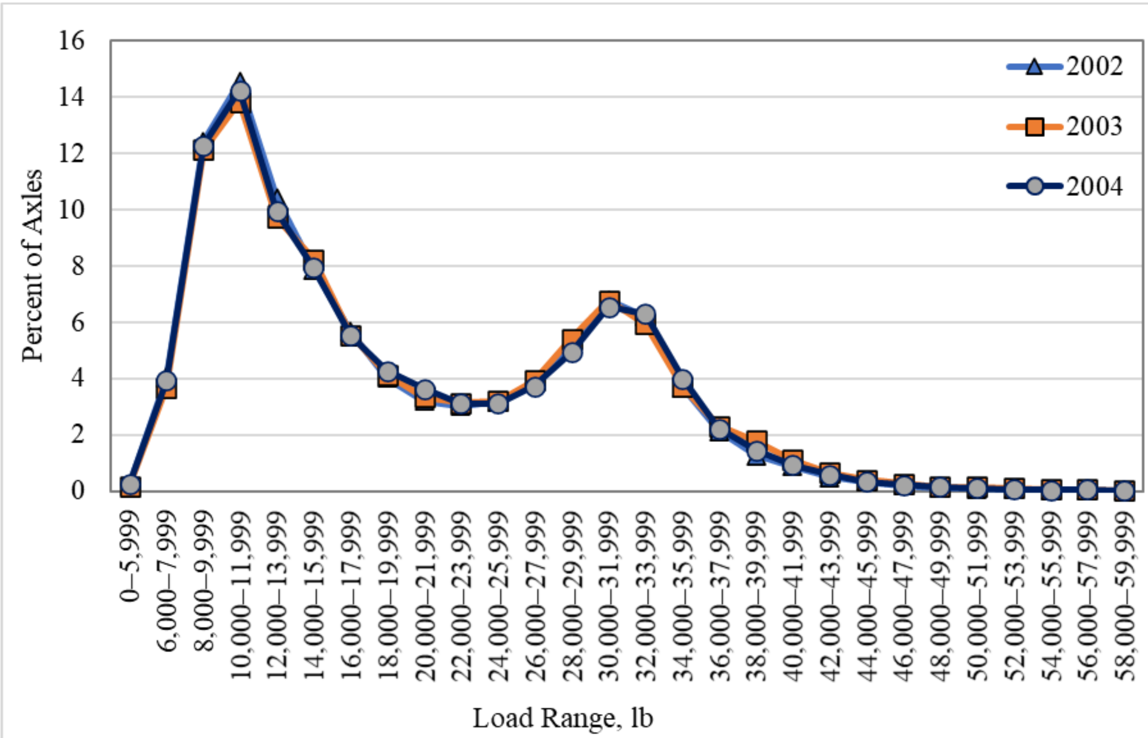
This example demonstrates ALDF computation for tandem axle group for FHWA Class 9 vehicles for a site with good quality WIM data, but available data do not satisfy minimum data availability criteria to compute unique monthly ALDF (i.e., at least 200 axle counts for a selected vehicle class and axle group per month for each of the 12 calendar months for at least 1 yr). The same procedure should be used for all other vehicle classes and axle groups satisfying this annual data availability criterion.

ALDF values computed in this example represent axle loading for a typical day of the year. In MEPDG applications, this input is repeated for each calendar month (January to December) for a selected vehicle class and axle group. Tandem axle group for FHWA Class 9 vehicles for LTPP traffic site 090960 was selected for this example. ALDF were computed using the following procedure:

1. WIM calibration records show that LTPP traffic site 090960 has 3 yr of WIM data satisfying the performance parameters of Type I WIM systems per ASTM E1318-09. However, the available data do not have over 200 axles for each of 12 calendar month (January to December). This site has quartz piezo WIM sensors.

2. Available annual NALS for FHWA Class 9 tandem axle group vehicles for LTPP traffic site 090960 were extracted and reviewed using the plot shown in figure 10. All years

show a consistent camel-back distribution with a higher percentage of unloaded axles than loaded axles. There is virtually no variability in the distribution between the 3 yr. The location and shape of the loaded peak does not indicate any issues with equipment accuracy or precision.



Source: FHWA.

Figure 10. Chart. Annual NALS for LTPP traffic site 090960 FHWA Class 9 tandem axles from 2002 to 2004.

3. Average annual NALS were computed by averaging annual NALS over the 3 yr.

4. Average annual NALS were renormalized (i.e., expressed in percentile form) so the sum of percentages across all load bins equals 100 percent.

5. Fields in the TRF_MEPDG_ALDF table were populated with the computed percentages of axles for each load bin for the selected LTPP traffic site ID (090960), vehicle class (FHWA Class 9), and axle group (axle group 2 for tandems). The same distribution was repeated for each calendar month. Table 54 shows computed ALDF factors for FHWA Class 9 tandem axle group vehicles for LTPP traffic site 090960.

Table 54. ALDF table populated with records for FHWA Class 9 tandem axles for LTPP traffic site 090960.

Month	Class	Total	6,000 lb	8,000 lb	10,000 lb	12,000 lb	14,000 lb	16,000 lb	*	82,000 lb
January	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000

Month	Class	Total	6,000 lb	8,000 lb	10,000 lb	12,000 lb	14,000 lb	16,000 lb	*	82,000 lb
February	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
March	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
April	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
May	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
June	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
July	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
August	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
September	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
October	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
November	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000
December	9	100	0.20667	3.88000	12.28000	14.21667	10.02333	8.02000	*	0.00000

*Load bins between 16,000 and 82,000 lb are not shown for space saving.

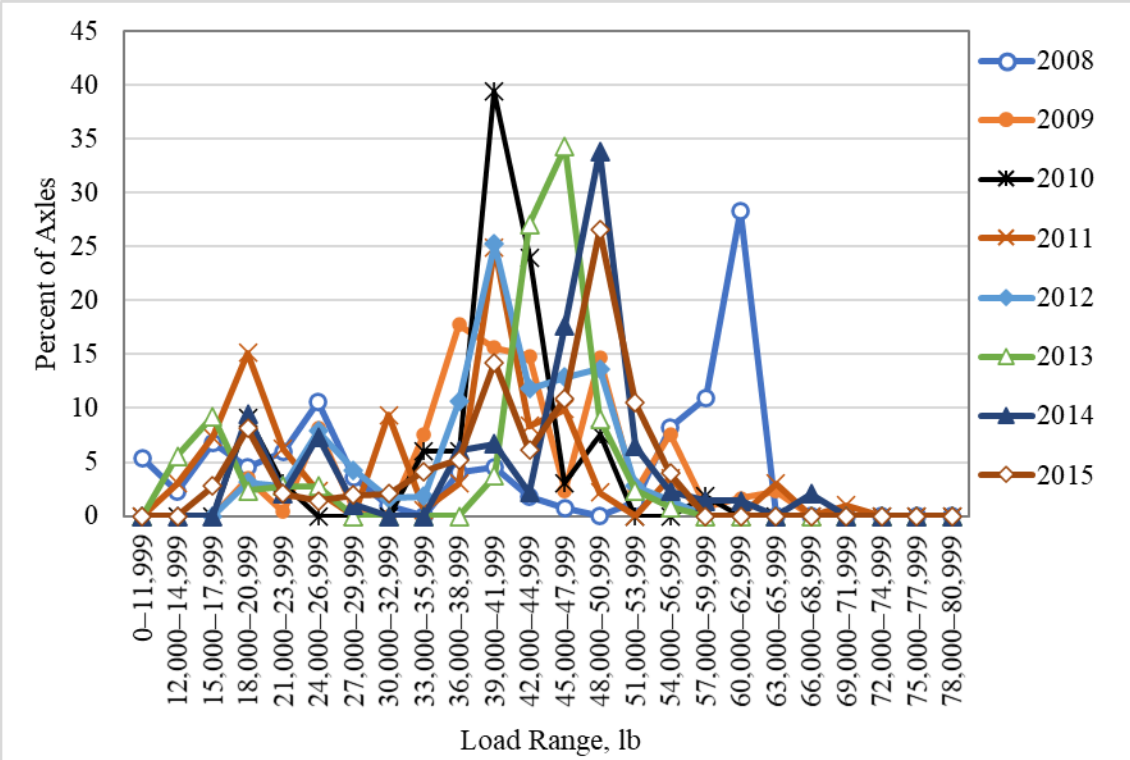
ALDF Representing a Typical Day of a Year Based on Site-Specific WIM Data (Method 1—Annual Combined)

This example demonstrates ALDF computation for tridem-axle group for FHWA Class 13 vehicles for a site with good quality WIM data but a low volume of FHWA Class 13 tridem axles. The low occurrence poses some challenges for computing representative values. The method used in this example is for computing ALDF for LTPP sites with fewer than 200 axle counts per year for a selected vehicle class and axle group. The same procedure should be used for all other vehicle classes and axle groups falling under this data availability criterion. ALDF computed in this example represent axle loading for a typical day of the year. In MEPDG applications, this input is repeated for each calendar month for a selected vehicle class and axle group.

Tridem-axle group for FHWA Class 13 vehicles for LTPP traffic site 060200 were selected for this example. ALDF were computed using the following procedure:

1. For LTPP traffic site 060200, available calibration and validation data indicate WIM data collected from 2008 to 2015 satisfying the performance parameters of Type I WIM systems per ASTM E1318-09. Figure 11 shows a plot of available tridem axle group annual NALS for FHWA Class 13 vehicles for LTPP traffic site 060200.

2. Annual axle counts were too low (between 25 and 69 counts per year) and too variable to identify a dominant shape of the distribution. Counts observed in the load bins range from 0 to 71,999 lb.

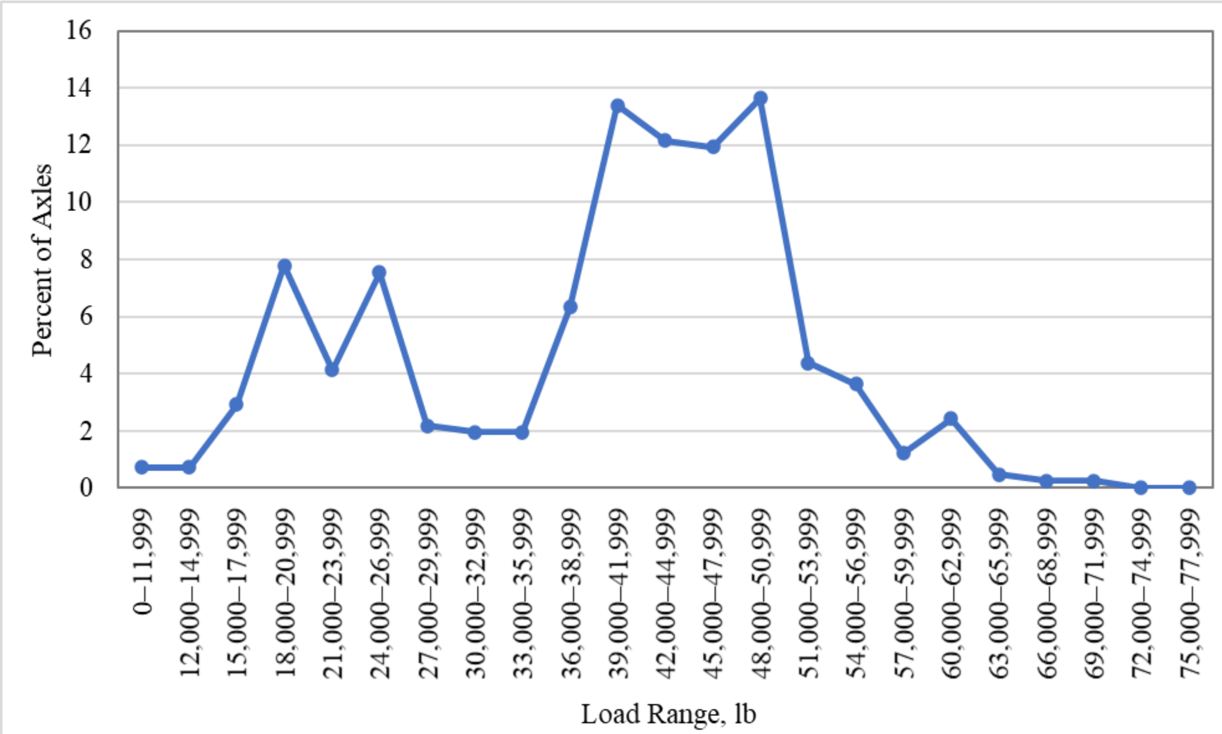


Source: FHWA.

Figure 11. Chart. Annual NALS for LTPP traffic site 060200 FHWA Class 13 tridem axles from 2008 to 2015.

3. Due to low values, NALS based on individual years were not used to compute average NALS, as in the previous example. Instead, axle counts in each load bin were summed over the years to compute the combined axle load distribution. The combined distribution was normalized (i.e., expressed in percentile form) to develop one representative NALS. This was accomplished by dividing the number of counts in each load bin by the total number of axle counts.

4. Figure 12 shows NALS computed based on axle counts combined for 2008–2015. The resulting distribution has a more defined shape with a major peak corresponding to loaded axles and two minor peaks corresponding to unloaded axles (15,000–26,9999 lb). The highest percentage of loads is between 39,000 and 50,999 lb.



Source: FHWA.

Figure 12. Chart. Axle load distribution for LTPP traffic site 060500 FHWA Class 13 tridem axles based on data from 2008 to 2015 combined.

5. Fields in the TRF_MEPDG_ALDF table were populated with the computed percentages of axles for each load bin for the selected LTPP traffic site ID (060500), vehicle class (FHWA Class 13), and axle group (axle group 3 for tridem). The same values are repeated for each calendar month. Table 55 shows computed ALDF for tridem-axle group for FHWA Class 13 vehicles for LTPP traffic site 060500.

Table 55. ALDF table populated with records for FHWA Class 13 tridem axles for LTPP traffic site 060200.

Month	Class	Total	12,000 lb	15,000 lb	18,000 lb	21,000 lb	24,000 lb	27,000 lb	*	102,000 lb
January	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
February	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
March	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
April	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
May	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
June	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
July	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
August	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
September	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000

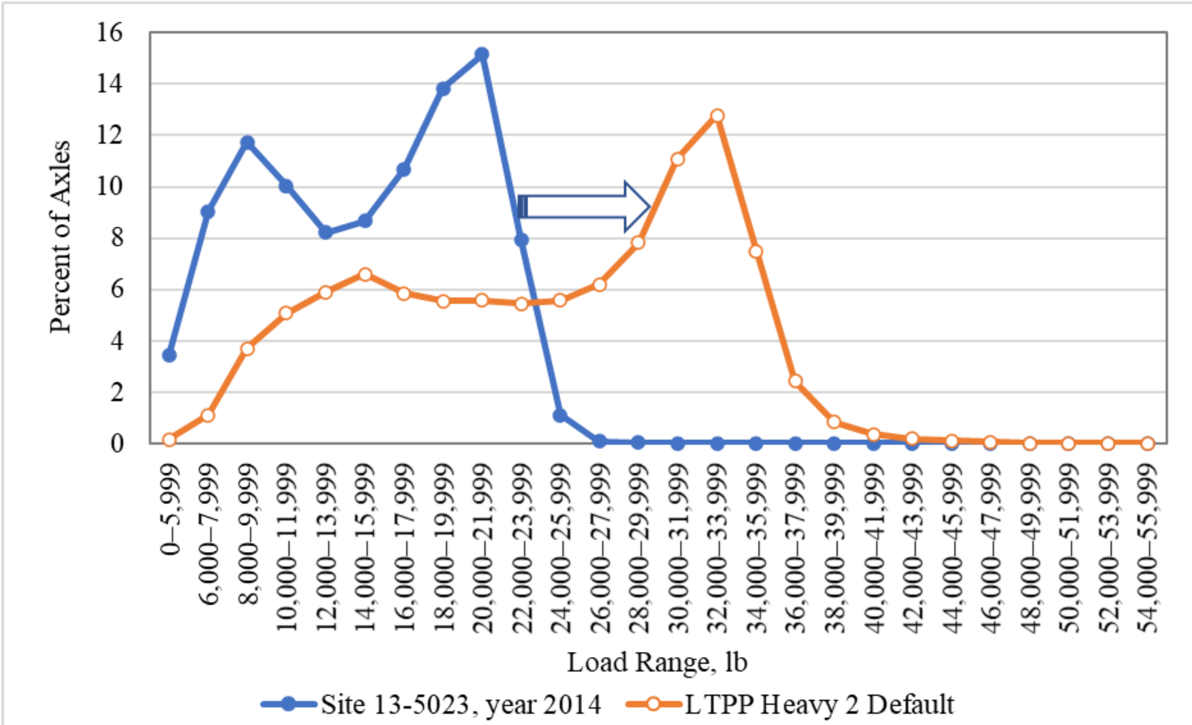
Month	Class	Total	12,000 lb	15,000 lb	18,000 lb	21,000 lb	24,000 lb	27,000 lb	*	102,000 lb
October	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
November	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000
December	13	100	0.66375	1.35750	3.27750	6.92125	3.15750	5.04250	*	0.00000

*Load bins between 27,000 and 102,000 lb are not shown for space saving.

ALDF Estimated for a Site with Insufficient Site-Specific WIM Data (Method 2—Limited Data)

This example demonstrates the ALDF computation for tandem axle group for FHWA Class 9 vehicles for LTPP traffic site 135023, which has limited WIM data of questionable quality. This site is located on I–95 in a rural area. I–95 is a major North–South interstate in the eastern United States and has a high volume of heavy loaded FHWA Class 9 trucks. There is only one annual NALS at Level E. This NALS is reported for 2014. The NALS for FHWA Class 9 tandem axle loads was developed based on site-specific WIM data shown in figure 13. This NALS has the expected shape for FHWA Class 9 tandem axle distribution with loaded and unloaded peaks clearly defined, but load bin values corresponding to both unloaded and loaded peaks are atypically low. This distribution shows no loaded FHWA Class 9 trucks during 2014 on I–95 and atypically light tandem loads even for empty trucks. Such low values are typically a sign of a significant negative measurement bias due to poor WIM calibration or calibration drift. If this distribution is used directly in pavement design or analysis, it would likely cause a significant underprediction of pavement distresses. Therefore, an alternative approach to characterize traffic loading at this site is needed. In this case, the site-specific distribution of tandem axle loads is used to describe a general loading pattern in terms of the relation between loaded and unloaded axles. Unloaded axles are assumed to be represented by the first peak in the site-specific NALS, and loaded axles are represented by the second peak. As shown in figure 13, the percentage of loaded axles exceed the percentage of unloaded axles. The ratio between the unloaded and loaded peak is about 0.77. Using table 51, the loading category based on the computed load ratio can be defined as "very heavy."

The available LTPP PLUG default best representing this shape of a distribution is labeled as "LTPP Heavy 2 Default," which is illustrated in figure 13. This type of default distribution is recommended for rural interstates subjected to heavy volumes of FHWA Class 9 trucks, which is consistent with truck traffic observed at LTPP traffic site 135023. Therefore, LTPP Heavy 2 Default is selected to represent tandem axle loading for FHWA Class 9 trucks for LTPP traffic site 135023 based on the limited site-specific WIM data and information about the location of this site.



Source: FHWA.

Figure 13. Chart. Axle load distribution for LTPP traffic site 135023 FHWA Class 9 tandem axles based on data from 2014 and LTPP Heavy 2 default distribution.

Default ALDF values selected in this example represent axle loading for a typical day of the year. In MEPDG applications, this input is repeated for each calendar month for the selected vehicle class and axle group. More information about LTPP defaults can be found in the LTPP PLUG.(10)

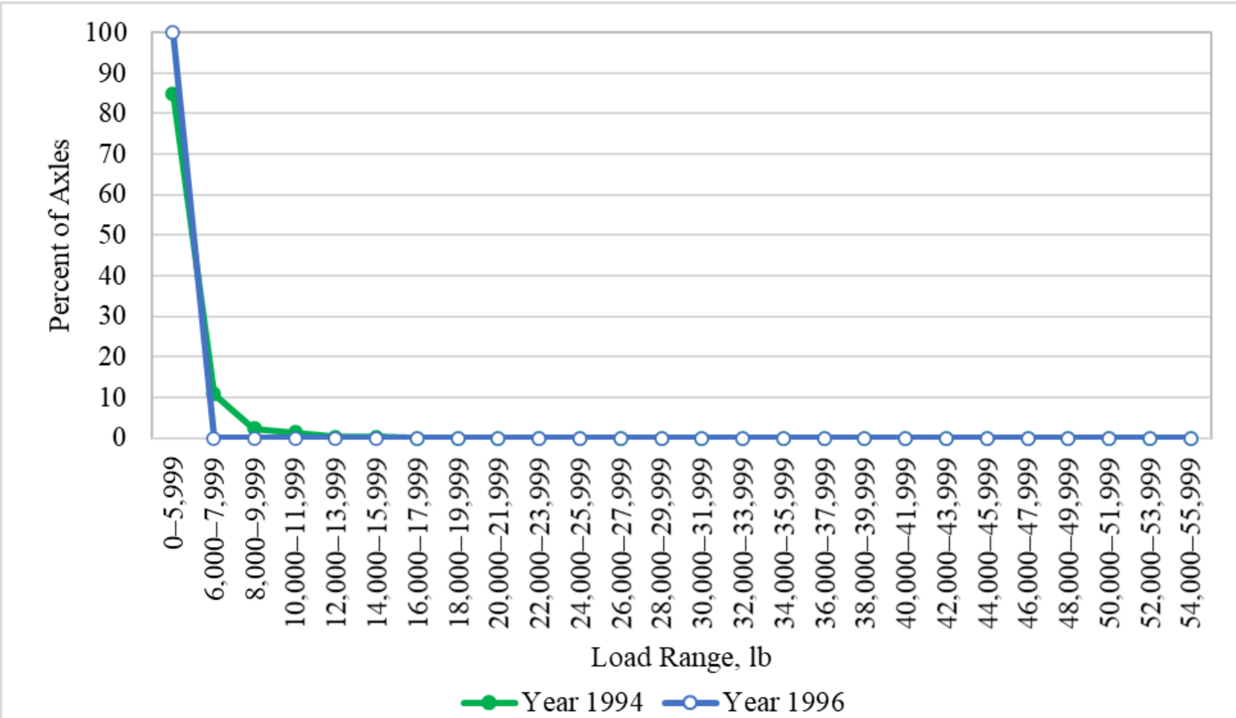
ALDF Estimated for Site with No Usable Site-Specific WIM Data (Method 2—No Usable Data)

For LTPP sites with insufficient data describing the general loading pattern or that contain no loading data, default values are selected using the approach presented in the following example.

For this example, LTPP traffic site 131001 was selected. This site is located on SR 10 in Georgia and has 2 yr of WIM data. However, available WIM data are highly questionable. These data were collected over a 2-d sampling period using a portable WIM that was not calibrated in accordance with ASTM E1318-09. ALDF were computed using the following procedure:

1. Available axle loading data were used to develop an axle loading distribution for tandem axle loads for FHWA Class 9 vehicles. The resulting NALS plot is shown in figure 14. Weights of the tandem axles (less than 6,000 lb) were much less than expected, even assuming all axles belong to empty FHWA Class 9 trucks (tandem axle weights between 12,000 and 18,000 lb are expected for FHWA Class 9 trucks with empty trailers).

Analysis of available loading data led to the conclusion that these data should not be used for pavement analysis; alternative data sources should be identified.



Source: FHWA.

Figure 14. Chart. Axle load distribution for LTPP traffic site 131003 FHWA Class 9 tandem axles based on data from 1994 and 1996.

2. Analysis of available truck volume and vehicle classification data for 1994 and 1996 revealed that LTPP traffic site 131003 had about 134 FHWA Class 9 vehicles per day in 1994 and only 13 in 1996. This dramatic change in volume further suggests data collection errors at this site. The percent of FHWA Class 9 trucks in the AADTT estimate is about 30.

