TRANSPORTATION RESEARCH COMMITTEE

TRC0402

Projected Traffic Loading for Mechanistic-Empirical Pavement Design Guide

Nam H. Tran, Kevin D. Hall

Final Report

2006

RESEARCH

Projected Traffic Loading for Mechanistic-Empirical Pavement Design Guide

PROJECT OBJECTIVES

The global objective for this research is to provide Arkansas design professionals guidance in selecting realistic traffic inputs for use in MEPDG. This guidance includes information relating to the sensitivity of the design analysis to variations of input values. The secondary global objective involves the development of a program or plan to continuously measure and update the sensitive traffic inputs. A number of specific objectives met in the study included: *documenting MEPDG traffic inputs; documenting / characterizing current AHTD traffic measurement capabilities; identifying useful AHTD traffic data and areas of data insufficiency; developing traffic input values specifically for Arkansas; developing recommendations regarding traffic input sensitivity.*

SCOPE

AHTD manages a continuous traffic count program featuring 79 automated traffic data collection sites, including 55 sites with weigh-in-motion (WIM) technology. Traffic data from the 55 WIM sites collected from 2003 through 2005 were provided for this study. After data quality checks were completed, only 25 sites provided sufficient data for the study, including 18 sites in rural areas and 7 sites urban areas. However, among the 25 WIM sites selected only 10 provided weight data suitable for the development of axle load spectra and 23 provided classification data suitable for the development of truck traffic volume adjustment factors.

FINDINGS

Major findings of the study included:

- Traffic data quality control checks – particularly for weight data – are critical; mis-estimating weight data by 4000 and 8000 lb could result in a difference in pavement service life of 9 to 25 percent respectively.
- In this study the FHWA *Trafload* program would not read, process, and prepare MEPDG traffic input files when using properly-formatted field data. It is unclear whether *Trafload* may be used to generate the traffic inputs for the MEPDG in Arkansas in the future. Two computer programs, named "CLASS.xls" and "WEIGHT.xls", were developed to perform quality control checks for the classification and weight data, and develop Level 1 traffic inputs for MEPDG. In order to use the programs, users are required to know the FHWA and LTPP quality control procedure and the procedure for developing traffic inputs in MEPDG.
- Statewide volume adjustment factors were developed based on the truck traffic classification (TTC) system. Three statewide volume adjustment factors, including monthly distribution factors, hourly distribution factors, and vehicle class distribution factors, were developed for seven TTC groups (3, 6, 7, 9, 10, 12, 13).
- One set of statewide axle load spectra was developed based on the weight data, due to the small size (10 WIM stations) of the 'suitable' data set.
- It is more difficult to group tandem axle load spectra into clusters that have similar load distribution characteristics. The TTC system cannot be used to groups tandem axle load spectra. One method used to group tandem axle load spectra in this study is based on the loading condition of the truck: fully loaded, partially loaded, and unloaded. This method should be used to group tandem axle load spectra when more WIM stations are available in the future.
- The statewide tridem axle load spectra are developed in the same manner as for the statewide tandem axle load spectra. Since very few quad axles are observed in the WIM data, the statewide quad axle load spectra are not developed in this study.
- Differences in predicted pavement distress based on the statewide (specific) and default monthly and hourly distribution factors are not significant. However, the differences in predicted distress using the statewide and default vehicle class distribution factors are significant.
- The differences in the predicted distresses based on the statewide and default axle load spectra are significant.

Recommendations from the study included:

- Calibration of WIM scales should be carefully monitored.
- Traffic data should be evaluated before they are used for design purposes, especially weight data. The process can be performed based on the evaluation procedure recommended by FHWA and LTPP.
- Two programs developed in this project can be used to facilitate the evaluation process, and users are required to know the evaluation process before using the programs. It is emphasized that the two programs are developed for analyses in this study and should not be considered as a product of this project.
- Annual average daily truck traffic (AADTT) should be site specific or Level 1. The information can be provided by the Technical Services of AHTD.
- The statewide vehicle class distribution factors for TTC groups 3, 6, 7, 9, 10, 12, and 13 should be used for pavement design with the MEPDG.
- Statewide axle load spectra should be used instead of the default axle load spectra.
- Default or user-defined values can be used for other inputs, such as monthly distribution factors, hourly distribution factors, and general traffic inputs unless specific information is obtained.
- Statewide vehicle class distribution factors and axle load spectra should be updated every three years unless no significant changes in these inputs are observed in the future.

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16. Abstract

A new Mechanistic-Empirical Pavement Design Guide (MEPDG) has been developed under National Cooperative Highway Research Program (NCHRP) Project 1-37A. Pavement design procedures recommended for use in MEPDG represent a total departure from those procedures currently used. Among significant improvements, MEPDG requires new traffic inputs for estimating the magnitude, configuration and frequency of the loads that are applied throughout the pavement design life. The primary objectives of this study are to develop traffic inputs for initial implementation of MEPDG and a procedure for updating these inputs in the future. Classification and weight data collected at 55 WIM stations in Arkansas were used in this study. Quality control checks were performed to ensure accurate interpretation of the data. Several stations had substantial missing data. For some stations, unexpected changes in vehicle class distribution were found, or the WIM scales were not working properly. A sensitivity analysis performed in this study showed that the effects of "bad" data on the pavement design were significant. Thus, only "good" traffic data were used to develop statewide traffic inputs for MEPDG. Based on another sensitivity analysis performed in this study, statewide vehicle class distribution factors and axle load spectra should be used instead of default values in the MEPDG software. Default or user-defined values for other traffic inputs, except for annual average daily truck traffic, should be used unless specific information is obtained. It is also recommended that the statewide traffic inputs be updated every three years unless no significant changes are observed in the future.

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FINAL REPORT

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EXECUTIVE SUMMARY

A new Mechanistic-Empirical Pavement Design Guide (MEPDG) has been developed under National Cooperative Highway Research Program (NCHRP) Project 1-37A. Pavement design procedures recommended for use in MEPDG represent a total departure from those procedures currently used. Among significant improvements, MEPDG requires new traffic inputs for estimating the magnitude, configuration and frequency of the loads that are applied throughout the pavement design life. The primary objectives of this study are to develop traffic inputs for initial implementation of MEPDG and a procedure for updating these inputs in the future. Classification and weight data collected at 55 WIM stations in Arkansas were used in this study. Quality control checks were performed to ensure accurate interpretation of the data. Several stations had substantial missing data. For some stations, unexpected changes in vehicle class distribution were found, or the WIM scales were not working properly. A sensitivity analysis performed in this study showed that the effects of "bad" data on the pavement design were significant. Thus, only "good" traffic data were used to develop statewide traffic inputs for MEPDG. Based on another sensitivity analysis