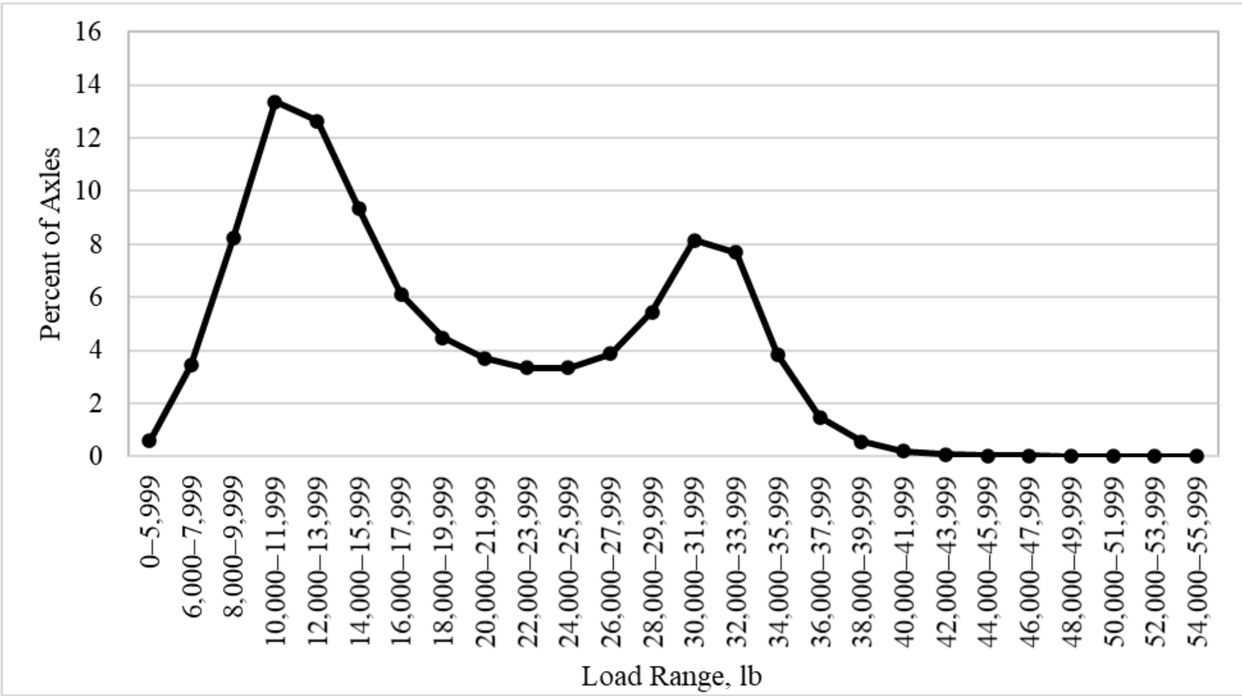
3. Using truck volume and classification information, the LTPP database was searched to see if any other sites in Georgia with similar truck traffic characteristics have usable weight data. The results of the search led to the following conclusions:

    - No Method 1 WIM site located on the same route is available in the LTPP database.

    - No Method 1 WIM site located in the same State with the same road functional classification (Rural Principal Arterial – Other) and similar AADTT and vehicle class distribution is available in LTPP database.

4. Since no suitable Method 1 site was identified, the LTPP PLUG default recommended for sites in the same road functional classification with similar AADTT and vehicle class distribution was selected. For FHWA Class 9 vehicles, the recommended LTPP default

axle loading categories were presented in table 52. Using table 52, the default NALS called "Moderate" was assigned to represent FHWA Class 9 tandem axle loads for LTPP traffic site 131001. This default NALS for tandem axle loads is graphically shown in figure 15.



Source: FHWA.

Figure 15. Chart. Axle load distribution selected for LTPP traffic site 131003 FHWA Class 9 tandem axles based on the LTPP PLUG "Moderate" default.

CHAPTER 9. ESTIMATING REPRESENTATIVE NUMBER OF AXLES PER TRUCK BY VEHICLE CLASS

COMPUTED PARAMETER DESCRIPTION

In AASHTOWare Pavement ME Design software, one set of representative values describing the number of axles per truck is used to estimate the number of axle loads for each of the 10 vehicle classes (FHWA Classes 4–13). Representative APTs are provided for heavy vehicles (i.e., those in FHWA Classes 4–13) for each axle group (i.e., single, tandem, tridem, and quad). The quad group includes axle groups with four or more axles. Without these values, the number of axle loads associated with individual vehicle classes cannot be estimated in AASHTOWare Pavement ME Design software.

DATA SOURCES USED FOR PARAMETER COMPUTATION

Data for computing representative APT values are available in the TRF_MEPDG_AX_PER_TRUCK table. In addition, the LTPP program developed a new table called VEHICLE_CLASS_AVG_AX_ANL containing similar data. These data represent annual APT values computed for LTPP sites for each year with WIM data reported in the LTPP database.

APT parameters are computed using site-specific total truck and axle count data. For LTPP sites, axle count data are only available for sites with individual vehicle weight records collected by WIM equipment. Therefore, site-specific APT can be developed only for LTPP sites with WIM data. For LTPP sites with no site-specific values, site-related values or default values, such as LTPP PLUG defaults, can be used.

METHODOLOGY FOR PARAMETER COMPUTING OR ESTIMATING

APT values are dependent on the truck fleet observed at the site and the vehicle classification algorithm used to collect vehicle classification data. Experience shows that truck configuration (i.e., number and spacing of axles) for a given truck type typically remains stable over the years with little to no change. Truck body and axle types within vehicle classes using a particular roadway also typically do not change significantly over time. Therefore, the methodology for computing representative site-specific APT values focuses on reviewing annual APT values in the VEHICLE_CLASS_AVG_AX_ANL table, identifying atypical values and potential vehicle classification issues, and averaging selected annual APT values to compute representative values.

The two approaches used to develop representative APT values, depending on WIM data availability, are as follows:

- Computing APT for LTPP sites with WIM data. This approach focuses on computing typical site-specific APT values.
- Estimating APT for LTPP sites without WIM data. This approach focuses on identifying site-related or default values using information about site location, road functional

classification, vehicle class distribution, and ADTT. Default values are selected using a hierarchical approach and may include values for the same roadway, same State, or national defaults.

COMPUTATIONAL PROCEDURE

Procedure to Compute Representative APT Based on Site-Specific WIM Data

The following procedure was used to compute representative APT for LTPP sites included in the VEHICLE_CLASS_AVG_AX_ANL table:

1. Obtain annual average APT values from the VEHICLE_CLASS_AVG_AX_ANL table for LTPP sites for the following years:

   1.1. For sites with site-specific ALDF entries in the TRF_MEPDG_ALDF table, use only years used to compute ALDF.

   1.2. For sites with no site-specific ALDF entries in the TRF_MEPDG_ALDF table, use all years in the VEHICLE_CLASS_AVG_AX_ANL table.

2. Compute average APT values for each LTPP site and vehicle class by averaging annual APT values selected in step 1 and save information in an intermediate table.

3. Compute the total average number of axles per truck per vehicle class for each LTPP site using values reported for each axle group in the intermediate table created in step 2.

4. Use the TRF_MONITOR_LTPP_LN table to identify the number of days with data and the number of trucks used to compute annual APT values for years selected in step 3. This is to identify years where APTs were computed based on small samples.

5. For each LTPP site, analyze average APT values for each vehicle class and axle group and the total number of axles per truck for each vehicle class. Note any significant deviations from typical ranges of APT values for each vehicle class and axle type. Typical ranges of APT values are provided in table 56. These values are based on the FHWA 13-bin vehicle classification scheme, the LTPP classification rules table, and observations based on data from TPF-5(004) WIM sites. A description of the FHWA TMG 13-bin vehicle classification scheme is provided in table 57.

6. Use data availability information and the results of annual APT values analysis to assign APT usability codes (table 98).

7. Save the computed average APT and the assigned APT usability codes to a new table called TRF_MEPDG_APT.

Table 56. Typical APT ranges for vehicles in FHWA Classes 4–13.

Vehicle Class	Number of Axles per Truck				
	Single	Tandem	Tridem	Quad	Total
4	Two	Zero or one	Zero	Zero	Two or three
5	Two or more*	Zero or one*	Zero	Zero	Two or more*
6	One	One	Zero	Zero	Three
7	One	Zero or one	Zero or one	Zero or one	Four or more
8	One, two, or three	Zero or one	Zero	Zero	Three or four
9	One, two, or three	Zero, one, or two	Zero or one	Zero	Five
10	One	One	Zero or one	Zero or one	Six or more
11	Five	Zero	Zero	Zero	Five
12	One, two, three, or four	One	Zero	Zero	Six
13	One, two, or three	Two, three, or four	Zero, one, or two	Zero, one, or two	Seven or more

*Allows lightweight trailer attached to two-axle unit per LTPP classification table.

Table 57. FHWA vehicle classification definitions.

Class Group	Class Definition	Class Includes	Number of Axles
1	Motorcycles	Motorcycles	Two
2	Passenger cars	All cars Cars with one-axle trailers Cars with two-axle trailers	Two, three, or four
3	Other two-axle, four-tire, single-unit vehicles	Pick-ups and vans Pick-ups and vans with one- and two-axle trailers	Two, three, or four
4	Buses	Two- and three-axle buses	Two or three
5	Two-axle, six-tire, single-unit trucks	Two-axle trucks	Two
6	Three-axle, single-unit trucks	Three-axle trucks Three-axle tractors without trailers	Three
7	Four-or-more-axle, single-unit trucks	Four-, five-, six- and seven-axle, single-unit trucks	Four or more
8	Four-or-fewer-axle, single-trailer trucks	Two-axle trucks pulling one- and two-axle trailers Two-axle tractors pulling one- and two-axle trailers Three-axle tractors pulling one-axle trailers	Three or four

Class Group	Class Definition	Class Includes	Number of Axles
9	Five-axle, single-trailer trucks	Two-axle tractors pulling three-axle trailers Three-axle tractors pulling two-axle trailers	Five
10	Six-or-more-axle, single-trailer trucks	Multiple configurations	Six or more
11	Five-or-fewer-axle multitrailer trucks	Multiple configurations	Four or five
12	Six-axle multitrailer trucks	Multiple configurations	Six
13	Seven-or-more-axle multitrailer trucks	Multiple configurations	Seven or more

Procedure to Estimate Representative APT for Sites with No Site-Specific WIM Data

The following hierarchical procedure was developed to estimate representative APT for LTPP sites with no reliable site-specific WIM data to compute APTs. The actual APT estimations were performed outside of this study by the LTPP program. The procedure to estimate representative APT is as follows:

1. Check if another LTPP WIM site is available in the TRF_MEPDG_APT table with the following attributes:
    - Site located on the same roadway as the site for which APTs are being estimated, no more than 200 mi away.
    - Has the same road functional classification.
    - Has similar AADTT.
    - Has similar vehicle class distribution.
    - Has representative APTs computed based on WIM data.

    1.1. If a site satisfying the above attributes is found, assign APTs from that site. If more than one site is found, use values from the closest site or average values from multiple sites.

    1.2. If no site is found, check if sites are available in the TRF_MEPDG_APT table in the same State and road functional classification with a similar vehicle class distribution as the site being evaluated (use only sites with site-specific APT values).

    1.2.1. If such sites are available, compute average APTs and assign them to the site being evaluated.

    1.2.2. If no sites are available for the same road functional classification or with a similar vehicle class distribution, check if sites are available in the TRF_MEPDG_APT table in the same State (use only sites with site-specific APT values).

1.2.2.1. If such sites are available, compute average APTs using sites from the same State (use only sites with site-specific APT values).

1.2.2.2. If no sites are available with APT values based on site-specific WIM data, and if none are available from the same State in the TRF_MEPDG_APT table, assign default values computed based on WIM data from TPF-5(004) study sites. These values are included in the LTPP PLUG. LTPP PLUG default APT values are provided in table 58. More information about LTPP defaults can be found in the LTPP PLUG.[10]

Table 58. LTPP PLUG default APT values.

Vehicle Class	Single	Tandem	Tridem	Quad
4	1.43	0.57	0.00	0.00
5	2.16	0.02	0.00	0.00
6	1.02	0.99	0.00	0.00
7	1.26	0.20	0.63	0.15
8	2.62	0.49	0.00	0.00
9	1.27	1.86	0.00	0.00
10	1.09	1.15	0.79	0.05
11	4.99	0.00	0.00	0.00
12	3.99	1.00	0.00	0.00
13	1.59	1.26	0.69	0.31

EXAMPLES OF ESTIMATING REPRESENTATIVE APTs

Estimating Representative APTs Based on Site-Specific WIM Data

LTPP traffic site 245807 was selected for this example. The procedure to estimate representative APTs is as follows:

1. Assessment of data in the TRF_MEPDG_ALDF table showed that this site has site-specific ALDF values. The years used for ALDF computation were 2002–2006. Annual APT values for these years were downloaded from the VEHICLE_CLASS_AVG_AX_ANL table and saved to the TRF_MONITOR_LTPP_LN table.

2. The TRF_MONITOR_LTPP_LN table was used to identify the number of days with data and the number of trucks used to compute annual APT values. Columns showing number of days with data and number of trucks were added to table 59 to facilitate further data assessment.

Table 59. Annual APT values for LTPP traffic site 245807 for years used in ALDF computation.

State Code	SHRP ID	Year	Vehicle Class	Single	Tandem	Tridem	Quad+	Trucks Weighed	Weight Days
24	5807	2002	4	1.82	0.18	0	0	2,199	51
24	5807	2002	5	2	0	0	0	8,199	51
24	5807	2002	6	1.05	0.98	0	0	2,291	51
24	5807	2002	7	1	0.13	0.87	0	715	43
24	5807	2002	8	2.52	0.45	0.01	0	1,327	51
24	5807	2002	9	1.07	1.96	0	0	4,458	51
24	5807	2002	10	1	1.45	0.55	0	47	34
24	5807	2002	11	5	0	0	0	5	5
24	5807	2002	12	4	1	0	0	1	1
24	5807	2003	4	1.8	0.2	0	0	13,905	268
24	5807	2003	5	2	0	0	0	49,268	268
24	5807	2003	6	1.05	0.97	0	0	10,678	268
24	5807	2003	7	1.02	0.15	0.86	0	1,086	212
24	5807	2003	8	2.63	0.35	0	0	7,226	268
24	5807	2003	9	1.08	1.96	0	0	23,074	268
24	5807	2003	10	1.06	1.47	0.48	0.07	321	199
24	5807	2003	11	5	0	0	0	71	68
24	5807	2003	12	4	1	0	0	13	13
24	5807	2003	13	1.11	1.5	1.61	0.67	13	13
24	5807	2004	4	1.84	0.16	0	0	19,886	308
24	5807	2004	5	2	0	0	0	59,409	308
24	5807	2004	6	1.05	0.98	0	0	10,833	308
24	5807	2004	7	1.02	0.2	0.8	0	840	250
24	5807	2004	8	2.61	0.37	0	0	10,270	308
24	5807	2004	9	1.07	1.96	0	0	24,110	308
24	5807	2004	10	1.05	1.4	0.56	0.05	322	220
24	5807	2004	11	5	0	0	0	71	69
24	5807	2004	12	4	1	0	0	23	23
24	5807	2004	13	1.33	2	1.75	0	6	6
24	5807	2005	4	1.83	0.17	0	0	20,290	313
24	5807	2005	5	2	0	0	0	58,355	313
24	5807	2005	6	1	1	0	0	10,773	313
24	5807	2005	7	1.01	0.11	0.9	0	1,123	262
24	5807	2005	8	2.35	0.64	0	0	17,414	313
24	5807	2005	9	1.07	1.96	0	0	22,425	313
24	5807	2005	10	1.02	1.34	0.6	0.07	243	183
24	5807	2005	11	5	0	0	0	187	169
24	5807	2005	12	3.95	1	0	0	26	26
24	5807	2005	13	1.33	1	1.5	1	3	3
24	5807	2006	4	1.82	0.18	0	0	17,082	255
24	5807	2006	5	2	0	0	0	47,743	255

State Code	SHRP ID	Year	Vehicle Class	Single	Tandem	Tridem	Quad+	Trucks Weighed	Weight Days
24	5807	2006	6	1	1	0	0	9,211	255
24	5807	2006	7	1.04	0.19	0.8	0	959	220
24	5807	2006	8	2.36	0.63	0	0	15,082	255
24	5807	2006	9	1.07	1.96	0	0	17,678	255
24	5807	2006	10	1.03	1.3	0.59	0.11	171	142
24	5807	2006	11	5	0	0	0	73	72
24	5807	2006	12	4	1	0	0	5	5
24	5807	2006	13	1.33	1	1.33	0	4	4

3. Using annual APTs for 2002–2006, average APT values were computed for FHWA Classes 4–13 by averaging the annual values. Results are shown in table 60. Computed representative values for individual axle groups were used to compute the average values for the total axles per truck column of table 60 using the following formula:

$$Total\ Axles\ per\ Truck = Single + 2*Tandem + 3*Tridem + 4*Quad$$

Where:
Total Axles per Truck = total number of axles per truck
Single = number of single axles per truck
Tandem = number of tandem axles per truck
Tridem = number of tridem axles per truck
Quad = number of quad+ axles per truck

Table 60. AASHTOWare Pavement ME Design software APT input and total axles per truck values for LTPP traffic site 245807.

Vehicle Class	Single	Tandem	Tridem	Quad	Total Axles per Truck
4	1.82	0.18	0	0	2.18
5	2	0	0	0	2
6	1.03	0.99	0	0	3.01
7	1.02	0.16	0.85	0	3.89
8	2.49	0.49	0	0	3.47
9	1.07	1.96	0	0	4.99
10	1.03	1.39	0.56	0.06	5.73
11	5	0	0	0	5
12	3.99	1	0	0	5.99
13	1.28	1.38	1.55	0.42	10.37

4. Computed average APT values were compared to expected values for each vehicle class provided in table 56. Minor deviations in the expected number of the total axles were noted for FHWA Classes 7 and 10, as shown in table 61.

Table 61. Flagged atypical values for average total axles for the LTPP site 245807.

STATE_ CODE	SHRP_ ID	VEHICLE_ CLASS	TOTAL_ AXLES	ATYPICAL_TOTAL_AXLES_FLAG
24	5807	7	3.89	Atypical total axles, four is expected
24	5807	10	5.73	Atypical total axles, six is expected

5. APT usability codes (table 98) were assigned using data availability information and results of analysis of annual APT values, as presented in table 62.

6. Results of APT computation and assigned APT usability codes were saved to the TRF_MEPDG_APT table. Records corresponding to LTPP traffic site 245807 are shown in table 62. Values shown in the Single, Tandem, Tridem, and Quad columns can be copied and pasted directly into the AASHTOWare Pavement ME Design software GUI for traffic inputs.

Table 62. APT records from the TRF_MEPDG_APT table for LTPP traffic site 245807.

STATE_CODE	SHRP_ID	VEHICLE_CLASS	Single	Tandem	Tridem	Quad	APT_USE_CODE
24	5807	4	1.82	0.18	0	0	1
24	5807	5	2	0	0	0	1
24	5807	6	1.03	0.99	0	0	1
24	5807	7	1.02	0.16	0.85	0	1, A0
24	5807	8	2.49	0.49	0	0	1
24	5807	9	1.07	1.96	0	0	1
24	5807	10	1.03	1.39	0.56	0.06	1, A0
24	5807	11	5	0	0	0	1
24	5807	12	3.99	1	0	0	5
24	5807	13	1.28	1.38	1.55	0.42	5

APT_USE_CODE 1 = APT is based on a sample of more than 200 trucks collected over more than 365 d in total: recommended for site-specific analyses; APT_USE_CODE 5 = APT is based on a sample of fewer than 100 trucks: use with caution in site-specific analyses or consider using defaults; APT_USE_CODE A0 = total number of axles per truck does not follow FHWA 13-bin vehicle classification rules for a given vehicle class.

Estimating Representative APT for Sites with No Site-Specific WIM Data

LTPP traffic site 011021 was selected for this example. The procedure to estimate representative APTs is as follows:

1. A review of records in the VEHICLE_CLASS_AVG_AX_ANL table indicated that LTPP traffic site 0101021 has no site-specific APT values in the LTPP database.

2. The TRF_MEPDG_AX_PER_TRUCK table was searched to see if other similar LTPP sites located in the same State had site-specific APT values. Only one, LTPP traffic site 011011 with similar AADTT values (low volume, AADTT <200) and the same road functional classification (rural minor arterial, State route) was found. LTPP traffic site 011011 had site-specific APT values based on WIM data.

3. APT values from LTPP traffic site 011011 were used to assign APT values to LTPP traffic site 011021. These values are shown in table 63 and can be used as an input to AASHTOWare Pavement ME Design software.

Table 63. APT values assigned for LTPP traffic site 011021.

VEH_CLASS	Single	Tandem	Tridem	Quad
4	2	0	0	0
5	2	0	0	0
6	1	1	0	0
7	0	0	0	0
8	2.1	0.9	0	0
9	1.12	1.94	0	0
10	1	2	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0

CHAPTER 10. ESTIMATING PARAMETERS DESCRIBING TRUCK LOADING AND TRUCK LOADING CHANGES OVER TIME

This chapter describes the procedures for estimating parameters describing the changes in truck loading over time.

ESAL FOR EACH IN-SERVICE YEAR, ALL TRUCKS COMBINED

Computed Parameter Description

Annual ESAL trend values provide traffic loading estimates in a form of ESAL for each in-service year. These values are frequently used in pavement performance analyses based on empirical methods. These values are also used as a source to compute cumulative ESAL for analyses based on the *AASHTO Guide for Design of Pavement Structures*.[5]

Data Sources Used for Parameter Computation

Annual ESAL values come from multiple LTPP data sources, including the following:

- Annual ESAL values provided by local highway agencies for years designated by the LTPP program as "historical" and "monitored" (TRF_HIST_EST_ESAL and TRF_MON_EST_ESAL tables). The TRF_MON_EST_ESAL table contains ESAL estimates provided by local highway agencies for years when no WIM data were collected.

- LTPP-computed ESAL values for years with acceptable WIM data submitted to the LTPP program (TRF_ESAL_COMPUTED table).

- Estimated annual ESAL based on representative ESAL included in REP_ESAL_PER_VEH_CLASS* and REP_ESAL_PER_TRUCK fields in the LTPP table TRF_REP. To compute annual ESAL, these values are multiplied by site-specific vehicle classification and truck volume values from the LTPP table TRF_TREND.

Methodology for Parameter Computation or Estimation

The following methodology was used to develop the ANNUAL_ESAL_TREND parameter:

1. Assess the extent of ESAL information currently available in TRF_HIST_EST_ESAL, TRF_MON_EST_ESAL, and TRF_ESAL_COMPUTED tables and identify data gaps (i.e., years without annual ESAL estimates).

2. For all LTPP sites and years with ESAL and truck volume data, compute annual ESAL-per-truck values.

3. For all LTPP sites, obtain representative ESAL-per-truck values for the TRF_REP table.

4. Assess the rationality of computed ESAL-per-truck values by identifying and flagging values with the following characteristics:

   a. Differ significantly from representative ESAL-per-truck values for the site.
   b. Outside of the reasonable range for a given road functional classification and vehicle mix observed at the site. Table 64 and table 65 show average, minimum, and maximum ESAL-per-truck values for different road functional classifications and different percentages of heavy trucks in vehicle class distribution. These values were computed using 1,198 LTPP sections (each SPS site had multiple sections with different structural number (SN) or depth (D) values, resulting in a different ESAL estimate) with annual ESAL values available in the LTPP TRF_ESAL_COMPUTED table and site- and year-specific NALS values passing data consistency and rationality assessments.

Table 64. ESAL-per-truck statistics for design lanes with different percentages of trucks in FHWA Classes 7 and 9–13.

Percentage of Vehicles in FHWA Classes 7 and 9–13 Combined	Average	Minimum	Maximum
0	0.51	0.19	0.54
10	0.50	0.20	0.86
20	0.52	0.20	1.45
30	0.66	0.28	1.71
40	0.74	0.30	1.60
50	0.82	0.33	2.49
60	0.88	0.39	2.04
70	1.12	0.32	2.28
80	1.30	0.49	2.53

Table 65. ESAL-per-truck statistics for design lane for different road functional classification.

LTPP Road Functional Classification Description	LTPP Road Functional Classification No.	Average	Minimum	Maximum
Rural principal arterial interstate	1	1.07	0.20	2.53
Rural principal arterial noninterstate	2	0.82	0.30	2.42
Rural minor arterial	6	0.74	0.19	1.71
Rural major collector	7	0.68	0.20	1.17
Rural local collector	9	0.68	0.68	0.68
Urban principal arterial interstate	11	1.01	0.42	2.02
Urban principal arterial freeway/expressway	12	1.04	0.37	1.48
Urban principal arterial other	14	0.91	0.28	1.39
Urban minor arterial	16	0.78	0.59	1.03

5. Use the following approach to populate the TRF_TREND table with ANNUAL_ESAL_TREND values:

    a. Review available annual ESAL values from LTPP sources.

    b. Check if data were flagged during the average ESAL-per-truck review and determine if data are typical for a given site.

    c. When multiple sources of annual ESAL are available for the same year, select the source with the most consistent and rational ESAL-per-truck values for a given site. Give preference to ESALs computed using site-specific WIM data overestimates provided by local highway agencies. Select the value closest to the computed representative ESAL-per-truck value.

    d. For years with no or questionable ESAL values reported in the LTPP database, compute estimated annual ESAL values using site-specific vehicle classification and truck volume data from the TFR_TREND table and representative ESAL-per-truck values.

6. Assign data source code to provide information about the source of annual ESAL values. Include the LOAD_SOURCE field in the TRF_TREND table to help users identify the source of data and infer confidence in ESAL estimates. In the LOAD_SOURCE field, enter one of the following values, as applicable:

    - 0—no annual ESAL provided for the virtual SPS site (*00) or any site with no pavement structure information.
    - 1—annual ESAL computed by LTPP program based on site- and year-specific WIM data.
    - 2—annual ESAL computed based on average ESAL-per-truck values computed using selected years of site-specific WIM data and site- and year-specific annual truck volume from the TRF_TREND table.
    - 3—annual ESAL supplied by a highway agency for years during the LTPP traffic monitoring program.
    - 4—annual ESAL supplied by a highway agency for years prior to the LTPP traffic monitoring program.
    - 5—annual ESAL estimated based on the representative ESAL-per-truck value from the TRF_REP table and site- and year-specific annual truck volume by vehicle class from the TRF_TREND table.
    - 6—annual ESAL is 0 due to no truck volume.

Procedure for Parameter Computation

The following procedure was used to develop values for the ANNUAL_ESAL_TREND field in the TRF_TREND table for each LTPP traffic site:

1. Obtain available annual ESAL values from the LTPP tables TRF_HIST_EST_ESAL, TRF_MON_EST_ESAL, and TRF_ESAL_COMPUTED and categorize them as historical, monitored, or computed.

2. For each LTPP traffic site, year, and available ESAL data source, compute ESAL-per-truck values by dividing available annual ESAL values from each LTPP ESAL table by the annual truck volume value (ANNUAL_TRUCK_VOLUME_TREND field from TRF_TREND table) for the same year. This will result in computed parameters "COMPUTED_ESAL_PER_TRUCK," "MON_ESAL_PER_TRUCK," and HIST_ESAL_PER_TRUCK."

3. Use the results of the research team's annual NALS rationality and consistency assessment to identify years with WIM data quality acceptable to compute year- and site-specific axle load distributions. Consider LTPP-computed annual ESAL values from the TRF_ESAL_COMPUTED table for these years as the most accurate and call them "VALIDATED" annual ESALs. Use "VALIDATED" annual ESALs to compute "VALIDATED_ESAL_PER_TRUCK" by dividing "VALIDATED" annual ESAL by the annual truck volume value (ANNUAL_TRUCK_VOLUME_TREND field from the TRF_TREND table) for the same year.

4. For each LTPP traffic site with "VALIDATED" ESAL-per-truck values, compute an average of the "VALIDATED" ESAL per truck values. Call this average value "AVG_VAL_ESAL_PER_TRUCK."

5. For each LTPP traffic site, obtain "REP_ESAL_PER_TRUCK" from the TRF_REP table.

6. Assess rationality of ESAL-per-truck values computed in steps 2-5 using the following:

   6.1 For each LTPP traffic site and year, identify ESAL-per-truck values outside the range of the expected ESAL-per-truck values for roadways with similar vehicle class distribution and/or the same road functional classification (table 64 and table 65).

   6.2 Flag ESAL-per-truck values outside the minimum and maximum values as "FLAG MIN" and "FLAG MAX," respectively.

   6.3 For each LTPP traffic site with AVG_VAL_ESAL_PER_TRUCK values, review available ESAL-per-truck values for each year computed based on data from TRF_HIST_EST_ESAL, TRF_MON_EST_ESAL, and TRF_ESAL_COMPUTED tables and identify years with ESAL-per-truck values significantly deviating (20 percent or more was selected based on analysis of ESAL-per-truck variability for sites with ALDF categories 1 or 2) (i.e., sites with high confidence of WIM data accuracy) from AVG_VAL_ESAL_PER_TRUCK values for the site. Flag these years and sources as "FLAG AV VAL."

   6.4 For each LTPP traffic site without AVG_VAL_ESAL_PER_TRUCK values, review available ESAL-per-truck values for each year computed based on data from TRF_HIST_EST_ESAL, TRF_MON_EST_ESAL, and TRF_ESAL_COMPUTED tables and identify ESAL-per-truck values significantly deviating (20 percent or more) from REP_ESAL_PER_TRUCK values for the site. Flag these years and sources as “FLAG REP.”

6.5 Review years with ESAL-per-truck values flagged in the aforementioned checks. If rationality of the reported values can be established, flags can be manually removed and ESAL-per-truck values accepted.

7. For each LTPP traffic site and year, determine method for determining the ANNUAL_ESAL_TREND parameter and assign ESAL source code. Use results of the ESAL-per-truck assessment from step 6 to guide the selection of the ESAL value best representing the loading condition for each LTPP traffic site and in-service year with the following steps:

7.1For the LTPP traffic sites with some years of accepted VALIDATED_ESAL_PER_TRUCK values, identify the ANNUAL_ESAL_TREND source for each year as follows:

7.1.1 If a year has a VALIDATED_ESAL_PER_TRUCK value that passed the checks, multiply the KESAL_YEAR value from the TRF_ESAL_COMPUTED table for that year by 1,000 to compute the ANNUAL_ESAL_TREND value. Assign code “1” to indicate the ANNUAL_ESAL_TREND value was assigned based on the site-specific ESAL value from the TRF_ESAL_COMPUTED table.

7.1.2 If a year has a VALIDATED_ESAL_PER_TRUCK value that did not pass the checks and the manual review, multiply the AVG_VAL_ESAL_PER_TRUCK value by the ANNUAL_TRUCK_VOLUME_TREND for a given year to compute the ANNUAL_ESAL_TREND value. Assign code “2” to indicate the ANNUAL_ESAL_TREND value was computed based on average ESAL-per-truck values computed using selected site-specific WIM data and site- and year-specific annual truck volume from the TRF_TREND table.

7.1.3 If a year has no VALIDATED_ESAL_PER_TRUCK value associated with it, check if ESAL-per-truck values from other sources are available that were not flagged during the ESAL-per-truck assessment by performing one of the following tasks:

7.1.3.1 If an annual ESAL value is available in one or more tables (e.g., TRF_ESAL_COMPUTED, TRF_MON_EST_ESAL, or TRF_HIST_EST_ESAL) and ESAL-per-truck values computed based on these sources passed the review described in step 6, select the kilo ESAL (KESAL) value in the following order of preference: TRF_ESAL_COMPUTED.KESAL_YEAR, TRF_MON_EST_ESAL.ANL_KESAL_LTPP_LN_YR, and TRF_HIST_EST_ESAL.ANL_KESAL_LTPP_LN_YR. Multiply the selected value by 1,000 to compute the ANNUAL_ESAL_TREND value. Assign code “1” if TRF_ESAL_COMPUTED was used as a source, indicating that

ANNUAL_ESAL_TREND was computed based on site-specific WIM data. Assign code “3” if TRF_MON_EST_ESAL was used as a source, indicating that TREND ESAL was computed based on estimates from the TRF_MON_EST_ESAL table. Assign code “4” if TRF_HIST_EST_ESAL was used as a source, indicating that ANNUAL_ESAL_TREND was computed based on estimates from the TRF_HIST_EST_ESAL table.

7.1.3.2 If no acceptable ESAL-per-truck values are available, multiply AVG_VAL_ESAL_PER_TRUCK value by ANNUAL_TRUCK_VOLUME_TREND for a given year to compute the ANNUAL_ESAL_TREND value. Assign code “2” to indicate the ANNUAL_ESAL_TREND value was computed based on the average ESAL-per-truck values using selected site-specific WIM data and year-specific annual truck volume from the TRF_TREND table.

7.2 For LTPP traffic sites with no years of accepted VALIDATED_ESAL_PER_TRUCK values, check if ESAL-per-truck values from other sources are available that were not flagged during the ESAL-per-truck assessment by performing one of the following tasks:

7.2.1 If an annual ESAL value is available in one or more tables (e.g., TRF_ESAL_COMPUTED, TRF_MON_EST_ESAL, or TRF_HIST_EST_ESAL) and ESAL-per-truck values computed based on these sources passed the review described in step 6, select a value in the following order of preference: TRF_ESAL_COMPUTED.KESAL_YEAR, TRF_MON_EST_ESAL.ANL_KESAL_LTPP_LN_YR, and TRF_HIST_EST_ESAL.ANL_KESAL_LTPP_LN_YR. Multiply the selected value by 1,000 to compute the ANNUAL_ESAL_TREND value. Assign code “1” if TRF_ESAL_COMPUTED was used as a source, indicating that TREND_ESAL was computed based on site-specific WIM data. Assign code “3” if TRF_MON_EST_ESAL was used as a source, indicating that TREND_ESAL was computed based on estimates from the TRF_MON_EST_ESAL table. Assign code “4” if TRF_HIST_EST_ESAL was used as a source, indicating that ANNUAL_ESAL_TREND was computed based on estimates from the TRF_HIST_EST_ESAL table.

7.2.2 If no ESAL-per-truck values are available, use TRF_TREND and TRF_REP tables to compute annual ESAL with the following steps:

7.2.2.1 For each vehicle class (*), multiply TRF_REP.REP_ESAL_PER_VEH_CLASS_* by TRF_TREND.AADTT_VEH_CLASS_*_TREND and sum the computed products across 10 vehicle classes (FHWA Classes 4–13).

7.2.2.2 Compute the number of days for each year included in the TRF_TREND table (the first and last year corresponding to each construction event in the TRF_TREND table are partial years) as

ANNUAL_TRUCK_VOLUME_TREND/AADTT_ALL_TRUCKS_TREND.

7.2.2.3 Multiply the results from the above two steps to come up with ANNUAL_ESAL_TREND value.

7.2.2.4 Assign code "5" to indicate the ANNUAL_ESAL_TREND value was estimated based on representative ESAL-per-truck values from the TRF_REP table and year-specific annual truck volume by vehicle class from the TRF_TREND table.

7.3 Store computed annual ESAL trend results in the ANNUAL_ESAL_TREND field in the TRF_TREND table

7.4 For LTPP traffic sites with ANNUAL_TRUCK_VOLUME_TREND values from the TRF_TREND table equal to "0" for a given year, assign code "6" to indicate this ANNUAL_ESAL_TREND value is "0" due to no truck volume.

7.5 For LTPP traffic sites with no ESAL-per-truck values accepted during the review, review available data about the site and manually assign estimated ESAL-per-truck values in the EST_ESAL_PER_TRUCK field based on site-specific traffic information and information about road use. Create a record describing the source or rationale of the EST_ESAL_PER_TRUCK value. Multiply EST_ESAL_PER_TRUCK by ANNUAL_TRUCK_VOLUME_TREND from the TRF_TREND table for a given year to compute the ANNUAL_ESAL_TREND value. Assign code "7" to indicate the ANNUAL_ESAL_TREND value was computed based on the estimated ESAL-per-truck value assigned by the analyst and year-specific annual truck volume from the TRF_TREND table.

7.6 For LTPP SPS sites and years without LTPP pavement structure information, such as virtual SPS master sites with SHRP_ID field codes "0*00" or codes that start with a letter followed by "*00" or sites that are out of study, assign code "0" to indicate there is no pavement structure associated with a site or site-year. The ANNUAL_ESAL_TREND value is "NULL."

Example of Parameter Estimating

This example demonstrates development of the annual ESAL trend for LTPP GPS-3 site 047613. The GPS-3 experiment is for JPCP. Slab thickness (the parameter used in ESAL estimation) remained unchanged during the experiment. The site was constructed in 1979 and participated in the LTPP GPS-3 experiment from the inception of the LTPP (originally SHRP) program in 1987 through 2001. In 1990, a maintenance event for partial-depth slab patching occurred, which changed the construction event number from "1" to "2" in the LTPP database.

Arizona DOT provided LTPP estimates of annual ESAL for LTPP GPS-3 site 047613 for years prior to the start of the GPS-3 experiment from 1979 to 1989. During the site's participation in the LTPP experiment, Arizona DOT provided additional ESAL estimates for 1991, 1992, and

2000. From 1993 to 1999 Arizona DOT collected and provided weight data to the LTPP database. The LTPP program used these weight data to estimate annual ESAL. However, due to low accuracy of early-generation WIM sensors, data quality was limited.

The following steps show how annual ESAL trend estimates were developed for LTPP GPS-3 site 047613 for the years since the site first opened to traffic through the end of its participation in the LTPP experiment:

1. Available annualized KESAL data were extracted from TRF_HIST_EST_ESAL, TRF_MON_EST_ESAL, and TRF_ESAL_COMPUTED tables. KESAL values were multiplied by 1,000 to convert to annual ESAL. The results, along with ANNUAL_TRUCK_VOLUME_TREND values extracted from TRF_TREND table, are shown in table 66.

Table 66. Annual ESAL values from multiple sources for LTPP GPS-3 site 047613.

STATE_ CODE	SHRP_ID	CONSTR_ NO	Year	TRF_ESAL_ COMPUTED	TRF_MON_ EST_ESAL	TRF_HIST_ EST_ESAL	ANNUAL_ TRUCK_ VOLUME_ TREND
4	7613	1	1979	—	—	2,475,000	25,300
4	7613	1	1980	—	—	3,183,000	128,100
4	7613	1	1981	—	—	3,448,000	146,000
4	7613	1	1982	—	—	5,040,000	209,875
4	7613	1	1983	—	—	5,658,000	237,250
4	7613	1	1984	—	—	5,835,000	237,900
4	7613	1	1985	—	—	6,789,000	255,500
4	7613	1	1986	—	—	7,250,000	301,125
4	7613	1	1987	—	—	8,311,000	337,625
4	7613	1	1988	—	—	8,223,000	338,550
4	7613	1	1989	—	—	8,930,000	365,000
4	7613	2	1990	—	—	—	298,205
4	7613	2	1991	—	190,000	—	309,155
4	7613	2	1992	—	200,000	—	320,616
4	7613	2	1993	187,000	—	—	277,400
4	7613	2	1994	249,000	—	—	385,440
4	7613	2	1995	275,000	—	—	462,455
4	7613	2	1996	190,000	—	—	466,284
4	7613	2	1997	228,000	—	—	190,530
4	7613	2	1998	293,000	—	—	343,465
4	7613	2	1999	223,000	—	—	397,485
4	7613	2	2000	—	871,000	—	335,256
4	7613	2	2001	—	—	—	365,255

— = No data.

2. Available data were accessed, and years without annual ESAL estimates were identified. Table 66 shows annual ESAL information is missing for 1990 and 2001.

3. ESAL-per-truck values were computed for each year with annualized ESAL data by dividing annualized ESAL from available sources by annualized total truck volume (ANNUAL_TRUCK_VOLUME_TREND). The TRF_TREND table was used as a source for ANNUAL_TRUCK_VOLUME_TREND values. ESAL-per-truck values based on data from multiple sources are shown in table 67.

4. Representative ESAL-per-truck values for LTPP GPS-3 site 047613 were obtained from the TRF_REP table. Minimum and maximum ESAL-per-truck values were obtained from table 64 and table 65. These values were added to table 67. The year used to compute representative ALDF was 1999, and the corresponding ESAL-per-truck value based on site-specific WIM data was 0.56.

Table 67. ESAL-per-truck values by year from multiple sources for LTPP GPS-3 site 047613.

STATE_CODE	SHRP_ID	Year	COMPUTED_ESAL_PER_TRUCK	MON_EST_ESAL_PER_TRUCK	HIST_EST_ESAL_PER_TRUCK	REP_ESAL_PER_TRUCK	MIN_RANGE	MAX_RANGE	Selected Source
4	7613	1979	—	—	24.66	0.53	0.2	1.45	2
4	7613	1980	—	—	24.92	0.53	0.2	1.45	2
4	7613	1981	—	—	23.62	0.53	0.2	1.45	2
4	7613	1982	—	—	24.01	0.53	0.2	1.45	2
4	7613	1983	—	—	23.85	0.53	0.2	1.45	2
4	7613	1984	—	—	24.59	0.53	0.2	1.45	2
4	7613	1985	—	—	26.57	0.53	0.2	1.45	2
4	7613	1986	—	—	24.08	0.53	0.2	1.45	2
4	7613	1987	—	—	24.62	0.53	0.2	1.45	2
4	7613	1988	—	—	24.36	0.53	0.2	1.45	2
4	7613	1989	—	—	24.47	0.53	0.2	1.45	2
4	7613	1990	—	—	—	0.53	0.2	1.45	2
4	7613	1991	—	0.61	—	0.53	0.2	1.45	3
4	7613	1992	—	0.63	—	0.53	0.2	1.45	3
4	7613	1993	0.67	—	—	0.53	0.2	1.45	1
4	7613	1994	0.65	—	—	0.53	0.2	1.45	1
4	7613	1995	0.59	—	—	0.53	0.2	1.45	1
4	7613	1996	0.41	—	—	0.53	0.2	1.45	2
4	7613	1997	1.2	—	—	0.53	0.2	1.45	2
4	7613	1998	0.85	—	—	0.53	0.2	1.45	2
4	7613	1999	0.56	—	—	0.53	0.2	1.45	1
4	7613	2000	—	2.61	—	0.53	0.2	1.45	2
4	7613	2001	—	—	—	0.53	0.2	1.45	2

— = No data.

5. The rationality of computed ESAL-per-truck values shown in table 67 was assessed by identifying and flagging the values meeting the following criteria:

a. Differ significantly from representative ESAL-per-truck values for the site (20 percent or more from value 0.53).

b. Differ significantly from the value used to develop representative ALDF (20 percent or more from value 0.56).

c. Outside of the reasonable range for a given road functional classification and vehicle mix observed at the site.

Results of the rationality assessment show that historical ESAL-per-truck values are outside the reasonable range and not rational for any type of trucks. These historical ESAL values most likely were provided for the roadway and not for the LTPP lane, resulting in much higher than expected ESAL-per-truck values. Arizona DOT estimates for 1991 and 1992 were in agreement with both representative ESAL-per-truck and ESAL-per-truck values used to develop ALDF. Arizona DOT estimates for 2000 seem too high when compared to ranges observed at all other LTPP traffic sites with high-quality WIM data. ESAL-per-truck values based on weight data collected in 1993–1995 and 1999 were in agreement with representative values, while ESAL-per-truck values based on weight data collected in 1996–1998 differ significantly. Close examination of WIM data for FHWA Class 9 vehicles indicates no calibration records are available. Review of the axle load distribution indicates shifts in weights indicative of calibration drift between years. Load spectra data from 1994, 1995, and 1999 look the most rational and follow the expected shape and position for FHWA Class 9 tandem axle load distribution.

6. Based on results of the rationality assessment of ESAL-per-truck values, annual ESAL trend sources were identified in the Selected Source column of table 67 using the following codes:

   - 1—annual ESAL trend value was computed from the KESAL value from the TRF_ESAL_COMPUTED table. This value was based on site- and year-specific WIM data.

   - 2—annual ESAL trend value was computed based on site-specific ESAL-per-truck values for years used to compute representative ALDF (the ESAL-per-truck value of 0.56 corresponds to the year used in ALDF computation) and site- and year-specific annual truck volume from the TRF_TREND table (shown in the ANNUAL_TRUCK_VOLUME_TREND column in table 66). To compute the annual ESAL trend value, the ESAL-per-truck value is multiplied by annual truck volume for a given year.

   - 3—annual ESAL trend value (from the TRF_MON_EST_ESAL table) was computed based on agency-supplied estimated annual KESAL for years during the LTPP program.

7. Annualized ESAL values were checked for partial-year instances. Only one instance of a partial year was found (1979). Since the ANNUAL_TRUCK_VOLUME_TREND value

used to compute the annual ESAL estimate for this year was already adjusted for partial year, no further adjustment was necessary. Final annual ESAL trend values and corresponding ESAL sources are shown in table 68.

Table 68. Annual ESAL trend estimates for LTPP GPS-3 site 047613.

STATE_CODE	SHRP_ID	CONSTRUCTION_NO	Year	ANNUAL_ESAL_TREND	TREND_ESAL_SOURCE
4	7613	1	1979	14,168	2
4	7613	1	1980	71,736	2
4	7613	1	1981	81,760	2
4	7613	1	1982	117,530	2
4	7613	1	1983	132,860	2
4	7613	1	1984	133,224	2
4	7613	1	1985	143,080	2
4	7613	1	1986	168,630	2
4	7613	1	1987	189,070	2
4	7613	1	1988	189,588	2
4	7613	1	1989	204,400	2
4	7613	2	1990	166,995	2
4	7613	2	1991	190,000	3
4	7613	2	1992	200,000	3
4	7613	2	1993	187,000	1
4	7613	2	1994	249,000	1
4	7613	2	1995	275,000	1
4	7613	2	1996	261,119	2
4	7613	2	1997	106,697	2
4	7613	2	1998	192,340	2
4	7613	2	1999	223,000	1
4	7613	2	2000	187,743	2
4	7613	2	2001	204,543	2

GESAL FOR EACH IN-SERVICE YEAR, ALL TRUCKS COMBINED

Computed Parameter Description

GESAL for each in-service year, all trucks combined takes advantage of the traditional ESAL formula to summarize traffic loading (with higher weight factors applied for heavier loads) but without a dependency on traditional nontraffic ESAL inputs like pavement structure or road serviceability. This statistic uses LEF values for flexible pavements with a structural number of “5” and a terminal serviceability index of “2.5.”

The primary purpose of GESAL for each in-service year is to provide users with a single-value statistic to characterize and compare traffic loading between different pavement sites while emphasizing the importance of and similarity in heavy loads. Annual GESAL trend values are provided for all pavement in-service years.

Data Sources Used for Parameter Computation

The annual GESAL trend parameter is computed using the following computed parameters available in the LTPP database:

- REP_GESAL_PER_TRUCK provided in the TRF_REP table.
- REP_GESAL_PER_VEH_CLASS_* provided in the TRF_REP table.
- ANNUAL_TRUCK_VOLUME_TREND provided in the TRF_TREND table.
- ALDF_USE_RATING provided in the MEPDG_AXLE_LOAD_DIST_FACTOR table.

In addition to this study, the LTPP program provided the GESAL_PER_VEH_CLASS_ALDF_YEARS_MONTHS_TSSC table that contained the VALIDATED_GESAL_PER_VEH_CLASS field with GESAL-per-vehicle-class values for each month and year used to compute site-specific ALDF. This table was used by the research team to compute average annual GESAL_VEH_CLASS_* by averaging 12 monthly VALIDATED_GESAL_PER_VEH_CLASS values.

Methodology and Computational Procedure for Parameter Computing

For each LTPP traffic site included in the TRF_TREND table, compute annual GESAL values for each in-service pavement year included in the TRF_TREND table using the following procedure:

1. For LTPP sites and years used to compute site- and year-specific ALDF values (i.e., LTPP sites with an ALDF_USABILITY_RATING of "1–4" in the MEPDG_AXLE_LOAD_DIST_FACTOR table), perform the following tasks:

    1.1. Identify years used to compute ALDF for each vehicle class.

    1.2. Select the parameters to compute annual GESAL-per-truck for ALDF years using codes in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table (chapter 8):

        1.2.1. If site-specific ALDF were computed based on data for all site-specific years combined for all vehicle classes (these sites contain the code "*YC*" in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table), assign GESAL-per-truck values from the REP_GESAL_PER_TRUCK field in the TRF_REP table. Treat these years as non-ALDF years and proceed to step 2.

        1.2.2. If site-specific ALDF were computed based on data for individual years for some or all vehicle classes for a given LTPP site, select GESAL-per-truck values from the following table fields:

- GESAL_VEH_CLASS_* values from the GESAL_PER_VEH_CLASS_ALDF_YEARS_MONTHS_TSSC table (custom table provided by the LTPP CSSC) for vehicles classes and years with ALDF values computed based on data from individual ALDF years.

- REP_GESAL_PER_VEH_CLASS_* values from the TRF_REP table for vehicle classes with ALDF values computed based on data for all ALDF years combined.

1.3. Create a new table called GESAL_PER_VEH_CLASS_ALDF_YEARS and populate it with annual GESAL-per-truck values by vehicle class for the ALDF years selected in the step 1.1.

1.4. To compute annual GESAL for ALDF years, perform the following tasks:

1.4.1. For each vehicle class (*), multiply GESAL_VEH_CLASS_* by AADTT_VEH_CLASS_*_TREND and sum the computed products across 10 vehicle classes (FHWA Classes 4–13).

1.4.2. Compute the number of days for each year included in the TRF_TREND table (the first and last year corresponding to each construction event in the TRF_TREND table are partial years) as ANNUAL_TRUCK_VOLUME_TREND/AADTT_ALL_TRUCKS_TREND.

1.4.3. Multiply the results from steps 1.4.1 and 1.4.2 to come up with ANNUAL_GESAL_ALDF_YEAR.

1.5. Review computed ANNUAL_GESAL_ALDF_YEAR values. For LTPP test sites with an ALDF_USABILITY_RATING of “3” or “4” in the MEPDG_AXLE_LOAD_DIST_FACTOR table or an ESAL_TREND data source not equal to “1,” check if using individual years created atypically high or low annual GESAL values. Decide on a site-by-site basis if GESAL estimates based on representative GESAL-per-vehicle-class values (computed based on site-specific data) and year-specific truck volume by class would be more appropriate than using year-specific annual GESAL. Create a table documenting LTPP sites and years with exceptions called SITE_YEARS_FOR_GESAL_ATL_EXCEPTIONS. Treat these years as non-ALDF years and proceed to step 2.

2. For all other LTPP sites and years (not used to compute site- and year-specific ALDF), perform the following tasks:

2.1. For each vehicle class (*), multiply REP_GESAL_PER_VEH_CLASS_* by AADTT_VEH_CLASS_*_TREND and sum the computed products across 10 vehicle classes (FHWA Classes 4–13) to compute total GESAL per day.

2.2. Compute the number of days for each year included in the TRF_TREND table (the first and last year corresponding to each construction event in the TRF_TREND table are partial years) as ANNUAL_TRUCK_VOLUME_TREND/AADTT_ALL_TRUCKS_TREND.

2.3. Multiply the results from steps 2.2 and 2.3 to come up with the ANNUAL_GESAL value based on representative GESAL per vehicle class and site-specific truck volume by class.

3. For each LTPP site, vehicle class, and in-service pavement year included in the TRF_TREND table, assign either ANNUAL_GESAL for non-ALDF years or ANNUAL_GESAL_ALDF_YEAR for ALDF years in the ANNUAL_GESAL_TREND field.

4. Assign an appropriate data source code for the annual GESAL trend parameter from the following options:

   - 1—annual GESAL was computed based on site- and year-specific WIM data.
   - 5—annual GESAL was estimated based on the representative GESAL-per-vehicle-class value from the TRF_REP table and site- and year-specific AADTT values by vehicle class from the TRF_TREND table.
   - 6—annual GESAL is “0” due to no truck volume.

5. Populate the ANNUAL_GESAL_TREND field in the TRF_TREND table with the annual GESAL results for each LTPP site and each in-service year included in the TRF_TREND table.

Example of Parameter Estimating

This example demonstrates the development of the annual GESAL trend for LTPP site 271085. The site was constructed in 1984 and participated in the LTPP experiment from the inception of LTPP (originally SHRP) program in 1987 through 1999.

1. For LTPP site 271085, 1996, 1997, and 1999 were identified as the years used to compute ALDF. A review of the codes in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table indicated that, for a majority of vehicle classes and axle groups, sample sizes used in ALDF computations were too low. These classes contained the code “*YC*” in the ALDF_METHOD field of the ALDF_ASSIGNMENT_METHOD table, as indicated in the “YC” Flag column in table 69.

Table 69. ALDF_METHOD records from the ALDF_ASSIGNMENT_METHOD table for LTPP traffic site 271085.

STATE_CODE	SHRP_ID	VEHICLE_CLASS	AXLE_GROUP	ALDF_METHOD	“YC” Flag
27	1085	4	1	M1UYC-Fair	YC
27	1085	4	2	M1UYC-Fair	YC
27	1085	5	1	M1U-Fair	—

STATE_CODE	SHRP_ID	VEHICLE_CLASS	AXLE_GROUP	ALDF_METHOD	"YC" Flag
27	1085	5	2	M1U-Fair	—
27	1085	6	1	M1U-Fair	—
27	1085	6	2	M1U-Fair	—
27	1085	7	1	M1UYC-Fair	YC
27	1085	7	2	M1UYC-Fair	YC
27	1085	7	3	M1UYC-Fair	YC
27	1085	7	4	M1UYC-Fair	YC
27	1085	8	1	M1U-Fair	—
27	1085	8	2	M1UYC-Fair	YC
27	1085	9	1	M1U-Fair	—
27	1085	9	2	M1U-Fair	—
27	1085	9	3	M1UYC-Fair	YC
27	1085	10	1	M1UYC-Fair	YC
27	1085	10	2	M1U-Fair	—
27	1085	10	3	M1UYC-Fair	YC
27	1085	10	4	M1UYC-Fair_AL	YC
27	1085	11	1	M1UYC-Fair_AL	YC
27	1085	11	2	M1UYC-Fair_AA_AL	YC
27	1085	11	3	M1UYC-Fair_AA_AL	YC
27	1085	12	1	M1UYC-Fair_AL	YC
27	1085	12	2	M1UYC-Fair_AL	YC
27	1085	12	3	M1UYC-Fair_AA_AL	YC
27	1085	12	4	—	—
27	1085	13	1	M1UYC-Fair_AL	YC
27	1085	13	2	M1UYC-Fair_AL	YC
27	1085	13	3	M1UYC-Fair_AL	YC
27	1085	13	4	M1UYC-Fair_AL	YC

— = No data.

2. For vehicle classes without an entry in the "YC" Flag column in table 69, monthly GESAL_VEH_CLASS_* values from the GESAL_PER_VEH_CLASS_ALDF_YEARS_MONTHS_TSSC table were extracted and averaged by year for ALDF years. The results are shown in Table 70.

Table 70. GESAL-per-vehicle class computed using data for individual ALDF years for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	GESAL_PER_VEH_CLASS_5	GESAL_PER_VEH_CLASS_6	GESAL_PER_VEH_CLASS_8	GESAL_PER_VEH_CLASS_9	GESAL_PER_VEH_CLASS_10
27	1085	1996	0.22182	0.42364	0.27545	0.84455	1.92091

STATE_ CODE	SHRP_ID	Year	GESAL_ PER_VEH_ CLASS_5	GESAL_ PER_VEH_ CLASS_6	GESAL_ PER_VEH_ CLASS_8	GESAL_ PER_VEH_ CLASS_9	GESAL_ PER_VEH_ CLASS_10
27	1085	1997	0.19333	0.40167	0.24167	0.65250	0.59917
27	1085	1999	0.33200	0.49400	0.28400	0.74400	1.04800

3. For vehicle classes identified as "YC" in table 69, GESAL-per-truck values were extracted from REP_GESAL_PER_VEH_CLASS_* fields in the TRF_REP table. The results are shown in Table 71.

Table 71. GESAL-per-vehicle class based on representative values for ALDF years for LTPP site 271085.

STATE_ CODE	SHRP_ID	Year	REP_GESAL_ PER_VEH_ CLASS_4	REP_GESAL_ PER_VEH_ CLASS_7	REP_GESAL_ PER_VEH_ CLASS_11	REP_GESAL_ PER_VEH_ CLASS_12	REP_GESAL_ PER_VEH_ CLASS_13
27	1085	1996	0.7011	1.2785	1.0033	0	0
27	1085	1997	0.7011	1.2785	1.0033	0	0
27	1085	1999	0.7011	1.2785	1.0033	0	0

4. Extracted GESAL-per-vehicle-class values were saved to a table called GESAL_PER_VEH_CLASS_ALDF_YEARS. The results are shown in Table 72.

Table 72. GESAL-per-vehicle-class values for ALDF years for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	GESAL_VEH_CLASS_4	GESAL_VEH_CLASS_5	GESAL_VEH_CLASS_6	GESAL_VEH_CLASS_7	GESAL_VEH_CLASS_8	GESAL_VEH_CLASS_9	GESAL_VEH_CLASS_10	GESAL_VEH_CLASS_11	GESAL_VEH_CLASS_12	GESAL_VEH_CLASS_13
27	1085	1996	0.7011	0.2218	0.4236	1.2785	0.2755	0.8445	1.9209	1.0033	0.0000	0.0000
27	1085	1997	0.7011	0.1933	0.4017	1.2785	0.2417	0.6525	0.5992	1.0033	0.0000	0.0000
27	1085	1999	0.7011	0.3320	0.4940	1.2785	0.2840	0.7440	1.0480	1.0033	0.0000	0.0000

5. For years not used to compute ALDF, GESAL-per-truck values were extracted for each vehicle class from REP_GESAL_PER_VEH_CLASS_* fields in the TRF_REP table in the following sequence:

Table 73. GESAL-per-vehicle-class values for non-ALDF years for LTPP site 271085.

STATE_CODE	SHRP_ID	REP_GESAL_PER_VEH_CLASS_4	REP_GESAL_PER_VEH_CLASS_5	REP_GESAL_PER_VEH_CLASS_6	REP_GESAL_PER_VEH_CLASS_7	REP_GESAL_PER_VEH_CLASS_8	REP_GESAL_PER_VEH_CLASS_9	REP_GESAL_PER_VEH_CLASS_10	REP_GESAL_PER_VEH_CLASS_11	REP_GESAL_PER_VEH_CLASS_12	REP_GESAL_PER_VEH_CLASS_13
27	1085	0.7011	0.2558	0.4403	1.2785	0.2588	0.7411	1.1526	1.0033	0	0

a. A daily GESAL estimate was computed by multiplying REP_GESAL_PER_VEH_CLASS_* by AADTT_VEH_CLASS_*_TREND for each vehicle class (*) and then summing the products across 10 vehicle classes (FHWA Classes 4–13).

b. To account for partial years of service, the number of days for each year was computed by dividing ANNUAL_TRUCK_VOLUME_TREND by AADTT_ALL_TRUCKS_TREND.

c. Daily GESAL estimates were multiplied by the number of days in service per year to compute the annual GESAL trend estimate for each in-service year, as shown in table 74.

Table 74. Truck volume, AADTT, and daily and annual GESAL trend values for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	ANNUAL_TRUCK_VOLUME_TREND	AADTT_ALL_TRUCKS_TREND	DAYS_IN_SERVICE	DAILY_GESAL	ANNUAL_GESAL_TREND	SOURCE_ANNUAL_GESAL_TREND
27	1085	1984	32,940	90	366	51	18,554	5
27	1085	1985	32,850	90	365	51	18,503	5

STATE_CODE	SHRP_ID	Year	ANNUAL_ TRUCK_ VOLUME_ TREND	AADTT_ ALL_ TRUCKS_ TREND	DAYS_IN_ SERVICE	DAILY_ GESAL	ANNUAL_ GESAL_ TREND	SOURCE_ ANNUAL_ GESAL_ TREND
27	1085	1986	32,850	90	365	51	18,503	5
27	1085	1987	32,850	90	365	51	18,503	5
27	1085	1988	32,940	90	366	51	18,554	5
27	1085	1989	34,675	95	365	54	19,569	5
27	1085	1990	27,375	75	365	42	15,467	5
27	1085	1991	23,360	64	365	35	12,820	5
27	1085	1992	33,672	92	366	54	19,724	5
27	1085	1993	27,740	76	365	44	15,914	5
27	1085	1994	28,470	78	365	42	15,503	5
27	1085	1995	31,025	85	365	49	17,764	5
27	1085	1996	30,378	83	366	51	18,817	1
27	1085	1997	31,390	86	365	41	14,809	1
27	1085	1998	29,200	80	365	46	16,793	5
27	1085	1999	10,150	70	145	42	6,101	1

6. Computed annual GESAL results were checked for atypically high or low annual GESAL values. For this suite, GESAL-per-year values typically range from 15,000 to 20,000. Observed exceptions to this range were 1991 and 1999. The low value in 1991 is explained by low AADTT observed for that year, and the low value in 1999 is explained by that year being the last partial year with low annual truck volumes. Because deviations from typical values had logical explanations, no changes to the computed values were necessary.

7. Data source codes for annual GESAL trend parameter were assigned in the SOURCE_ANNUAL_GESAL_TREND column in table 74 as follows:

   - 1—annual GESAL was computed based on site- and year-specific WIM data.

   - 5—annual GESAL was estimated based on the representative GESAL-per-vehicle-class value from the TRF_REP table and site- and year-specific AADTT by vehicle class from the TRF_TREND table.

8. Computed annual GESAL trend values and data source codes were added to the ANNUAL_GESAL_TREND field in the TRF_TREND table.

Table 75. Annual GESAL trend and data source code values for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	ANNUAL_ GESAL_TREND	SOURCE_ANNUAL_ GESAL_TREND
27	1085	1984	18,554	5
27	1085	1985	18,503	5
27	1085	1986	18,503	5
27	1085	1987	18,503	5

STATE_CODE	SHRP_ID	Year	ANNUAL_ GESAL_TREND	SOURCE_ANNUAL_ GESAL_TREND
27	1085	1988	18,554	5
27	1085	1989	19,569	5
27	1085	1990	15,467	5
27	1085	1991	12,820	5
27	1085	1992	19,724	5
27	1085	1993	15,914	5
27	1085	1994	15,503	5
27	1085	1995	17,764	5
27	1085	1996	18,817	1
27	1085	1997	14,809	1
27	1085	1998	16,793	5
27	1085	1999	6,101	1

ANNUAL TOTAL GVW FOR EACH IN-SERVICE YEAR, ALL TRUCKS COMBINED

Computed Parameter Description

Annual total GVW for each in-service year, all trucks combined provides an estimate of total annual vehicular loading from vehicles in FHWA Classes 4–13. All vehicular loads are treated equally when computing this summary loading statistic. Thus, a site with a high truck volume and high percentage of light trucks may have the same annual total GVW statistic as a site with a low truck volume but high percentage of heavy trucks. This parameter is provided for all pavement in-service years.

Data Sources used for Parameter Computation

The annual total GVW trend parameter is computed using the following parameters available in the LTPP database:

- REP_GVW_VEH_CLASS_* provided in the TRF_REP table.
- AX_CT_* (annualized axle counts by vehicle class, axle group, load bin, and year) provided in the TRF_MONITOR_AXLE_DISTRIB table.
- ANNUAL_TRUCK_VOLUME_TREND and AADTT_ALL_TRUCKS_TREND provided in the TRF_TREND table.

In addition, data from the ALDF_METHOD field of the ALDF_ASSIGNMENT_METHOD table used to develop ALDF were also used to compute the annual total GVW trend parameter.

Methodology and Computational Procedure for Parameter Computing

Annual total GVW values are computed using the following procedure:

1. For LTPP sites with site-specific ALDF values in the MEPDG_AXLE_LOAD_DIST_FACTOR table computed based on years with sufficient quantity of good-quality WIM data, do the following:

1.1. Use values in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table to check if all ALDF for the site were computed based on data from combined years (ALDF based on combined years were computed for sites with either lower quality WIM data for individual years or annual WIM data samples that were too small to be representative) or if the ANNUAL_ESAL_TREND data source code for ALDF years was not "1." Treat these years as non-ALDF years and proceed to step 2.

1.2. Compute the total annualized axle load for each LTPP site, vehicle class, axle group, and year by multiplying the annualized number of axle counts reported in each load bin in the TRF_MONITOR_AXLE_DISTRIB table by the corresponding midvalue of that load bin for a given axle group and summing the products over all load bins.

1.3. Compute the total annualized GVW for each LTPP site and ALDF year by summing the total annual axle load computed in step 1.2 for each LTPP site, vehicle class, and axle group over all axle groups and vehicle classes.

1.4. To account for partial years included in the TRF_TREND table, multiply the total annualized GVW computed in step 1.3 by a ratio of ANNUAL_TRUCK_VOLUME_TREND/(YEAR_DAYS*AADTT_ALL_TRUCKS_TREND) using parameters found in the TRF_TREND table (where YEAR_DAYS is either 365 or 366 for leap years). Save the results as the parameter ANNUAL_TOTAL_GVW_ALDF_YEARS.

2. For all other LTPP sites and years included in the TRF_TREND table, do the following for each LTPP site and year:

2.1. For each vehicle in FHWA Classes 4–13, select the representative GVW per vehicle class values from REP_GVW_VEH_CLASS_* fields in the TRF_REP table and the AADTT by vehicle class values from AADTT_VEH_CLASS_*_TREND fields in the TRF_TREND table.

2.2. Multiply the representative GVW per vehicle class value by the AADTT value for the same vehicle class and sum products over all vehicle classes (FHWA Classes 4–13). This value represents the annual average daily load for a given LTPP site and year.

2.3. Multiply the annual average daily load by the number of days corresponding to the year reported in the TRF_TREND table. The number of days for each year is estimated by dividing ANNUAL_TRUCK_VOLUME_TREND by AADTT_ALL_TRUCKS_TREND, which are found in the TRF_TREND table. Save the results as the parameter ANNUAL_TOTAL_GVW_NON_ALDF_YEARS.

3. For each LTPP site, vehicle class, and in-service pavement year included in the TRF_TREND table, assign either an ANNUAL_TOTAL_GVW_NON_ALDF_YEARS value (for non-ALDF years) or an ANNUAL_TOTAL_GVW_ALDF_YEARS value (for ALDF years) in the ANNUAL_TOTAL_GVW_TREND field.

4. Assign one of the following data source codes for annual total GVW parameter, as applicable:

- 1—annual total load was computed based on site- and year-specific WIM data.
- 5—annual total load was estimated based on the representative GVW-per-truck value from the TRF_REP table and the site- and year-specific annual truck volume from the TRF_TREND table.
- 6—annual total load is "0" due to no truck volume.

5. Store the annual total GVW results in the ANNUAL_TOTAL_GVW_TREND field in the TRF_TREND table for each LTPP site and each in-service year included in the TRF_TREND table.

Example of Parameter Estimating

This example demonstrates development of the total annual GVW trend for LTPP site 271085. The site was constructed in 1984 and participated in LTPP experiment from the inception of the LTPP (originally SHRP) program in 1987 through 1999.

1. For LTPP site 271085, 1996, 1997, and 1999 were identified as the years used to compute ALDF. A review of codes in the ALDF_METHOD field in the ALDF_ASSIGNMENT_METHOD table presented in table 69 indicated that not all vehicle classes and axle groups have code "*YC*" in the ALDF_METHOD field. Therefore, the TRF_MONITOR_AXLE_DISTRIB table can be used to compute annual total GVW for ALDF years.

2. To compute the annual total axle load (ATL_CLASS_AXLE) for each vehicle class, axle group and ALDF year, the annualized number of axle counts reported in each load bin in the TRF_MONITOR_AXLE_DISTRIB table was multiplied by the corresponding midvalue of the corresponding load bin for a given axle group and summed over all load bins. The resulting annual total axle loads by vehicle class and axle group are shown in table 76 in ATL_CLASS_AXLE column.

Table 76. Annual total axle loads by vehicle class and axle group for LTPP site 271085.

STATE_ CODE	SHRP_ID	Year	VEHICLE_ CLASS	AXLE_ GROUP	ATL_CLASS_ AXLE (lb)
27	1085	1996	4	1	8,965,500
27	1085	1996	4	2	6,349,000
27	1085	1996	5	1	107,448,000
27	1085	1996	5	2	6,092,000
27	1085	1996	6	1	27,304,500
27	1085	1996	6	2	44,222,000
27	1085	1996	7	1	6,656,000
27	1085	1996	7	2	5,083,000
27	1085	1996	7	3	11,256,000
27	1085	1996	7	4	12,625,500
27	1085	1996	8	1	35,907,500
27	1085	1996	8	2	12,246,000
27	1085	1996	9	1	170,621,000

STATE_ CODE	SHRP_ID	Year	VEHICLE_ CLASS	AXLE_ GROUP	ATL_CLASS_ AXLE (lb)
27	1085	1996	9	2	528,724,000
27	1085	1996	9	3	4,621,500
27	1085	1996	10	1	10,614,000
27	1085	1996	10	2	20,606,000
27	1085	1996	10	3	22,809,000
27	1085	1996	10	4	15,910,500
27	1085	1996	11	1	2,481,500
27	1085	1996	11	2	1,142,000
27	1085	1996	11	3	876,000
27	1085	1996	12	1	186,500
27	1085	1996	12	2	321,000
27	1085	1996	12	3	367,500
27	1085	1996	13	1	678,500
27	1085	1996	13	2	1,352,000
27	1085	1996	13	3	4,275,000
27	1085	1996	13	4	1,800,000
27	1085	1997	4	1	7,280,000
27	1085	1997	4	2	4,560,000
27	1085	1997	5	1	118,011,500
27	1085	1997	6	1	32,927,500
27	1085	1997	6	2	51,215,000
27	1085	1997	7	1	5,964,500
27	1085	1997	7	2	77,000
27	1085	1997	7	3	7,704,000
27	1085	1997	7	4	7,500,000
27	1085	1997	8	1	37,067,000
27	1085	1997	8	2	9,419,000
27	1085	1997	9	1	163,167,500
27	1085	1997	9	2	524,370,000
27	1085	1997	9	3	28,500
27	1085	1997	10	1	8,405,500
27	1085	1997	10	2	23,223,000
27	1085	1997	10	3	11,407,500
27	1085	1997	10	4	490,500
27	1085	1997	11	1	2,386,000
27	1085	1997	12	1	438,000
27	1085	1997	12	2	186,000
27	1085	1997	13	1	73,000
27	1085	1997	13	2	50,000
27	1085	1997	13	3	295,500
27	1085	1999	4	1	579,000
27	1085	1999	4	2	669,000
27	1085	1999	5	1	92,140,000

STATE_ CODE	SHRP_ID	Year	VEHICLE_ CLASS	AXLE_ GROUP	ATL_CLASS_ AXLE (lb)
27	1085	1999	6	1	30,677,500
27	1085	1999	6	2	52,485,000
27	1085	1999	7	1	4,392,000
27	1085	1999	7	2	3,619,000
27	1085	1999	7	3	2,260,500
27	1085	1999	7	4	6,963,000
27	1085	1999	8	1	31,185,500
27	1085	1999	8	2	8,133,000
27	1085	1999	9	1	167,206,500
27	1085	1999	9	2	497,506,000
27	1085	1999	10	1	5,223,000
27	1085	1999	10	2	25,032,000
27	1085	1999	10	3	372,000
27	1085	1999	10	4	207,000
27	1085	1999	11	1	1,023,000
27	1085	1999	11	2	475,000

3. To compute the annualized total GVW for each ALDF year, ATL_CLASS_AXLE values computed in step 2 were summed over all vehicle classes and axle groups. The resulting annualized GVW values (ANNUALIZED_GVW_FOR_ALDF_YEARS) are shown in table 77.

Table 77. Total annualized GVW for ALDF years for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	ANNUALIZED_ GVW_FOR_ALDF_YEARS (lb)
27	1085	1996	1,071,541,000
27	1085	1997	1,016,246,500
27	1085	1999	930,148,000

4. To account for partial ALDF years included in the TRF_TREND table, the annualized total GVW computed in step 3 (ANNUALIZED_GVW_FOR_ALDF_YEARS) was multiplied by a year fraction. The year fraction was computed as a ratio of ANNUAL_TRUCK_VOLUME_TREND/(DAYS_IN_YEAR*AADTT_ALL_TRUCKS_ TREND) using parameters found in the TRF_TREND table (where DAYS_IN_YEAR value is either 365 or 366 for leap years). For LTPP site 271085, 1999 was a partial year with only 145 d included in the experiment. Table 78 shows annual total GVW for ALDF years, prorated for partial years.

Table 78. Annual total GVW for ALDF years, prorated for partial years for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	ANNUAL_ TRUCK_ VOLUME_ TREND	AADTT_ ALL_ TRUCKS_ TREND	DAYS_ IN_ YEAR	YEAR_ FRACTION	ANNUALIZED_ GVW_FOR_ ALDF_YEARS	ANNUAL_ TOTAL_GVW_ ALDF_YEARS (lb)
27	1085	1996	30,378	83	366	1	1,071,541,000	1,071,541,000
27	1085	1997	31,390	86	365	1	1,016,246,500	1,016,246,500
27	1085	1999	10,150	70	145	0.3973	930,148,000	369,510,849

5. For years not used to compute ALDF, representative GVW per vehicle class values were extracted from REP_GVW_VEH_CLASS_* fields in the TRF_REP table, and AADTT by vehicle class values were extracted from AADTT_VEH_CLASS_*_TREND fields in the TRF_TREND table, as shown in table 79 and table 80, respectively.

Table 79. AADTT by vehicle class for LTPP site 271085.

STATE_ CODE	SHRP_ ID	Year	AADTT_ VEH_ CLASS_4_ TREND	AADTT_ VEH_ CLASS_5_ TREND	AADTT_ VEH_ CLASS_6_ TREND	AADTT_ VEH_ CLASS_7_ TREND	AADTT_ VEH_ CLASS_8_ TREND	AADTT_ VEH_ CLASS_9_ TREND	AADTT_ VEH_ CLASS_10_ TREND	AADTT_ VEH_ CLASS_11_ TREND	AADTT_ VEH_ CLASS_12_ TREND	AADTT_ VEH_ CLASS_13_ TREND
27	1085	1984	1	26	9	1	5	45	3	0	0	0
27	1085	1985	1	26	9	1	5	45	3	0	0	0
27	1085	1986	1	26	9	1	5	45	3	0	0	0
27	1085	1987	1	26	9	1	5	45	3	0	0	0
27	1085	1988	1	26	9	1	5	45	3	0	0	0
27	1085	1989	1	27	10	1	5	48	3	0	0	0
27	1085	1990	1	21	8	1	4	38	2	0	0	0
27	1085	1991	0	19	7	1	4	32	1	0	0	0
27	1085	1992	1	24	9	1	4	49	3	1	0	0
27	1085	1993	1	23	7	1	4	38	3	0	0	0
27	1085	1994	1	26	7	1	4	37	2	0	0	0
27	1085	1995	1	25	8	1	4	42	4	0	0	0
27	1085	1998	0	19	10	1	5	43	2	0	0	0

Table 80. Representative GVW in pounds by vehicle class for LTPP site 271085.

STATE_ CODE	SHRP_ID	REP_ GVW_ VEH_ CLASS_4	REP_ GVW_ VEH_ CLASS_5	REP_ GVW_ VEH_ CLASS_6	REP_ GVW_ VEH_ CLASS_7	REP_ GVW_ VEH_ CLASS_8	REP_ GVW_ VEH_ CLASS_9	REP_ GVW_ VEH_ CLASS_10	REP_ GVW_ VEH_ CLASS_11	REP_ GVW_ VEH_ CLASS_12	REP_ GVW_ VEH_ CLASS_13
27	1085	31,162	12,948	27,270	62,908	24,285	47,419	62,554	58,757	0	0

6. To compute daily total GVW for each non-ALDF year, the representative GVW per vehicle class value for each vehicle class shown in table 80 was multiplied by the AADTT value for the corresponding vehicle class shown in table 79 and the results were summed across all vehicle classes. Results computed for each non-ALDF year are shown in table 81.

Table 81. Daily total GVW estimate for each non-ALDF year for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	DAILY_ TOTAL_GVW (lb)
27	1085	1984	3,119,090
27	1085	1985	3,119,090
27	1085	1986	3,119,090
27	1085	1987	3,119,090
27	1085	1988	3,119,090
27	1085	1989	3,301,565
27	1085	1990	2,608,308
27	1085	1991	2,176,912
27	1085	1992	3,317,342
27	1085	1993	2,669,488
27	1085	1994	2,598,359
27	1085	1995	2,974,884
27	1085	1998	2,867,170

7. To compute annual total GVW for each non-ALDF year, total days in service per year were computed for each year and multiplied by the daily total GVW estimate. The number of in-service days for each year were computed by dividing the annual truck volume (ANNUAL_TRUCK_VOLUME_TREND) by the AADTT (AADTT_ALL_TRUCKS_TREND), found in the TRF_TREND table. Results of this computation are shown in table 82.

Table 82. Annual total GVW estimate for each non-ALDF year for LTPP site 271085.

STATE_CODE	SHRP_ID	Year	DAYS_IN_SERVICE	DAILY_TOTAL_ GVW	ANNUAL_TOTAL_GVW_ NON_ALDF (lb)
27	1085	1984	366	3,119,090	1,141,586,940
27	1085	1985	365	3,119,090	1,138,467,850
27	1085	1986	365	3,119,090	1,138,467,850
27	1085	1987	365	3,119,090	1,138,467,850
27	1085	1988	366	3,119,090	1,141,586,940
27	1085	1989	365	3,301,565	1,205,071,225
27	1085	1990	365	2,608,308	952,032,420
27	1085	1991	365	2,176,912	794,572,880
27	1085	1992	366	3,317,342	1,214,147,172
27	1085	1993	365	2,669,488	974,363,120

STATE_CODE	SHRP_ID	Year	DAYS_IN_SERVICE	DAILY_TOTAL_ GVW	ANNUAL_TOTAL_GVW_ NON_ALDF (lb)
27	1085	1994	365	2,598,359	948,401,035
27	1085	1995	365	2,974,884	1,085,832,660
27	1085	1998	365	2,867,170	1,046,517,050

8. For each in-service pavement year included in the TRF_TREND table for LTPP site 271085, ANNUAL_TOTAL_GVW_NON_ALDF values were assigned for non-ALDF years and ANNUAL_TOTAL_GVW_ALDF_YEARS values were assigned for ALDF years in the ANNUAL_TOTAL_GVW_TREND field in the TRF_TREND table. In addition, the following data source codes were assigned, as applicable:

   - 1—annual total GVW was computed based on site- and year-specific WIM data.
   - 5—annual total GVW was estimated based on representative GVW per truck values from the TRF_REP table and site- and year-specific annual truck volumes from the TRF_TREND table.

The results of this assignment are shown in table 83.

Table 83. Annual total GVW trend for LTPP site 271085.

STATE_CODE	SHRP_ID	CONSTRUCTION_ NO	Year	ANNUAL_TOTAL_ GVW_TREND (lb)	SOURCE_ANNUAL_ TOTAL_GVW_TREND
27	1085	1	1984	1,141,586,940	5
27	1085	1	1985	1,138,467,850	5
27	1085	1	1986	1,138,467,850	5
27	1085	1	1987	1,138,467,850	5
27	1085	1	1988	1,141,586,940	5
27	1085	1	1989	1,205,071,225	5
27	1085	1	1990	952,032,420	5
27	1085	1	1991	794,572,880	5
27	1085	1	1992	1,214,147,172	5
27	1085	1	1993	974,363,120	5
27	1085	1	1994	948,401,035	5
27	1085	1	1995	1,085,832,660	5
27	1085	1	1996	1,071,541,000	1
27	1085	1	1997	1,016,246,500	1
27	1085	1	1998	1,046,517,050	5
27	1085	1	1999	369,510,849	1

CHAPTER 11. DESIGN OF THE CPTS

The new CPTs were designed to hold analysis-ready traffic input parameters frequently used in LTPP analyses and selected traffic inputs parameters for MEPDG-based pavement analyses using AASHTOWare Pavement ME Design software. Details about each CPT's purpose and specific data fields (i.e., data dictionary) are provided in the ensuing sections.

TRF_TREND

The TRF_TREND table contains annual traffic statistics computed or estimated for each in-service and in-experiment year. The TRF_TREND table is useful when a complete time history of changes in traffic is a desired input for analyses. Traffic trend values are developed based on data consolidated from multiple sources with any discrepancies between multiple data sources resolved and missing values estimated. The data source or estimation method for each year is also provided in the TRF_TREND table.

Table 84. Field names and descriptions for the TRF_TREND table.

Field Name	Field Type	Description
STATE_CODE	NUMBER(2)	Numerical code for State or Province. U.S. codes are consistent with Federal Information Processing Standards.
SHRP_ID	VARCHAR2(4)	Test section identification number assigned by the LTPP program. Must be combined with STATE_CODE to be unique.
CONSTRUCTION_NO	NUMBER(2)	Event number used to relate changes in pavement structure with other time-dependent data elements. This field is set to "1" when a test section is initially accepted into the LTPP program and is incremented with each change to the layer structure.
YEAR	NUMBER(4)	Year for which values apply.
AADTT_ALL_TRUCKS_TREND	NUMBER(6)	AADTT for each year for vehicles in FHWA Classes 4–13 combined for the LTPP lane.
ANNUAL_TRUCK_VOLUME_TREND	NUMBER(8)	Estimate of the total number of trucks (FHWA Classes 4–13) passing over a test section, during a calendar year, while a construction event was part of the LTPP experiment.
AADTT_VEH_CLASS_4_TREND	NUMBER(5)	AADTT estimate for FHWA Class 4 vehicles in the LTPP lane.
AADTT_VEH_CLASS_5_TREND	NUMBER(5)	AADTT estimate for FHWA Class 5 vehicles in the LTPP lane.

Field Name	Field Type	Description
AADTT_VEH_CLASS_6_TREND	NUMBER(5)	AADTT estimate for FHWA Class 6 vehicles in the LTPP lane.
AADTT_VEH_CLASS_7_TREND	NUMBER(5)	AADTT estimate for FHWA Class 7 vehicles in the LTPP lane.
AADTT_VEH_CLASS_8_TREND	NUMBER(5)	AADTT estimate for FHWA Class 8 vehicles in the LTPP lane.
AADTT_VEH_CLASS_9_TREND	NUMBER(5)	AADTT estimate for FHWA Class 9 vehicles in the LTPP lane.
AADTT_VEH_CLASS_10_TREND	NUMBER(5)	AADTT estimate for FHWA Class 10 vehicles in the LTPP lane.
AADTT_VEH_CLASS_11_TREND	NUMBER(5)	AADTT estimate for FHWA Class 11 vehicles in the LTPP lane.
AADTT_VEH_CLASS_12_TREND	NUMBER(5)	AADTT estimate for FHWA Class 12 vehicles in the LTPP lane.
AADTT_VEH_CLASS_13_TREND	NUMBER(5)	AADTT estimate for FHWA Class 13 vehicles in the LTPP lane.
CMLTV_VOL_VEH_CLASS_9_TREND	NUMBER(9)	Estimate of the cumulative volume of FHWA Class 9 vehicles that passed over a test section since the site opened to traffic after assigned Construction Event.
CMLTV_VOL_HEAVY_TRUCKS_TREND	NUMBER(9)	Estimate of the cumulative volume of heavy trucks (FHWA Classes 4 and 6–13) that passed over a test section since the site opened to traffic after assigned Construction Event.
ANNUAL_ESAL_TREND	NUMBER(8)	Estimated annual ESAL for vehicles in FHWA Classes 4–13.
ANNUAL_GESAL_TREND	NUMBER(8)	Estimated annual GESAL for vehicles in FHWA Classes 4–13.
ANNUAL_TOTAL_GVW_TREND	NUMBER(8)	Estimated annual total truck load for vehicles in FHWA Classes 4–13.
AADTT_SOURCE	VARCHAR2(10)	Code indicating source of truck volume data.
VEH_CLASS_SOURCE	VARCHAR2(10)	Code indicating source of vehicle classification data.
ESAL_SOURCE	VARCHAR2(10)	Code indicating source of data for ESAL trend estimate.
GESAL_SOURCE	VARCHAR2(10)	Code indicating source of data for GESAL trend estimate.
GVW_SOURCE	VARCHAR2(10)	Code indicating source of data for total annual GVW trend estimate.

TRF_REP

The TRF_REP table contains representative truck volume, vehicle classification, and loading summary parameters. For most LTPP sites, these values are developed based on available traffic monitoring data determined as representative of truck traffic characteristics at each LTPP site. For sites with insufficient monitoring data, these values were developed based on data from alternative sources or based on default values. The data source or estimation method is also provided in the TRF_REP table.

Table 85. Field names and descriptions for the TRF_REP table.

Field Name	Field Type	Description
STATE_CODE	NUMBER(2)	Numerical code for State or Province. U.S. codes are consistent with Federal Information Processing Standards.
SHRP_ID	VARCHAR2(4)	Test section identification number assigned by the LTPP program. Must be combined with STATE_CODE to be unique.
EXPERIMENT_NO	VARCHAR2(3)	Code indicating to which LTPP experiment a pavement section is assigned.
GPS_SPS	VARCHAR2(1)	Code indicating if the section is a GPS or SPS section.
ASSIGN_DATE	DATE	Date when a test section was assigned to the LTPP experiment. The experiment designation for a test section is the combination of EXPERIMENT_NO and GPS_SPS fields in the record.
DEASSIGN_DATE	DATE	Date when a test section changed to another experiment or was placed in out-of-study status in the LTPP program.
REP_AADTT	NUMBER(6)	Representative average annual daily truck volume since the roadway was opened to traffic. Computed as the mean value of AADTT values for all years from the site's opening to traffic until it leaves the experiment. If the site is part of a continuing experiment, this value is based on the data available at the end of 2016.
REP_PERCENT_VEH_CLASS_4	NUMBER(5,2)	Representative percent of trucks in FHWA Class 4 for the LTPP lane.
REP_PERCENT_VEH_CLASS_5	NUMBER(5,2)	Representative percent of trucks in FHWA Class 5 for the LTPP lane.
REP_PERCENT_VEH_CLASS_6	NUMBER(5,2)	Representative percent of trucks in FHWA Class 6 for the LTPP lane.
REP_PERCENT_VEH_CLASS_7	NUMBER(5,2)	Representative percent of trucks in FHWA Class 7 for the LTPP lane.

Field Name	Field Type	Description
REP_PERCENT_VEH_CLASS_8	NUMBER(5,2)	Representative percent of trucks in FHWA Class 8 for the LTPP lane.
REP_PERCENT_VEH_CLASS_9	NUMBER(5,2)	Representative percent of trucks in FHWA Class 9 for the LTPP lane.
REP_PERCENT_VEH_CLASS_10	NUMBER(5,2)	Representative percent of trucks in FHWA Class 10 for the LTPP lane.
REP_PERCENT_VEH_CLASS_11	NUMBER(5,2)	Representative percent of trucks in FHWA Class 11 for the LTPP lane.
REP_PERCENT_VEH_CLASS_12	NUMBER(5,2)	Representative percent of trucks in FHWA Class 12 for the LTPP lane.
REP_PERCENT_VEH_CLASS_13	NUMBER(5,2)	Representative percent of trucks in FHWA Class 13 for the LTPP lane.
REP_GESAL_SINGLE_AXLE	NUMBER(4,2)	Representative GESAL per single axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_GESAL_TANDEM_AXLE	NUMBER(4,2)	Representative GESAL per tandem axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_GESAL_TRIDEM_AXLE	NUMBER(4,2)	Representative GESAL per tridem axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_GESAL_QUAD_AXLE	NUMBER(4,2)	Representative GESAL per quad axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_GESAL_PER_TRUCK	NUMBER(5,2)	Representative GESAL-per-truck, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_4	NUMBER(5,2)	Representative GESAL per FHWA Class 4 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_5	NUMBER(5,2)	Representative GESAL per FHWA Class 5 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_6	NUMBER(5,2)	Representative GESAL per FHWA Class 6 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_7	NUMBER(5,2)	Representative GESAL per FHWA Class 7 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_8	NUMBER(5,2)	Representative GESAL per FHWA Class 8 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_9	NUMBER(5,2)	Representative GESAL per FHWA Class 9 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_10	NUMBER(5,2)	Representative GESAL per FHWA Class 10 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_11	NUMBER(5,2)	Representative GESAL per FHWA Class 11 truck for the LTPP lane.
REP_GESAL_PER_VEH_CLASS_12	NUMBER(5,2)	Representative GESAL per FHWA Class 12 truck for the LTPP lane.

Field Name	Field Type	Description
REP_GESAL_PER_VEH_CLASS_13	NUMBER(5,2)	Representative GESAL per FHWA Class 13 truck for the LTPP lane.
REP_RPPIF_SINGLE_AXLE	NUMBER(3,2)	Representative RPPIF per single axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_RPPIF_TANDEM_AXLE	NUMBER(3,2)	Representative RPPIF per tandem axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_RPPIF_TRIDEM_AXLE	NUMBER(3,2)	Representative RPPIF per tridem axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_RPPIF_QUAD_AXLE	NUMBER(3,2)	Representative RPPIF per quad axle, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_RPPIF_PER_TRUCK	NUMBER(4,2)	Representative RPPIF per truck, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_4	NUMBER(5,2)	Representative RPPIF per FHWA Class 4 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_5	NUMBER(5,2)	Representative RPPIF per FHWA Class 5 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_6	NUMBER(5,2)	Representative RPPIF per FHWA Class 6 truck for LTPP lane.
REP_RPPIF_PER_VEH_CLASS_7	NUMBER(5,2)	Representative RPPIF per FHWA Class 7 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_8	NUMBER(5,2)	Representative RPPIF per FHWA Class 8 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_9	NUMBER(5,2)	Representative RPPIF per FHWA Class 9 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_10	NUMBER(5,2)	Representative RPPIF per FHWA Class 10 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_11	NUMBER(5,2)	Representative RPPIF per FHWA Class 11 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_12	NUMBER(5,2)	Representative RPPIF per FHWA Class 12 truck for the LTPP lane.
REP_RPPIF_PER_VEH_CLASS_13	NUMBER(5,2)	Representative RPPIF per FHWA Class 13 truck for the LTPP lane.
REP_GVW_TRUCK	NUMBER(6)	Representative GVW, considering vehicles in FHWA Classes 4–13 for the LTPP lane.
REP_GVW_VEH_CLASS_4	NUMBER(6)	Representative GVW for FHWA Class 4 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_5	NUMBER(6)	Representative GVW for FHWA Class 5 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_6	NUMBER(6)	Representative GVW for FHWA Class 6 trucks for the LTPP lane.

Field Name	Field Type	Description
REP_GVW_VEH_CLASS_7	NUMBER(6)	Representative GVW for FHWA Class 7 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_8	NUMBER(6)	Representative GVW for FHWA Class 8 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_9	NUMBER(6)	Representative GVW for FHWA Class 9 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_10	NUMBER(6)	Representative GVW for FHWA Class 10 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_11	NUMBER(6)	Representative GVW for FHWA Class 11 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_12	NUMBER(6)	Representative GVW for FHWA Class 12 trucks for the LTPP lane.
REP_GVW_VEH_CLASS_13	NUMBER(6)	Representative GVW for FHWA Class 13 trucks for the LTPP lane.
REP_ESAL_SINGLE_AXLE	NUMBER(4,2)	Representative ESAL per single axle for vehicles in FHWA Classes 4–13 combined for the LTPP lane.
REP_ESAL_TANDEM_AXLE	NUMBER(4,2)	Representative ESAL per tandem axle for FHWA Classes 4–13 combined for the LTPP lane.
REP_ESAL_TRIDEM_AXLE	NUMBER(4,2)	Representative ESAL per tridem axle for vehicles in FHWA Classes 4–13 combined for the LTPP lane.
REP_ESAL_QUAD_AXLE	NUMBER(4,2)	Representative ESAL per quad axle, considering vehicles in FHWA Classes 4–13.
REP_ESAL_PER_TRUCK	NUMBER(5,2)	Representative ESAL per truck, considering vehicle Classes 4–13 for LTPP lane.
REP_ESAL_PER_VEH_CLASS_4	NUMBER(5,2)	Representative ESAL per FHWA Class 4 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_5	NUMBER(5,2)	Representative ESAL per FHWA Class 5 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_6	NUMBER(5,2)	Representative ESAL per FHWA Class 6 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_7	NUMBER(5,2)	Representative ESAL per FHWA Class 7 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_8	NUMBER(5,2)	Representative ESAL per FHWA Class 8 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_9	NUMBER(5,2)	Representative ESAL per FHWA Class 9 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_10	NUMBER(5,2)	Representative ESAL per FHWA Class 10 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_11	NUMBER(5,2)	Representative ESAL per FHWA Class 11 truck for the LTPP lane.

Field Name	Field Type	Description
REP_ESAL_PER_VEH_CLASS_12	NUMBER(5,2)	Representative ESAL per FHWA Class 12 truck for the LTPP lane.
REP_ESAL_PER_VEH_CLASS_13	NUMBER(5,2)	Representative ESAL per FHWA Class 13 truck for the LTPP lane.
REP_AADTT_USE_RATING	VARCHAR2(10)	Code providing an indication of how effectively the REP_AADTT value represents the lifetime of AADTT at a site.
REP_VEH_CLASS_USE_RATING	VARCHAR2(10)	Code indicating source of representative vehicle classification distribution data.
REP_LOAD_USE_RATING	VARCHAR2(10)	Code indicating source of representative loading information.

MEPDG_TRUCK_VOL_PARAMETERS

The MEPDG_TRUCK_VOL_PARAMETERS table contains parameters used in AASHTOWare Pavement ME Design software to estimate traffic volume for FHWA Classes 4–13 (as defined in the FHWA TMG) over the analysis or design period, including the following for each LTPP site and experiment: LTPP lane AADTT for the first year the site was opened to traffic, normalized vehicle class volume distribution factors, and truck volume growth information.[14] Values included in the MEPDG_TRUCK_VOL_PARAMETERS table are derived from available data best representing changes in truck traffic over each pavement's service life using functions integrated into AASHTOWare Pavement ME Design software. The LTPP program recommends researchers not use these values outside of AASHTOWare Pavement ME Design software; instead, values from the TRF_TREND table should be used. The MEPDG_TRUCK_VOL_PARAMETERS table is designed to resemble the AASHTOWare Pavement ME Design software input table to facilitate data entry using a copy–paste operation.

Table 86. Field names and descriptions for the MEPDG_TRUCK_VOL_PARAMETERS table.

Field Name	Field Type	Description
STATE_CODE	NUMBER(2)	Numerical code for State or Province. U.S. codes are consistent with Federal Information Processing Standards.
SHRP_ID	VARCHAR2(4)	Test section identification number assigned by the LTPP program. Must be combined with STATE_CODE to be unique.
EXPERIMENT_NO	VARCHAR2(4)	Code indicating to which LTPP experiment a pavement section is assigned.
GPS_SPS	VARCHAR2(1)	Code indicating if a test section is a GPS or SPS experiment.
TRAFFIC_OPEN_DATE_EXP_NO	DATE	Date when pavement first opened to traffic for a corresponding LTPP experiment.
TRAFFIC_OPEN_YEAR_EXP_NO	NUMBER(4)	First year a site opened to traffic for a corresponding LTPP experiment.
END_YEAR	NUMBER(4)	Last year of site participation in the LTPP experiment or last year of estimate.
AADTT_FIRST_YEAR_LTPP_LANE	NUMBER(8)	AADTT (for FHWA Classes 4–13 combined) for the first full year of service when pavement was first opened to traffic for a corresponding LTPP experiment.
VEHICLE_CLASS	NUMBER(2)	Vehicle classification code using 13 bins as described in the FHWATMG.
VEH_CLASS_DIST_PERCENT	NUMBER(5,2)	Percent of trucks representing first year for each vehicle in FHWA Classes 4–13 in the LTPP lane for a period corresponding to the LTPP experiment.

Field Name	Field Type	Description
VEH_CLASS_GROWTH_FUNCTION	VARCHAR2(10)	Type of truck volume growth function associated with each vehicle in FHWA Classes 4–13 for a period corresponding to the LTPP experiment. There are two options available in AASHTOWare Pavement ME Design software: linear or compound.
VEH_CLASS_GROWTH_RATE	NUMBER(3,2)	Annual truck volume growth rate associated with each vehicle in FHWA Classes 4–13 corresponding to the truck growth function type entered in the VEH_CLASS_GROWTH_FUNCTION field for a period corresponding to the LTPP experiment.
VEH_CLASS_GROWTH_USE_RATING	VARCHAR2(10)	Code indicating the source of the truck growth function and base year AADTT and vehicle class distribution.

MEPDG_AXLE_LOAD_DIST_FACTOR

The MEPDG_AXLE_LOAD_DIST_FACTOR table contains normalized ALDF for use with AASHTOWare Pavement ME Design software. One set of ALDF values is provided for each LTPP site. In addition, information about the data or method used to develop ALDF is included. The MEPDG_AXLE_LOAD_DIST_FACTOR table is designed to resemble the AASHTOWare Pavement ME Design software input table to facilitate data entry using a copy–paste operation.

Table 87. Field names and descriptions for the MEPDG_AXLE_LOAD_DIST_FACTOR table.

Field Name	Data Type	Description
STATE_CODE	NUMBER(2)	Numerical code for State or Province. U.S. codes are consistent with Federal Information Processing Standards.
SHRP_ID	VARCHAR2(4)	Test section identification number assigned by the LTPP program. Must be combined with STATE_CODE to be unique.
ALDF_USE_RATING	VARCHAR(255)	Code indicating source of data and method for developing ALDF estimate.
AXLE_GROUP	NUMBER(1)	Type of axle for which these percentages of axles apply.
MONTH	NUMBER(2)	Numeric value for each calendar month.

Field Name	Data Type	Description
MONTH_NAME	VARCHAR2(10)	Name of month, per AASHTOWare Pavement ME Design software format. All 12 mo must be present for a site to be used as an input for AASHTOWare Pavement ME Design software.
VEHICLE_CLASS	NUMBER(2)	Vehicle classification code using 13 bins as described in the TMG.
TOTAL	NUMBER(3)	Total axle percentage computed as a summation of values in load bins MEPDG_LG01 through MEPDG_LG39. This field value must equal to 100 percent to be used as an input for AASHTOWare Pavement ME Design software.
MEPDG_LG01	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 0–2,999 lb for single axles; 0–5,999 lb for tandem axles; and 0–11,999 lb for tridem and quad axles.
MEPDG_LG02	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 3,000–3,999 lb for single axles; 6,000–7,999 lb for tandem axles; and 12,000–14,999 lb for tridem and quad axles.
MEPDG_LG03	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 4,000–4,999 lb for single axles; 8,000–9,999 lb for tandem axles; and 15,000–17,999 lb for tridem and quad axles.
MEPDG_LG04	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 5,000–5,999 lb for single axles; 10,000–11,999 lb for tandem axles; and 18,000–20,999 lb for tridem and quad axles.
MEPDG_LG05	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 6,000–6,999 lb for single axles; 12,000–13,999 lb for tandem axles; and 21,000–23,999 lb for tridem and quad axles.
MEPDG_LG06	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 7,000–7,999 lb for single axles; 14,000–15,999 lb for tandem axles; and 24,000–26,999 lb for tridem and quad axles.
MEPDG_LG07	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 8,000–8,999 lb for single axles; 16,000–17,999 lb for tandem axles; and 27,000–29,999 lb for tridem and quad axles.
MEPDG_LG08	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 9,000–9,999 lb for single axles; 18,000–19,999 lb for tandem axles; and 30,000–32,999 lb for tridem and quad axles.
MEPDG_LG09	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 10,000–10,999 lb for single axles; 20,000–21,999 lb for tandem axles; and 33,000–35,999 lb for tridem and quad axles.
MEPDG_LG10	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 11,000–11,999 lb for single axles; 22,000–23,999 lb for tandem axles; and 36,000–38,999 lb for tridem and quad axles.
MEPDG_LG11	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 12,000–12,999 lb for single axles; 24,000–25,999 lb for tandem axles; and 39,000–41,999 lb for tridem and quad axles.

Field Name	Data Type	Description
MEPDG_LG12	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 13,000–13,999 lb for single axles; 26,000–27,999 lb for tandem axles; and 42,000–44,999 lb for tridem and quad axles.
MEPDG_LG13	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 14,000–14,999 lb for single axles; 28,000–29,999 lb for tandem axles; and 45,000–47,999 lb for tridem and quad axles.
MEPDG_LG14	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 15,000–15,999 lb for single axles; 30,000–31,999 lb for tandem axles; and 48,000–50,999 lb for tridem and quad axles.
MEPDG_LG15	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 16,000–16,999 lb for single axles; 32,000–33,999 lb for tandem axles; and 51,000–53,999 lb for tridem and quad axles.
MEPDG_LG16	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 17,000–17,999 lb for single axles; 34,000–35,999 lb for tandem axles; and 54,000–56,999 lb for tridem and quad axles.
MEPDG_LG17	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 18,000–18,999 lb for single axles; 36,000–37,999 lb for tandem axles; and 57,000–59,999 lb for tridem and quad axles.
MEPDG_LG18	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 19,000–19,999 lb for single axles; 38,000–39,999 lb for tandem axles; and 60,000–62,999 lb for tridem and quad axles.
MEPDG_LG19	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 20,000–20,999 lb for single axles; 40,000–41,999 lb for tandem axles; and 63,000–65,999 lb for tridem and quad axles.
MEPDG_LG20	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 21,000–21,999 lb for single axles; 42,000–43,999 lb for tandem axles; and 66,000–68,999 lb for tridem and quad axles.
MEPDG_LG21	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 22,000–22,999 lb for single axles; 44,000–45,999 lb for tandem axles; and 69,000–71,999 lb for tridem and quad axles.
MEPDG_LG22	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 23,000–23,999 lb for single axles; 46,000–47,999 lb for tandem axles; and 72,000–74,999 lb for tridem and quad axles.
MEPDG_LG23	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 24,000–24,999 lb for single axles; 48,000–49,999 lb for tandem axles; and 75,000–77,999 lb for tridem and quad axles.
MEPDG_LG24	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 25,000–25,999 lb for single axles; 50,000–51,999 lb for tandem axles; and 78,000–80,999 lb for tridem and quad axles.
MEPDG_LG25	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 26,000–26,999 lb for single axles; 52,000–53,999 lb for tandem axles; and 81,000–83,999 lb for tridem and quad axles.
MEPDG_LG26	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 27,000–27,999 lb for single axles; 54,000–55,999 lb for tandem axles; and 84,000–86,999 lb for tridem and quad axles.

Field Name	Data Type	Description
MEPDG_LG27	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 28,000–28,999 lb for single axles; 56,000–57,999 lb for tandem axles; and 87,000–89,999 lb for tridem and quad axles.
MEPDG_LG28	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 29,000–29,999 lb for single axles; 58,000–59,999 lb for tandem axles; and 90,000–92,999 lb for tridem and quad axles.
MEPDG_LG29	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 30,000–30,999 lb for single axles; 60,000–61,999 lb for tandem axles; and 93,000–95,999 lb for tridem and quad axles.
MEPDG_LG30	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 31,000–31,999 lb for single axles; 62,000–63,999 lb for tandem axles; and 96,000–98,999 lb for tridem and quad axles.
MEPDG_LG31	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 32,000–32,999 lb for single axles; 64,000–65,999 lb for tandem axles; and 99,000–101,999 lb for tridem and quad axles.
MEPDG_LG32	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 33,000–33,999 lb for single axles; and 66,000–67,999 lb for tandem axles.
MEPDG_LG33	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 34,000–34,999 lb for single axles; and 68,000–6,9999 lb for tandem axles.
MEPDG_LG34	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 35,000–35,999 lb for single axles; and 70,000–71,999 lb for tandem axles.
MEPDG_LG35	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 36,000–36,999 lb for single axles; and 72,000–73,999 lb for tandem axles.
MEPDG_LG36	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 37,000–37,999 lb for single axles; and 74,000–75,999 lb for tandem axles.
MEPDG_LG37	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 38,000–38,999 lb for single axles; and 76,000–77,999 lb for tandem axles.
MEPDG_LG38	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 39,000–39,999 lb for single axles; and 78,000–79,999 lb for tandem axles.
MEPDG_LG39	NUMBER(10, 7)	Percent of axles whose weight falls in the bin 40,000–40,999 lb for single axles; and 80,000–81,999 lb for tandem axles.

MEPDG_AXLE_PER_TRUCK

The MEPDG_AXLE_PER_TRUCK table contains representative APT for each truck class (FHWA Classes 4–13) and axle group for use with AASHTOWare Pavement ME Design software, including source of data or method used to develop APT. For LTPP sites with site-specific factors in the MEPDG_AXLE_LOAD_DIST_FACTOR table, APT was computed using the same years as data used to develop ALDF. For LTPP sites with default factors in the MEPDG_AXLE_LOAD_DIST_FACTOR table, all years with available axle count data were used. The MEPDG_AXLE_PER_TRUCK table was designed to resemble the AASHTOWare Pavement ME Design input table using a copy–paste operation.

Table 88. Field names and descriptions for the MEPDG_AXLE_PER_TRUCK table.

Field Name	Field Type	Description
STATE_CODE	NUMBER(2)	Numerical code for State or Province. U.S. codes are consistent with Federal Information Processing Standards.
SHRP_ID	VARCHAR2(4)	Test section identification number assigned by the LTPP program. Must be combined with STATE_CODE to be unique.
APT_USE_RATING	VARCHAR (255)	Code indicating source of APT data.
VEHICLE_CLASS	NUMBER(2)	Vehicle classification code using 13 bins as described in the TMG.
SINGLE_AXLES	NUMBER(4,2)	Average number of single axles for each truck class (FHWA Classes 4–13).
TANDEM_AXLES	NUMBER(4,2)	Average number of tandem axles for each truck class (FHWA Classes 4–13).
TRIDEM_AXLES	NUMBER(4,2)	Average number of tridem axles for each truck class (FHWA Classes 4–13).
QUAD_AXLES	NUMBER(4,2)	Average number of quad axles for each truck class (FHWA Classes 4–13).

CODES DESCRIBING DATA AND METHODS USED FOR PARAMETER COMPUTATION, AND PARAMETER USABILITY

To help LTPP data users assess the accuracy and applicability of available LTPP traffic loading data and computed parameters, a set of codes was developed and included in each CPT. LTPP CPT names and fields containing data–usability codes are summarized in table 89. Table 90 through table 99 provide a description of codes used for each field. Using these codes, LTPP researchers can identify LTPP sites with traffic parameters meeting analysis criteria based on data source and quality information.

Table 89. CPT fields describing sources of data and methods used to develop different traffic parameters.

LTPP CPT	CPT Field
TRF_TREND	AADTT_SOURCE
	VEH_CLASS_SOURCE
	ESAL_SOURCE
	GESAL_SOURCE
	GVW_SOURCE
TRF_REP	REP_AADTT_USE_RATING

LTPP CPT	CPT Field
	REP_VEH_CLASS_USE_RATING
	REP_LOAD_USE_RATING
MEPDG_TRUCK_VOL_PARAMETERS	VEH_CLASS_GROWTH_USE_RATING
MEPDG_AXLE_LOAD_DIST_FACTOR	ALDF_USE_RATING
MEPDG_AXLE_PER_TRUCK	APT_USE_RATING

Table 90. Codes for AADTT_SOURCE and VEH_CLASS_SOURCE fields.

Code	Description Short	Description Long
M	Monitored	AADTT value submitted in monitoring data.
Mc	Monitored calculated	AADTT value computed from vehicle classification data obtained from the monitoring data collection program.
S	State-supplied	Based on State-supplied historical data collection efforts prior to the LTPP traffic monitoring program.
H	Historical	State-supplied historical AADTT value.
Ec	Estimated compound	Estimated based on other years of data at a site to fill in gaps in data coverage using a best fit compound growth equation.
El	Estimate linear	Estimated based on other years of data at a site to fill in gaps in data coverage using a best fit linear growth equation.
D	Default	Default value based on an external source.
A	AADTT-based	Calculated based on AADTT value and mean vehicle class percentage.
N	Not open to traffic	A site has not yet opened to traffic.

Table 91. Codes for ESALS_SOURCE, GESALS_SOURCE, and GVW_SOURCE fields.

Code	Description Short	Description Long
0	No ESAL for *00 SPS sites	No annual ESAL provided for the virtual SPS site (*00) or any site with no pavement structure information.
1	Site- and year-specific data	Annual estimate computed by the LTPP program based on site- and year-specific WIM data.
2	Based on average ESAL per truck and year-specific annual truck volume	Annual ESAL computed based on average ESAL-per-truck values computed using selected years of site-specific WIM data and site- and year-specific annual truck volume from the TRF_TREND table.
3	Agency-supplied historical annual ESAL	Agency-supplied annual ESAL for years during the LTPP traffic monitoring program.
4	Agency-supplied annual ESAL	Agency-supplied annual ESAL for years prior to the LTPP traffic monitoring program.

Code	Description Short	Description Long
5	Based on representative per-truck loading value and site- and year-specific truck volume	Annual estimate based on representative per-truck loading value from the TRF_REP table and site- and year-specific annual truck volume by vehicle class from the TRF_TREND table.
6	No truck volume	Annual estimate is “0” due to no truck volume.

Table 92. Codes for the ESALS_SOURCE field.

Code	Description Short	Description Long
0	No ESAL for *00 SPS sites	No annual ESAL provided for the virtual SPS site (*00) or any site with no pavement structure information.
1	Site- and year-specific data	Annual estimate computed by the LTPP program based on site- and year-specific WIM data.
2	Based on average ESAL per truck and year-specific annual truck volume	Annual ESAL computed based on average ESAL-per-truck values computed using selected years of site-specific WIM data and site- and year-specific annual truck volume from the TRF_TREND table.
3	Agency-supplied historical annual ESAL	Agency-supplied annual ESAL for years during the LTPP traffic monitoring program.
4	Agency-supplied annual ESAL	Agency-supplied annual ESAL for years prior to the LTPP traffic monitoring program.
5	Based on representative per-truck loading value and site- and year-specific truck volume	Annual estimate based on representative per-truck loading value from the TRF_REP table and site- and year-specific annual truck volume by vehicle class from the TRF_TREND table.
6	No truck volume	Annual estimate is “0” due to no truck volume.

Table 93. Codes for the GESALS_SOURCE field.

Code	Description Short	Description Long
1	Site- and year-specific data	Annual estimate computed by the LTPP program based on site- and year-specific WIM data.
5	Based on representative per-truck loading value and site- and year-specific truck volume	Annual estimate based on representative per-truck loading value from the TRF_REP table and site- and year-specific annual truck volume by vehicle class from the TRF_TREND table.
6	No truck volume	Annual estimate is “0” due to no truck volume.

Table 94. Codes for the GVW_SOURCE field.

Code	Description Short	Description Long
1	Site- and year-specific data	Annual GVW estimate computed by the LTPP program based on site- and year-specific WIM data.
5	Based on representative per-truck loading value and site- and year-specific truck volume	Annual GVW based on representative per-truck loading value from the TRF_REP table and site- and year-specific annual truck volume by vehicle class from the TRF_TREND table.
6	No truck volume	Annual GVW estimate is “0” due to no truck volume.

Table 95. Codes for the REP_AADTT_USE_RATING field.

Code	Description Short	Description Long
1	Best	More than 75 percent of annual AADTT estimates used for REP_AADTT computation have an AADTT_Source of "M" and no years during that period experience a year-to-year change in AADTT both greater than 25 percent and larger than 50 trucks.
2	Better	More than 75 percent of annual AADTT estimates used for REP_AADTT computation have an AADTT_Source of either "M" or "S" and no years during that period experience a year-to-year change in AADTT both greater than 25 percent and larger than 50 trucks.
3	Good	More than 50 percent of annual AADTT estimates used for REP_AADTT computation have an AADTT_Source of "M," but less than 75 percent of AADTT_Source values are either "M" or "S" and no years during that period experience a year-to-year change in AADTT both greater than 25 percent and larger than 50 trucks.
4	Fair	More than 25 percent of annual AADTT estimates used for REP_AADTT computation have an AADTT_Source of "M," but less than 50 percent of AADTT_Source values are either "M" or "S," or 1 yr or more during that period experience a year-to-year change in AADTT both greater than 25 percent and larger than 50 trucks and more than 25 percent of annual AADTT estimates used to compute the equation have an AADTT_Source of either "M" or "S."
5	Poor	Less than 25 percent of annual AADTT estimates used for REP_AADTT computation have an AADTT_Source of either "M" or "S."

Table 96. Codes for REP_VEH_CLASS_USE_RATING and VEH_CLASS_GROWTH_USE_RATING fields.

Code	Description Short	Description Long
1	Best	More than 75 percent of years of data used to determine vehicle growth by class function have vehicle class data from the traffic monitoring program and during no year of traffic monitoring data does the year-to-year percentage of truck traffic falling within one FHWA class change by more than 15 percent (e.g., FHWA Class 9 trucks does not grow from 50 percent to more than 65 percent of total truck traffic).
2	Better	More than 50 percent of years of data used to determine vehicle growth by class function have vehicle class data from the traffic monitoring program and during no year of traffic monitoring data does the year-to-year percentage of truck traffic falling within one FHWA class change by more than 15 percent no years during that

Code	Description Short	Description Long
		period experience a year-to-year change in AADTT both greater than 25 percent and larger than 50 trucks.
3	Good	More than 50 percent, but less than 75 percent, of years of data used to determine vehicle growth by class function have vehicle class data from the traffic monitoring program and during no year of traffic monitoring data does the year-to-year percentage of truck traffic falling within one FHWA class change by more than 15 percent, but the site experienced a year-to-year change in AADTT both greater than 25 percent and larger than 50 trucks.
4	Fair	No Good, Better, or Best code was assigned, and more than 25 percent of years of data used to determine vehicle growth by class function have vehicle class data from the traffic monitoring program.
5	Poor	Less than 25 percent of years of data used to determine vehicle growth by class function have data from the traffic monitoring program, but at least 1 yr of traffic monitoring data per FHWA vehicle classification is present during the experiment.
6	Bad	No monitoring data are present.

Table 97. Codes for the ALDF_USE_RATING field.

Code	Description Short	Description Long
1	Best	Based on WIM data satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 and passing data reasonableness checks. Data are available for at least one occurrence of each of 12 calendar months with at least one occurrence for each DOW for each calendar month. All computed parameters are based on monthly axle loading data summaries developed by the LTPP program. These data are acceptable for site-specific MEPDG analyses and developing traffic loading defaults.
2	Better	Based on WIM data satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 and passing data reasonableness checks. Data are available for at least 1 yr but not all 12 mo are present in the dataset. All computed parameters are based on annual axle loading data summaries developed by the LTPP program. These data are acceptable for site-specific MEPDG analyses and developing traffic loading defaults if no additional usability codes are assigned to this ALDF.
3	Good	Based on WIM data collected by equipment without a calibration record, thus data quality cannot be quantified. Computed parameters are based on annual axle loading data summaries developed by the LTPP program using data passing QC checks, research team data reasonableness checks, and minimum data availability requirements. These data are acceptable for site-specific MEPDG analyses and developing traffic loading defaults if no additional usability codes are assigned to this ALDF.

Code	Description Short	Description Long
4	Fair	Based on WIM data collected by equipment without a calibration record, thus data quality cannot be quantified. Computed parameters are based on annual axle loading data summaries developed by the LTPP program using data passing QC checks, minimum data availability requirements, and most research team data reasonableness checks. Annual axle load distributions selected for parameter computation were manually reviewed and specific years were selected to minimize the effects of low precision and bias observed in WIM data. Potential WIM data issues were noted for each site to inform users about lower-quality data. These lower-quality data may have low to moderate effects on MEPDG analysis results and should be used with caution. Using default values following similar axle loading distribution may be an alternative approach.
10	Agency ESAL-based	No directly usable axle loading distribution. Agency ESAL distribution is more reasonable than distribution computed from single available distribution and was used as the basis for loading distribution selection.
11	ESALCalc-based	No directly usable axle loading distribution. ESALCalc estimate distribution is more reasonable than the agency estimate and was used as the basis for loading distribution selection.
12	Quantitative acceptance	Single available axle loading distribution quantitatively screened and accepted for direct use. No better than "Fair" quality.
13	Location-based	No axle loading data or agency-provided ESAL estimates. Axle loading distributions were selected based on location information only.
AA	Atypical axle type	Axle group is not typical for a given vehicle class. ALDF values are not recommended for developing defaults.
ALC	Low axle count	Computed values are based on low axle count (fewer than 200 axles) and may not be representative of typical loading conditions for a given site. ALDF values are not recommended for developing defaults.
ALS	Based on small axle sample	Computed values are based on a low number of days with data and may not be representative of typical loading conditions for a given site. ALDF values are not recommended for developing defaults.
NA	Not applicable	No ALDF; vehicle class–axle combination is not present in supporting data.
DEF	Default for low truck volume	Vehicle class is not present in dataset. Defaults are selected using low-volume criterion for the vehicle class.
20	Typical as representative	Multiple years of unknown data quality with typical distribution accepted as representative.
21	ESAL-based acceptance of typical	Multiple years of data of unknown quality. Agency ESAL estimates are consistent with ESALs computed from distribution. Typical distribution is accepted for use.

Code	Description Short	Description Long
22	Typical more reasonable than ESAL-based	Multiple years of data of unknown quality. Agency ESAL estimates are reasonable but smaller than ESALs computed from distribution. Typical distribution is accepted for use.
23	Estimated ESAL-based	Multiple years of data of unknown quality. Agency ESAL estimates are reasonable but larger than ESALs computed from distribution. Distributions are selected based on estimated ESALs.
24	Default using typical distribution ESALs	Multiple years of data of unknown quality. Agency ESAL estimates are not reasonable. Distributions are selected based on ESALs computed from distributions.
25	Default using agency ESAL estimate higher than distribution ESALs	Multiple years of data of unknown quality. Agency ESAL estimates are reasonable. ESALs computed from distributions are lower than reasonable. Axle distributions are based on agency ESALs.
26	Default using agency ESAL estimate lower than distribution ESALs	Multiple years of data of unknown quality. Agency ESAL estimates are reasonable. ESALs computed from distributions are higher than reasonable. Axle distributions are based on agency ESALs.
27	Location-based, loading provided rejected	Multiple years of data of unknown quality. Agency ESAL estimates and ESALs computed from distributions are higher than reasonable. Axle distributions are selected based on location.

Table 98. Codes for the APT_USE_RATING field.

Code	Description Short	Description Long
1	Extensive data availability	APT based on a sample of more than 200 trucks collected over more than 365 d in total. Recommended for site-specific analysis. APT values are recommended to develop default values if no "A" codes are assigned.
2	Good data availability	APT based on a sample of more than 200 trucks collected over more than 210 and less than 365 d in total. Recommended for site-specific analysis. APT values are recommended to develop default values if no "A" codes are assigned.
3	Sufficient data availability	APT based on a sample of more than 200 trucks collected over less than 210 d in total. APT values are recommended for site-specific analysis.
4	Limited data availability	APT based on a sample of less than 200 trucks. Use with caution in site-specific analysis or consider using defaults. APT values are not recommended to develop default values.
5	Marginal data availability	APT based on a sample of less than 100 trucks. Use with caution in site-specific analysis or consider using defaults. APT values are not recommended to develop default values.
0	No information on data availability	No information is available on the extent of availability of data used to compute the APT parameter.

Code	Description Short	Description Long
A0	Atypical total axles	Total number of axles per truck does not follow FHWA 13-bin vehicle classification rules for a given vehicle class. APT values are not recommended to develop default values. These lower-quality APT may have low to moderate effects on MEPDG analysis results and should be used with caution. Using default values may be an alternative approach.
A1	Atypically low single axles	Less than 0.95 single axles per truck (all trucks should have at least one single steering axle). Values are not recommended to develop default values. These lower-quality APT may have low to moderate effects on MEPDG analysis results and should be used with caution. Using default values may be an alternative approach.
A2	Atypical tandem axle type	Tandem axle is atypical for a given vehicle class. Values are not recommended to develop default values.
A3	Atypical tridem axle type	Tridem axle is atypical for a given vehicle class. Values are not recommended to develop default values.
A4	Atypical quad axle type	Quad axle is atypical for a given vehicle class. Values are not recommended to develop default values.
AW	Low-quality weight data	The quality of associated data is too low to estimate weight but does not affect classification and axle-count data applicability.
NA	Not applicable	No APT; vehicle class is not present in supporting data.
D1	Agency and roadway type default	Agency- and route-based default using average axles for routes in the same Agency with the same type of route signing (e.g., Interstate, U.S.).
D2	Country and roadway type default	Country- and route-based default using average axles for routes in the same country with the same type of route signing (e.g., Interstate, U.S.).
D3	Agency average default	Agency-based default using average axles for all routes in the same State/Province.

Table 99. Codes for the REP_LOAD_USE_RATING field.

Code	DefinitionDescription Short	Description Long
1	Best	Based on WIM data satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 and passing data reasonableness checks. Data are available for at least one occurrence of each of the 12 calendar months with at least one occurrence of each DOW for each calendar month. All computed parameters are based on monthly WIM data summaries developed by the LTPP program. These data are acceptable for site-specific MEPDG analyses and developing traffic loading defaults.
2	Better	Based on WIM data that satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 and passing data reasonableness checks. Data are available for at least 1 yr but not all 12 mo are present in the dataset. All computed parameters are based on annual WIM data summaries developed by the LTPP

Code	DefinitionDescription Short	Description Long
		program. These data are acceptable for site-specific MEPDG analyses and developing traffic loading defaults if no additional usability codes are assigned to this ALDF.
3	Good	Based on WIM data collected by equipment without a calibration record, thus data quality cannot be quantified. Computed parameters are based on annual data summaries developed by the LTPP program using data passing QC checks, research team data reasonableness checks, and minimum data availability requirements. These data are acceptable for site-specific MEPDG analyses and developing traffic loading defaults if no additional usability codes are assigned to this ALDF.
4	Fair	Based on WIM data collected by equipment without a calibration record, thus data quality cannot be quantified. Computed parameters are based on annual data summaries developed by the LTPP program using data passing QC checks, minimum data availability requirements, and most research team data reasonableness checks. Annual axle load distributions selected for parameter computation were manually reviewed and specific years were selected to minimize the effects of low precision and bias observed in WIM data. Potential WIM data issues were noted for each site to inform users about lower-quality data. These lower-quality data may have low to moderate effects on MEPDG analysis results and should be used with caution. Using default values following similar axle loading distributions may be an alternative approach.
10	ESAL selected axle distribution	Estimate based on axle distributions selected using ESAL values and truck volumes as inputs.
12	Typical basis	Based on typical axle distribution for a site.
13	Location-based distribution	Estimate based on axle distributions selected as a function of site location.

CHAPTER 12. OVERVIEW OF THE USER GUIDE FOR SELECTING AND USING LONG-TERM PAVEMENT PERFORMANCE TRAFFIC DATA

PURPOSE OF THE GUIDE

An outcome of this study is the *Guide*, which helps LTPP data users navigate available LTPP traffic data and computed parameters.(1) Users can also refer to the Guide for assistance with the following:

- Understanding the meaning of LTPP traffic parameters, along with the data and computational principals used to develop these parameters.
- Identifying traffic parameters suitable for different pavement analyses.
- Using InfoPave to identify LTPP tables containing these parameters and extract desired LTPP traffic data.

The Guide also provides practical examples with step-by-step instructions for obtaining traffic parameters for different types of LTPP analyses. In summary, the Guide helps streamline LTPP users' identification of desired LTPP traffic data and parameters and maximizes the use of LTPP traffic data in achieving their pavement analysis objectives.

OVERVIEW OF THE GUIDE

This Guide consists of two parts. Part one describes traffic parameters available from the LTPP program sources and provides details about the methods used to collect traffic data and compute the parameters. Part one also contains recommendations for the most applicable traffic parameters for different types of pavement analyses. Part one of the Guide includes the following chapters:

- Chapter 1, Introduction—describes the purpose, scope, and organization of the Guide.

- Chapter 2, Overview of LTPP Traffic Data and Parameters—describes LTPP traffic data and computed parameters with references to database tables containing these parameters.

- Chapter 3, LTPP Traffic Metadata—describes sources of LTPP traffic data and methods used to collect traffic data and provides references to methods used to compute traffic parameters. It describes indices and codes available in LTPP database tables that can be used to identify data sources and computational methods and how to use this information as an aid in traffic data and parameter selection.

- Chapter 4, Selecting LTPP Traffic Data and Parameters for Analysis—provides recommendations about types of traffic data and parameters suitable for various common pavement analyses, including references to traffic parameter names and LTPP tables containing these parameters.

- Chapter 5, Tools and Procedures for Extracting LTPP Traffic Data—describes available tools for selecting and extracting LTPP traffic data and parameters. It discusses using default values for parameters not included in LTPP database tables, including applicability and limitations of default values.

Part two of the Guide is a playbook of practical examples showing different traffic data selection and extraction scenarios. It shows examples of how to use InfoPave to obtain various types of traffic parameters for LTPP sites. For parameters not included in the LTPP database, examples of computational procedures are provided showing how available LTPP traffic data can be used to compute or estimate a desired parameter. For traffic parameters that cannot be computed using available LTPP traffic data, references to available default values and alternative data sources are provided. Traffic data-selection scenarios included in the playbook are as follows:

- Scenario 1—Obtain traffic volume information.
- Scenario 2—Obtain vehicle classification information.
- Scenario 3—Obtain detailed axle or truck loading information.
- Scenario 4—Obtain summary traffic loading information.
- Scenario 5—Obtain MEPDG traffic inputs for use in AASHTOWare Pavement ME Design software.

CHAPTER 13. SUMMARY OF STUDY RESULTS

OVERVIEW OF STUDY OUTCOMES

The goal of this study was to develop analysis-ready traffic parameters necessary to support most LTPP analyses and help LTPP users identify and obtain LTPP traffic parameters necessary for different pavement analysis objectives.

The following sections provide information about the analysis-ready traffic parameters developed in this study, including statistics about the number of LTPP traffic sites for which these parameters were developed. LTPP sites with traffic loading data issues identified during the study and sites lacking site-specific data were not included in Phase III of this study. The analysis-ready traffic parameters for these sites are under development using other LTPP program resources.

To provide LTPP data users with guidance about the traffic data and computed parameters, the Guide was developed. See chapter 13 for an overview of the Guide.

To help users apply traffic inputs based on HPMS traffic data to LTPP prediction models , a procedure for estimating truck volume by class in the design lane (i.e., truck lane) using HPMS directional traffic data was developed and presented in chapter 13.

NEW TRAFFIC PARAMETERS DEVELOPED IN THIS STUDY

Analysis-ready traffic parameters developed in this study include the following:

- MEPDG base (first) year AADTT LTPP lane (AASHTOWare Pavement ME Design software input).
- MEPDG truck traffic growth function by vehicle class (AASHTOWare Pavement ME Design software input).
- MEPDG truck traffic growth rate by vehicle class (AASHTOWare Pavement ME Design software input).
- MEPDG vehicle class volume distribution (AASHTOWare Pavement ME Design software input).
- MEPDG Axle Load Distribution Factors (AASHTOWare Pavement ME Design software input).
- MEPDG number of axles per truck (AASHTOWare Pavement ME Design software input).
- AADTT in LTPP lane for each year, for vehicles in FHWA Classes 4–13 combined and for each truck class (FHWA Classes 4–13).
- Cumulative volume of heavy trucks (vehicles in FHWA Classes 4 and 6–13 combined), estimated annually.
- Cumulative volume of FHWA Class 9 trucks, estimated annually.
- Annual ESAL for LTPP lane for each year for vehicles in FHWA Classes 4–13 combined.

- Annual GESAL for LTPP lane for each year for vehicles in FHWA Classes 4–13 combined.
- Annual total GVW for LTPP lane for each year for vehicles in FHWA Classes 4–13 combined.
- Annual total truck volume for LTPP lane for each year for vehicles in FHWA Classes 4–13 combined.
- Representative AADTT in LTPP lane, all classes combined.
- Representative percent of trucks in each class for FHWA Classes 4–13 for LTPP lane.
- Codes describing traffic data sources and methods used for parameter estimation.

In addition, recommendations were made to the LTPP program to include the following additional analysis-ready traffic parameters in the LTPP database. These parameters were described in detail in chapters 2 and 3 of this report. The following parameters were developed by the LTPP program outside of this study:

- Representative ESAL per truck, considering vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative EESAL per each vehicle in FHWA Classes 4–13 for LTPP lane.
- Representative ESAL per single, tandem, tridem, and quad axle, considering vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative GESAL-per-truck, considering vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative GESAL per each vehicle class in FHWA Classes 4–13 for LTPP lane.
- Representative GESAL per single, tandem, tridem, and quad axle, considering vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative RPPIF per truck, considering vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative RPPIF per each vehicle in FHWA Classes 4–13 for LTPP lane.
- Representative RPPIF per single, tandem, tridem, and quad axle, considering vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative GVW, considering all vehicles in FHWA Classes 4–13 for LTPP lane.
- Representative GVW for each vehicle in FHWA Classes 4–13 for LTPP lane.

AVAILABILITY OF ANALYSIS-READY TRAFFIC PARAMETERS FOR LTPP TRAFFIC SITES

Truck Volume, Growth, and Vehicle Classification Parameters for AASHTOWare Pavement ME Design Software Input

The MEPDG_TRUCK_VOL_PARAMETERS table includes traffic input sets for use in AASHTOWare Pavement ME Design software. Each traffic input set includes the AADTT for the first year at each LTPP test site, the percentage distribution of that truck volume occurring within each of the 10 FHWA vehicle classes, and a growth formula (annual percentage change) for each of those classes. Each formula takes either a linear or compound shape. Which formula should be used for each equation is also described. The type of formula used (linear or compound) can be different for different vehicle classifications at a site (i.e., the appropriate growth formula for FHWA Class 9 trucks can be a linear function, but the formula for FHWA Class 10 can be a compound function). As a result, growth equations for each site come in sets of 10, with a separate equation for each classification of trucks.

The MEPDG_TRUCK_VOL_PARAMETERS table includes a total of 1,632 unique sets of traffic inputs for use in AASHTOWare Pavement ME Design software. In general, these traffic input sets are present for every SPS experiment site and every GPS test section. For SPS sites, inputs are provided at the site-level (i.e., SHRP_CODE is *00). Each SPS site typically contains more than one LTPP test section (e.g., SPS-1 site 010100 consists of a series of test sections (010101–010163.)) One set of MEPDG traffic inputs is provided in the MEPDG_TRUCK_VOL_PARAMETERS table for SPS-1 site 010100. Those equations are applicable across test sections 010101–010163.

A total of 247 SPS sites have traffic inputs in the MEPDG_TRUCK_VOL_PARAMETERS table. SPS-10 sites (SHRP_IDs in the form of “AAxx”) are not included in the MEPDG_TRUCK_VOL_PARAMETERS table. These sites did not have traffic data in SDR 30.

Some LTPP test sites experience significant construction activity when they are part of the LTPP program. When construction activity is significant enough to cause a test section’s structural characteristics to change, an additional set of traffic inputs is developed for that new structural condition. Often, but not always, this second set of traffic inputs is associated with a change in what LTPP experiment a given section is associated with (e.g., as an SPS test section nears the end of its useful life, that section receives an overlay and becomes part of a GPS experiment). When this occurs, a second set of MEPDG traffic inputs is provided for that test section (e.g., at LTPP site 390900, test section 390901 was overlaid with a 1.5-inch AC pavement in 2011 and moved to GPS-6S). That section was then overlaid a second time 1 yr later with an additional 2-inch AC pavement. Test section 390902 was never overlaid, and test section 390903 was overlaid once in 2012 when it was moved to GPS-6S. Thus, these test sections are treated differently in the MEPDG_TRUCK_VOL_PARAMETERS table. Specifically, a single set of MEPDG traffic volume input parameters is present in the MEPDG table and should be applied to the time each of these test sites participated in the SPS experiment. Two additional sets of MEPDG traffic volume input parameters are present for test section 390901. Both are labeled as applying to the GPS-6S experiment, with one set of parameters present for each of the two different overlay events. For test section 390902, only the original set of MEPDG traffic volume input parameters (labeled 390900) is present. Test section 390903 has an additional set of MEPDG traffic volume input parameters. These apply to the time this site spends in the GPS-6S experiment.

A total of 1,376 GPS sections (including those moving from SPS experiments) have traffic inputs in the MEPDG_TRUCK_VOL_PARAMETERS table. As noted in the previous paragraph, if a GPS test section received a treatment significantly changing the structural strength of that pavement, an additional set of traffic inputs are developed for that GPS section.

With all LTPP experiments, some test sections have better, more reliable, data than others. This is particularly true with traffic monitoring data, where State and Provincial agencies collected considerable data at some sites and relatively little data at others. To help users select the best sites for their research and analysis, CPTs contains a code describing the usability or confidence associated with a given set of traffic parameters. One code is present for each set of traffic growth parameters. The code accounts for two basic factors: the amount of quality traffic monitoring data available for calibrating traffic growth equations and the continuity (or lack of continuity) in truck volumes at a site.

More data and more year-to-year continuity in data increases the degree to which the traffic growth equation—the method selected by the MEPDG to input truck volume data—can replicate actual truck volumes traveling over the pavement.

Users should have confidence in the reliability of analyses using forecasts rated "Best" and "Better." "Good" and "Fair" ratings can mean that results need testing for sensitivity to traffic inputs, as the lack of data, or high level of variation observed in truck volumes at a site, means that actual truck volumes experienced by a test pavement may be substantially different from those input into the model.

Truck traffic growth parameters rated "Poor" should only be used with extreme caution.

Truck traffic growth parameters rated "Bad" mean no data are available for a site. For SPS-8 experiments, this may correctly define the level of truck traffic present—no trucks. However, with no data collected, this cannot be confirmed. Users should proceed accordingly.

Axle Loading Distribution Factors for AASHTOWare Pavement ME Design Software Input

At the beginning of this study, 647 LTPP traffic sites (including GPS sections and SPS sites) were identified by the LTPP program as candidates for developing site-specific representative ALDF values. These sites are included in appendix B of this report.

Available WIM data for 647 sites were reviewed to determine if data quality and quantity are sufficient to compute site-specific ALDF values for use as an AASHTOWare Pavement ME Design software input. WIM data availability and reasonableness checks described in chapter 8 were used to evaluate and categorize monthly and annual axle load distributions. The following data quality and usability categories were developed and used to categorize WIM data for each LTPP site:

- Best—WIM data satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 and data reasonableness requirements described in chapter 8 are available for at least one occurrence for each calendar month in a dataset with at least one occurrence for each DOW for each month. These data were used to develop AASHTOWare Pavement ME Design software ALDF with unique values for each calendar month.

- Better—WIM data satisfying the performance requirements of Type I WIM systems for ASTM E1318-09 and data reasonableness requirements described in chapter 8 are available for at least 1 yr, but not all 12 mo have data present in the dataset. These data were used to develop ALDF with the same average annual values repeated for each month in the AASHTOWare Pavement ME Design software ALDF input.

- Good—available WIM data are of unknown quality, but at least 1 yr is available that passed QC checks and data reasonableness checks described in chapter 8. These data were used to develop ALDF representing a typical day of the year. The same representative annual values were repeated for each month in the AASHTOWare Pavement ME Design software ALDF input. Sites in this category required additional manual review and selection of specific years to compute ALDF.

- Fair—available WIM data are of unknown quality but passed QC checks and most data reasonableness checks described in chapter 8. Annual axle load distributions for these sites were manually reviewed and specific years were selected to compute ALDF to minimize the effects of low precision and bias observed in WIM data. Potential WIM data issues were noted for each site to inform users about lower-data quality. These data were used to develop ALDF representing a typical day of the year. The same representative annual values were repeated for each month in the AASHTOWare Pavement ME Design software ALDF input. These lower-quality data may have low to moderate effects on MEPDG analysis results and should be used with caution. Using default values may be an alternative approach for LTPP sites with ALDF based on load distributions labeled as “Fair.”

- Poor, site-specific loading pattern—available WIM data are of unknown quality and did not pass data reasonableness checks described in chapter 8. These data show an identifiable loading pattern for dominant truck classes (typically FHWA Class 9). Loading pattern information can be used to identify alternative LTPP WIM sites with similar loading patterns with better quality WIM data to compute AASHTOWare Pavement ME Design software ALDF or select ALDF default values with similar loading patterns. Default values were assigned for these sites.

- Bad, no site-specific loading pattern—available WIM data are of unknown quality and did not pass data reasonableness checks described in chapter 8. These data do not follow any rational patterns. Sites in this category required assignment of default values using methodology not based on site-specific WIM data. Default values were assigned for these sites.

Out of 647 LTPP traffic sites with WIM data, 460 had data suitable to compute site-specific ALDF inputs. For these sites, ALDF parameters were computed and included in the MEPDG_AXLE_LOAD_DIST_FACTOR table. Another 161 sites had enough WIM data to support developing site-specific loading patterns for dominant heavy truck classes (primarily FHWA Class 9) that can be used to select appropriate default values from the LTPP PLUG or other sources. Another observation showed that only 26 of the 647 LTPP WIM sites identified for this study had useable data regarding a site’s traffic loading patterns. In general, LTPP SPS sites had better quality WIM data compared to GPS sites.

The distribution of LTPP traffic sites by confidence in computed ALDF parameters is presented in table 100.

Table 100. ALDF assessment results.

ALDF Use Category	Number of LTPP WIM Sites
Best	23
Better	36
Good	177
Fair	224
Default value, site-specific loading pattern	161
Default value, no site-specific loading pattern	26

Information in table 100 is based on WIM data assessment for FHWA Class 9 vehicles. Because the number of axle counts observed at each LTPP site varies by vehicle class and axle group, not all vehicle classes and axle groups for a given LTPP site have sufficient data to compute unique monthly or annual ALDF values. If monthly axle counts were below 200 (using all available years of data combined for a given month) for a given site and class–axle combination, available annual values were used to compute ALDF. If the class–axle combination for a given site did not have axle count data to compute ALDF (i.e., vehicle class and/or axle group were not present in the ALDF computation dataset), the ALDF factor was reported as "0."

For LTPP sites without necessary data to compute site-specific ALDF, default values were assigned using LTPP PLUG default NALS axle load and additional defaults described in the forthcoming *Predicting Truck and Axle Load Patterns*.(22) ALDF values based on default NALS were developed outside of this study. As a result, all LTPP sites should have ALDF values available in the MEPDG_AXLE_LOAD_DIST_FACTOR table.

Axles Per Truck Parameters for AASHTOWare Pavement ME Design Software Input

APT parameters were computed for 791 LTPP traffic sites with axle count data reported in the VEHICLE_CLASS_AVG_AX_ANL table. LTPP traffic sites with site-specific APT inputs are ready for use in AASHTOWare Pavement ME Design software. The parameters are stored in the MEPDG_AXLE_PER_TRUCK table. Sites without axle count data were assigned APT default values from LTPP PLUG in the MEPDG_AXLE_PER_TRUCK table. The default APT assignment was performed outside of this study. As a result, all LTPP sites should have APT values available in the MEPDG_AXLE_PER_TRUCK table.

Traffic Trend Parameters for LTPP Analyses

The TRF_TREND table is the primary CPT for truck volume and traffic loading summary parameters (e.g., AADTT, ESAL, GESAL, total GVW). There are 2,743 unique STATE_CODE and SHRP_ID combinations in the TRF_TREND table. These identifiers are used to characterize 1,353 GPS sites and 1,955 SPS sections. The same pavement section may participate in multiple GPS and SPS experiments during its service life, so the number of GPS sites and SPS sections is greater than the number of unique STATE_CODE and SHRP_ID combinations. Records of truck volume and summary loading statistics are present for each GPS and SPS section with traffic data reported in SDR 30. Because a variety of construction activities occur and may be of interest to researchers, records are present for each test site for every year to identify every construction event in the CONSTRUCTION_NO field in the TRF_TREND table. This allows users to directly select annual traffic conditions applying to specific test sections and events of interest to them. Note that no annual ESAL value is provided for virtual SPS WIM sites (i.e., sites with SHRP_ID ending in “00”) because no actual pavement structure is associated with these virtual sites.

Cumulative total truck volumes are also provided in the TRF_TREND table. Because the cumulative total is a function of when the roadway section opened to traffic, this value changes from year to year depending on the life of that specific pavement section (i.e., when a pavement is overlaid, the life of that pavement is reset to zero, and the accumulation of truck traffic starts over).

Note that some records in the TRF_TREND table report zero traffic. These are records for either SPS-8 sites with no truck traffic (some SPS-8 sites were specifically constructed to experience no truck traffic) or for years at an LTPP site that entered the LTPP experiment prior to opening to traffic. In these cases, a record is present for each year or partial year the site was part of the LTPP experiment, even if those years were prior to opening to traffic. For example, a site was assigned to the LTPP experiment in 1995 while still under construction. It did not open to traffic until spring 1997. The records for that site for 1995 and 1996 have no volumes in all 10 truck classes.

Although no specific statistical accuracy is assigned to the truck volume statistics presented in the TRF_TREND table, some test sections have better, more reliable data than others. To help users select the best possible sites for their research and analysis, the TRF_TREND table contains several codes (e.g., AADTT_SOURCE, VEH_CLASS_SOURCE, ESAL_SOURCE, GESAL_SOURCE, and GVW_SOURCE) describing the basis for annual truck volume and traffic loading estimates recorded.

In general, annual statistics based on traffic monitoring data (i.e., data collected specifically at a test site in response to the LTPP program) are considered the most reliable sources of truck volume. Estimates from State/Provincial highway agencies are based on short-duration counts made prior to the start of the LTPP program. State/Provincial highway agencies also provide historical estimates, but they are typically based on counts taken some distance from a test site and are often factored for growth. They are far less reliable than traffic monitoring counts but are often the only estimates of traffic loads prior to the start of the LTPP program. At some test sites, historical estimates can be substantially different from volumes observed in the traffic monitoring program. This can be a sign of inaccurate historical estimates; it can also be caused by changing economic conditions or changes in the local roadway network resulting in shifting truck travel patterns.

The TRF_TREND table is the best available estimate of annual truck traffic at LTPP test sites. Where historical and monitored traffic data show different truck volume patterns, users should take additional steps to test the sensitivity of their results to variations in truck traffic volumes because some of these estimates have limited reliability.

Representative Traffic Parameters for High-Level Pavement Performance Analyses

The TRF_REP table is a CPT allowing LTPP data users to quickly categorize LTPP test sections by the type of truck traffic passing over that pavement (i.e., categorize a section as experiencing high, moderate, or low truck volumes). Because AADTT is present, a user can select their own definition of how many trucks are needed for a pavement to experience heavy truck traffic. In addition to providing a single representative AADTT value, the TRF_REP table records the nature of trucks passing over a test pavement, which allows a user to select pavements not only with high truck volumes but where those high volumes are specifically found within heavy, single-unit truck classes (e.g., FHWA Classes 6 or 7) or any other type of truck.

There are 2,743 unique STATE_CODE and SHRP_ID combinations in the TRF_REP table. These identifiers are used to characterize 1,353 GPS sites and 1,955 SPS sections. The same pavement section may participate in multiple GPS and SPS experiments during its service life, so the number of GPS sites and SPS sections is greater than the number of unique STATE_CODE and SHRP_ID combinations. One record is present for each experiment and test site combination (i.e., if a test site was only part of one LTPP experiment, only one record is present for that site). However, if a test section was part of three different experiments, three different records are present for that site, one for each experiment. For SPS test sites where more than one test section is present (e.g., SPS test site 010100, which has attached sections 010101–010163) at least one record is present for each test section.

Separate records are present to help account for changes in truck traffic over time. The nature of truck traffic occurring at a site during the first experiment may differ from truck traffic occurring during the last experiment.

Using only one statistic to represent a distribution of traffic conditions at each test section over the course of each experiment does not account for truck traffic changes over time. Where there is little variation in truck traffic patterns, representative values are good descriptors of truck travel patterns. Where traffic patterns vary heavily during the course of a pavement section’s participation in a given experiment, a single representative value is a less reliable descriptor of truck traffic for that pavement.

To help users quickly understand the level of confidence they should have in these best available representative values, two metadata codes, REP_VEH_CLASS_USE_RATING and REP_AADTT_USE_RATING, are included in each data record. Each code accounts for two basic factors: the amount of quality traffic monitoring data available to compute representative values and the continuity (or lack of continuity) in truck volumes at a site during a specific experiment.

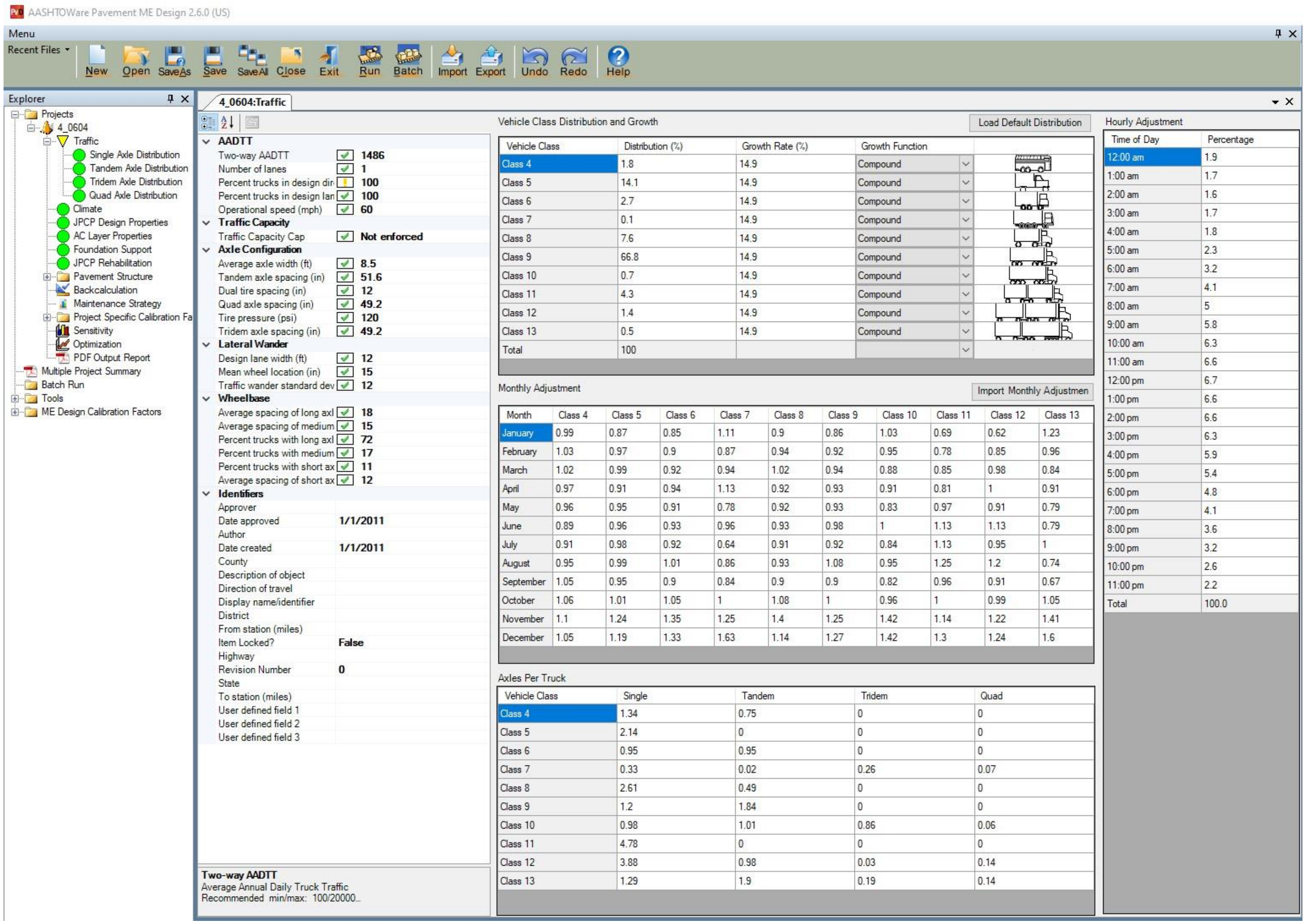
The more LTPP-specific traffic monitoring data available to compute reported statistics and the more year-to-year continuity in those data, the more confidence a user should have in a statistic’s accuracy to describe traffic throughout the life of a pavement in an experiment.

Users should have higher confidence in the analyses outcomes using statistics rated as “Best” and “Better.” “Good” and “Fair” ratings can mean that results need testing for sensitivity to traffic inputs, as the lack of data, or high level of variation observed in truck volumes at a site, means that actual truck volumes experienced by a test pavement may be substantially different from representative values reported.

Data rated “Poor” or “Bad” should only be used with extreme caution.

APPENDIX A. SCREENSHOTS OF AASHTOWARE PAVEMENT ME DESIGN SOFTWARE GUIs FOR TRAFFIC INPUTS

Figure 16 through figure 22 are screenshots of AASHTOWare Pavement ME Design software GUIs for different traffic input tables.



Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software. Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Figure 16. Screenshot. Traffic inputs main screen.

Vehicle Class Distribution and Growth

Load Default Distribution

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	0.9	3.5	Compound
Class 5	9.64	3.5	Compound
Class 6	3.53	3.5	Compound
Class 7	1.59	3.5	Compound
Class 8	3.63	3.5	Compound
Class 9	74.42	3.5	Compound
Class 10	0.58	3.5	Compound
Class 11	4.25	3.5	Compound
Class 12	1.31	3.5	Compound
Class 13	0.15	3.5	Compound
Total	100		

Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software. Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Figure 17. Screenshot. Vehicle class distribution and growth inputs.

Monthly Adjustment

Import Monthly Adjustmen

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
February	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
March	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
April	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
May	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
June	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
July	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
August	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
September	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
October	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
November	1	1	1	1	1	1	1	1	1	1
December	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software. Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

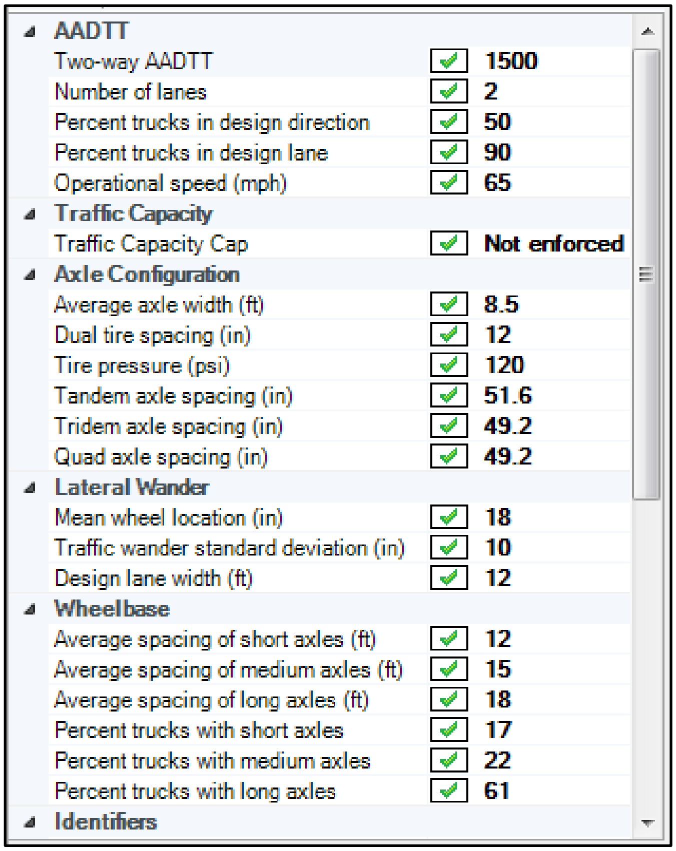
Figure 18. Screenshot. Monthly adjustments inputs.

Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.61	0.39	0	0
Class 5	2.03	0.06	0	0
Class 6	1.03	0.98	0	0
Class 7	1.05	0.02	0.97	0
Class 8	2.24	0.79	0	0
Class 9	1.28	1.84	0	0
Class 10	1.13	1.02	0.92	0
Class 11	4.94	0	0	0
Class 12	3.37	1.28	0	0
Class 13	1.39	0.77	0.81	0.27

Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software. Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Figure 19. Screenshot. APT inputs.



AADTT		
Two-way AADTT	✓	1500
Number of lanes	✓	2
Percent trucks in design direction	✓	50
Percent trucks in design lane	✓	90
Operational speed (mph)	✓	65
Traffic Capacity		
Traffic Capacity Cap	✓	Not enforced
Axle Configuration		
Average axle width (ft)	✓	8.5
Dual tire spacing (in)	✓	12
Tire pressure (psi)	✓	120
Tandem axle spacing (in)	✓	51.6
Tridem axle spacing (in)	✓	49.2
Quad axle spacing (in)	✓	49.2
Lateral Wander		
Mean wheel location (in)	✓	18
Traffic wander standard deviation (in)	✓	10
Design lane width (ft)	✓	12
Wheelbase		
Average spacing of short axles (ft)	✓	12
Average spacing of medium axles (ft)	✓	15
Average spacing of long axles (ft)	✓	18
Percent trucks with short axles	✓	17
Percent trucks with medium axles	✓	22
Percent trucks with long axles	✓	61
Identifiers		

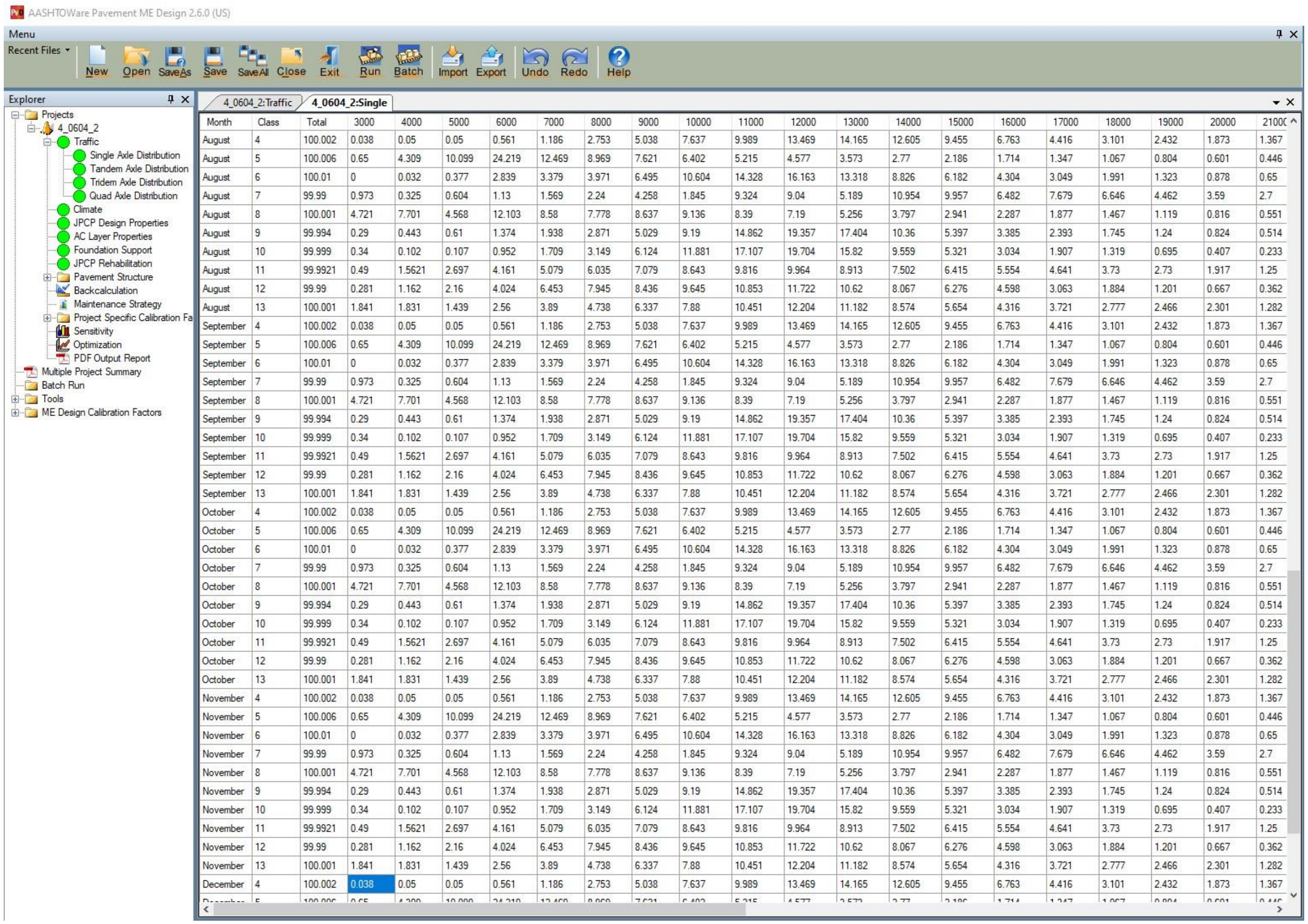
Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software. Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Figure 20. Screenshot. AADTT, traffic capacity, axle configuration, lateral wander, and wheelbase inputs.

Note 1: Average axle width, mean wheel location, design lane width, and all wheelbase inputs shown in Figure 20 are only used for rigid pavement analyses.

Note 2: For analyses of LTPP sites, the AADTT values represents all trucks within the LTPP lane only. Therefore, the values entered in the AASHTOWare Pavement ME Design software for number of lanes, percent trucks in design direction, and percent trucks in design lane are 1, 100, and 100, respectively. Using these values ensures that the LTPP truck volume data are represented accurately.

Note 3: The green checkmarks shown in Figure 20 mean that the values entered are within the minimum and maximum input values for which the software was designed.



Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software. Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Figure 21. Screenshot. ALDF inputs.

Note 1: To access ALDF inputs for different axle groups, click on the green circles in the top left corner, identified by the red rectangle on the screenshot.

Hourly Adjustment

Time of Day	Percentage
12:00 am	2.5
1:00 am	2.28
2:00 am	2.26
3:00 am	2.44
4:00 am	2.77
5:00 am	3.37
6:00 am	4.2
7:00 am	4.66
8:00 am	4.9
9:00 am	5.14
10:00 am	5.31
11:00 am	5.39
12:00 pm	5.37
1:00 pm	5.43
2:00 pm	5.56
3:00 pm	5.58
4:00 pm	5.38
5:00 pm	5.05
6:00 pm	4.63
7:00 pm	4.2
8:00 pm	3.84
9:00 pm	3.59
10:00 pm	3.28
11:00 pm	2.87
Total	100.0

Source: Screen capture performed by Applied Research Associates, Inc. from the AASHTOWare Pavement ME Design Software.
Reference: AASHTOWare Pavement ME Design Software, Version 2.6.0, June 2020, American Association of State Highway and Transportation Officials 555 12th Street NW, Suite 1000, Washington, DC, 20004.

Figure 22. Screenshot. Hourly adjustment inputs.

Note 1: Hourly adjustments are only used in rigid pavement analyses.

APPENDIX B. LTPP WIM SITES CONSIDERED FOR ALDF COMPUTATION

Table 101 provides a list of LTPP WIM sites with axle loading data evaluated in this study.

Table 101. LTPP WIM sites considered for ALDF computation.

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
1	1001	Pattern L2
1	1019	Pattern H1
1	4073	Good, small sample
1	4129	Fair, small sample
1	6012	Pattern VH
2	1001	Pattern L1
2	1002	Pattern VL
2	1004	Pattern VH
2	1008	Pattern VL
2	6010	Pattern LE
2	9035	Pattern E
4	0100	Best
4	0200	Best
4	0500	Fair
4	0600	No pattern
4	0900	Good
4	1001	Good, small sample
4	1002	Pattern H2
4	1006	Good, small sample
4	1007	Fair
4	1016	Pattern E
4	1017	Good, small sample
4	1024	No pattern
4	1025	Pattern H2
4	1034	Fair, small sample
4	1036	Good
4	1062	Pattern H2
4	6053	Pattern VH
4	6055	Fair
4	6060	Good
4	7079	Fair
4	7613	Good
4	7614	Fair, small sample
4	A900	Good
4	B900	Fair
5	0100	Good
5	0200	Best

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
5	0800	Pattern L1
5	2042	Good, small sample
5	3011	Fair
5	3048	Fair
5	3058	Good
5	3059	Good
5	3074	Fair
5	4019	Pattern L2
5	4021	Good, small sample
5	4023	Fair
5	4046	Fair
5	5803	Good, small sample
5	5805	Fair, small sample
5	A600	Good
6	0200	Best
6	0500	Good
6	0600	Good
6	1253	Pattern L2
6	2002	Good
6	2040	Better
6	2051	Pattern L2
6	2053	Fair
6	2647	Good
6	3005	Good
6	3021	Good
6	3024	Good
6	3030	Better
6	3042	Good
6	6044	Good
6	7452	Good
6	7454	Pattern E
6	7455	Good
6	7493	Good
6	8149	Good
6	8150	Good
6	8151	Good
6	8153	Pattern L2
6	8156	Fair, small sample
6	8201	Fair, small sample
6	8202	Fair
6	8534	Good
6	8535	Good
6	9049	Good

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
6	9107	Good
8	0200	Better
8	0500	Fair
8	1029	Pattern L1
8	1047	Pattern L2
8	1053	Pattern LE
8	3032	Pattern H1
8	6002	Fair
8	7035	No pattern
8	7776	Fair
8	7780	No pattern
8	7783	Pattern E
8	9019	Fair
8	9020	Fair
9	0900	Better
9	0960	Better
9	1803	Fair
9	4008	Fair
9	4020	Pattern L1
9	5001	Better
10	0100	Better
10	1201	Pattern L2
10	1450	Fair
10	4002	Good, small sample
10	5004	Good, small sample
10	5005	Fair
12	0100	Best
12	0500	Better
12	1030	Pattern L2
12	1060	No pattern
12	1370	Good
12	3804	No pattern
12	3811	Good, small sample
12	3996	No pattern
12	3997	Pattern E
12	4000	Good
12	4057	Good
12	4059	Pattern L1
12	4096	No pattern
12	4097	No pattern
12	4099	Pattern H2
12	4100	Good
12	4103	Pattern H2

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
12	4105	Pattern L1
12	4106	Good
12	4107	Pattern L2
12	4108	No pattern
12	4109	Good
12	4135	No pattern
12	4136	No pattern
12	4137	Pattern E
12	4138	Fair
12	4154	Fair, small sample
12	9054	No pattern
13	3017	No pattern
13	3020	No pattern
13	4118	Pattern LE
15	1003	Pattern VL
15	1006	Pattern E
15	1008	Pattern L1
15	7080	No pattern
16	1001	Fair
16	1005	Fair
16	1007	Pattern H1
16	1009	Good
16	1010	Pattern H1
16	1020	Fair
16	1021	Good
16	3017	Good
16	3023	Good
16	5025	Fair
16	6027	No pattern
16	9032	Good
16	9034	Fair
17	0600	Best
17	1002	Good
17	1003	Fair
17	4074	Pattern LE
17	4082	Fair, small sample
17	5151	Good
17	5217	Pattern H1
17	5423	Fair, small sample
17	5453	Fair, small sample
17	5843	Fair
17	5849	Fair
17	5854	Fair

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
17	5869	Fair, small sample
17	5908	Good
17	7937	Fair
17	9327	Pattern H1
18	0600	Best
18	0900	Fair
18	1028	Good
18	1037	Good
18	2008	Good
18	2009	Good
18	3002	Good
18	3030	Good
18	3031	Good
18	4021	Better
18	5022	Fair
18	5043	Fair
18	5518	Good
18	5528	Good
18	6012	Fair
18	9020	Pattern E
18	A900	Fair
19	0100	Good
19	0200	Good
19	0600	Fair
19	0700	Fair
19	1044	Fair
19	3006	Fair
19	3009	Good
19	3028	Good
19	3033	Good, small sample
19	3055	Good
19	5042	Fair
19	6049	Fair
19	6150	Fair
19	9116	Fair
19	9126	Fair
20	0100	Good
20	0200	Best
20	1005	Pattern L1
20	1006	Fair, small sample
20	1009	Fair
20	3015	Fair
20	4016	Fair, small sample

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
20	4052	Pattern LE
20	4053	Pattern L2
20	4063	Fair
20	4067	Fair
20	6026	Fair, small sample
20	7085	Pattern E
21	1010	Pattern L1
21	1014	Pattern VL
21	1034	Fair
21	3016	Fair
21	4025	Fair
21	6040	Pattern L2
21	6043	Pattern L1
22	0100	Better
22	3056	Fair, small sample
23	0500	Better
23	1009	Good, small sample
23	1028	Good
24	0500	Better
24	0900	Pattern L2
24	0960	Pattern L2
24	1632	Pattern L1
24	2401	Fair
24	5807	Fair
25	1002	Fair, small sample
25	1004	Pattern L1
26	0100	Better
26	0200	Best
26	0600	Fair
26	0900	Best
26	1001	Fair
26	1004	Pattern L1
26	1010	Pattern L1
26	1012	Good
26	1013	Fair, small sample
26	3068	Fair
26	4015	Best
26	5363	Fair
26	6016	Pattern E
26	7072	Pattern VL
26	9029	Better
26	9030	Good
27	0500	Better

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
27	0700	Pattern VH
27	1003	Good
27	1016	Good
27	1018	Pattern VH
27	1019	Good
27	1023	Fair
27	1028	Fair
27	1029	Pattern L1
27	1085	Fair
27	1087	Fair
27	3003	Pattern E
27	3013	Good
27	4033	Good
27	4037	Good
27	4040	Fair
27	4054	Good, small sample
27	4055	Good, small sample
27	5076	Fair
27	6251	Fair, small sample
27	6300	Pattern H2
27	7090	Fair
27	9075	Fair
28	0500	Pattern H2
28	0900	Good
28	1001	Fair
28	1016	Pattern L1
28	1802	Fair
28	2807	Fair
28	3018	Good
28	3019	Good
28	3081	Good
28	3082	Fair
28	3087	Pattern L2
28	3089	Fair
28	3091	Fair
28	3093	Good
28	3094	Good
28	3099	Fair
28	4024	Fair
28	5006	Fair
28	5025	Pattern L2
28	5803	Fair
28	7012	Pattern H1

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
28	9030	Good
29	0600	Fair
29	0700	Good
29	0900	Good
29	1002	Good, small sample
29	1005	Fair
29	1008	Fair, small sample
29	1010	Fair
29	4036	Good
29	4069	Good, small sample
29	5000	Good, small sample
29	5047	Pattern E
29	5393	Good
29	5413	Fair, small sample
29	5473	Good
29	5483	Fair, small sample
29	5503	Good
29	6067	Fair
29	7054	Fair
29	7073	Pattern H1
30	0100	Fair
30	0500	Good
30	0800	Good, small sample
30	1001	Good
30	6004	Good
30	7066	Good
30	7075	Good
30	7088	Good
30	8129	Good
31	0100	Good
31	1030	Pattern L2
31	3018	Fair
31	3023	Pattern H2
31	3024	Pattern H2
31	3028	Pattern L2 SHIFT S
31	3033	Fair
31	4019	Fair
31	5052	Pattern H1
31	6700	Pattern L1
31	6701	Pattern L2
31	6702	Fair
31	7005	Fair
31	7017	Pattern L2

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
31	7040	Pattern H2
31	7050	Pattern H1
32	0100	Good
32	0200	Good
32	1020	Pattern E
32	1030	Pattern L2
32	3010	Pattern VH
32	3013	Good
32	7000	Good
32	7084	Fair, small sample
33	1001	Pattern L1
34	0500	Better
34	1003	Better
34	1011	Best
34	1030	Good, small sample
34	1031	Better
34	1033	Better
34	1034	Better
34	1638	Better
34	4042	Good
34	6057	Fair
35	0100	Better
35	0500	Best
35	0900	Pattern VH
35	1022	Good
35	1112	Pattern L2
35	2006	Good
35	2007	Good
35	2118	No pattern
35	3010	Pattern L1
35	6033	Pattern H2
35	6401	No pattern
36	1008	Pattern L1
36	1011	Pattern E
36	1643	Pattern H1
36	1644	Pattern L1
36	4018	Good, small sample
37	0200	Good
37	0900	Pattern L1
37	1006	Fair
37	1024	Fair
37	1028	Pattern L1
37	1030	Pattern L1

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
37	1040	Fair, small sample
37	1352	Fair, small sample
37	1645	Better
37	1801	Fair, small sample
37	1803	Good, small sample
37	1814	Fair
37	1817	Fair
37	1992	Fair
37	2819	Better
37	2824	Better, small sample
37	2825	Fair
37	3008	Fair, small sample
37	3011	Good, small sample
37	3044	Pattern E
37	3807	Good
37	3816	Fair
37	5037	Fair, small sample
37	5826	Fair, small sample
37	5827	Good, small sample
37	A900	Good
38	2001	Pattern H1
38	3005	Fair, small sample
38	3006	Good
38	5002	Fair
39	0100	Best
39	0200	Better
39	3013	Good
39	3801	Good
39	4018	Good
39	4031	Good
39	5003	Good
39	5010	Good
39	5569	Good
39	7021	Good
39	9006	Better
39	9022	Fair
40	0100	Better
40	0500	Good
40	0600	Good
40	1015	Pattern L2
40	3018	Fair, small sample
40	4154	Fair
40	4155	Fair

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
40	4157	Fair
40	4158	Good
40	4160	Fair
40	4161	Fair
40	4162	Pattern L1
40	4163	Pattern L2
40	4165	Good
40	4166	Good, small sample
40	5021	Fair
40	6010	Pattern L2
40	7024	Fair, small sample
41	2002	Pattern E
41	5005	Pattern H1
41	5006	Fair
41	5008	Fair, small sample
41	5021	Good
41	5022	Good
41	6011	Fair, small sample
41	7018	Good
41	7019	Pattern L2 SHIFT S
41	7025	Good, small sample
41	7081	Good, small sample
42	0600	Best
42	1597	Pattern L2
42	1598	Fair
42	1599	Better
42	1605	Good
42	1606	Better
42	1608	Pattern L1
42	1610	Fair
42	1613	Fair, small sample
42	1614	Fair
42	1618	Pattern E
42	1623	Pattern L2
42	1627	Good
42	1690	Fair, small sample
42	1691	Fair
42	3044	Best
42	5020	Fair
42	7025	Fair
42	7037	Pattern E
42	9027	Best
44	7401	Pattern VL

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
45	1008	Fair
45	1011	Fair
45	1025	Pattern H2
45	5035	Fair
45	7019	Good
46	0600	Good
46	0800	Fair, small sample
46	3010	Good
46	3012	Good
46	3052	Good
47	0600	Best
47	1028	Pattern L2
47	2001	Pattern E
47	2008	Good, small sample
47	3075	No pattern
47	3104	No pattern
47	3108	Pattern H1
47	3110	Fair, small sample
47	6015	Pattern E
47	6022	Pattern L1
47	9025	Fair, small sample
48	0001	Fair, small sample
48	0100	Best
48	0800	Fair, small sample
48	0900	Fair
48	1039	Fair, small sample
48	1047	Pattern H2
48	1060	Fair
48	1068	Fair, small sample
48	1069	Good
48	1076	Pattern L1 TX
48	1087	Pattern E TX
48	1092	Good, small sample
48	1093	Fair, small sample
48	1094	Fair, small sample
48	1096	Fair, small sample
48	1119	Pattern L2 TX
48	1122	Fair, small sample
48	1123	Good
48	1130	Pattern L1 TX
48	1169	Pattern L2 TX
48	1174	Pattern VL TX
48	1181	Fair, small sample

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
48	2108	Fair, small sample
48	2133	Pattern E TX
48	2172	Pattern H2 TX
48	2176	Fair, small sample
48	3003	Pattern L1
48	3569	Pattern H1 TX
48	3589	Fair, small sample
48	3835	Fair, small sample
48	3845	Good, small sample
48	3855	Fair, small sample
48	3865	Fair, small sample
48	4142	Pattern L2 TX
48	4146	Pattern L2 TX
48	4152	Pattern L2 TX
48	5024	Pattern L2 TX
48	5035	Pattern L1 TX
48	5154	Fair
48	5274	Fair, small sample
48	5278	Fair, small sample
48	5283	Fair, small sample
48	5284	Fair, small sample
48	5287	Fair
48	5301	Pattern L2 TX
48	5310	Fair, small sample
48	5317	Pattern L1 TX
48	5323	Fair, small sample
48	5328	Good, small sample
48	5334	Fair
48	5335	Fair
48	5336	Good
48	6079	Fair, small sample
48	6086	Fair, small sample
48	6179	Pattern H2 TX
48	7165	Fair
48	9005	Pattern L1 TX
48	9167	Fair, small sample
48	9355	Fair, small sample
48	A500	Good
48	A800	No pattern
49	1006	No pattern
49	3011	No pattern
50	1002	Fair
50	1004	Fair

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
50	1681	Fair
50	1682	Fair
51	0100	Best
51	1002	Pattern VL
51	1023	Better
51	1417	Pattern E
51	1419	Fair
51	1423	Pattern L1
51	1464	Fair, small sample
51	2004	Fair, small sample
51	2021	Fair
51	2564	Fair
51	5008	Fair
51	5009	Pattern L1
51	5010	Fair
53	0200	Best
53	0800	No pattern
53	1002	Good
53	1005	Better
53	1006	Fair
53	1007	Best
53	1008	Good
53	1501	Fair
53	1801	Good
53	3011	Good
53	3013	Good
53	3014	Better
53	3019	Good
53	3812	Fair
53	3813	Better
53	6020	Fair
53	6048	Fair
53	6049	Fair
53	6056	Good
53	7322	Better
53	7409	Good
53	A800	Fair
54	1640	Pattern L2
54	4004	Pattern H1
54	5007	Good
54	7008	Fair
55	0100	Best
55	3009	Fair, small sample

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
55	3010	Good, small sample
55	3015	Good, small sample
55	3019	Pattern L2
55	6351	Good
55	A900	Good, small sample
55	B900	Good, small sample
56	1007	Fair, low count
56	2015	Fair
56	2017	Good
56	2019	Good
56	2020	Fair
56	2037	Fair
56	3027	Good
56	6029	Better, low count
56	6031	Fair, low count
56	6032	Pattern L1
56	7772	Good
56	7773	Fair
56	7775	Good
81	0500	Fair
81	A900	Fair
83	1801	No pattern
83	3802	Pattern L2
83	6450	Pattern H1
83	6452	Pattern H1
83	6454	Pattern E
84	1684	Pattern L1
84	1802	Pattern L1
84	6804	Fair, small sample
86	6802	Pattern VL
87	1620	Pattern L1
87	1622	Pattern E
87	2811	Fair
87	2812	Fair
88	1645	Fair
88	1646	Fair
88	1647	Good
89	1021	Fair
89	1125	Fair
89	1127	Good
89	2011	Pattern E
89	3001	Fair
89	3002	Fair, small sample

STATE_CODE	SHRP_ID	Data Availability Assessment for ALDF
89	3015	Better
89	3016	Pattern L1
89	9018	Fair, small sample
90	0900	Pattern E
90	6400	Pattern E
90	6405	Pattern L2
90	6410	Fair, small sample
90	6420	Fair, small sample

L = light; VL = very light; H = heavy; VH = very heavy; E = equal; TX = specific to Texas.

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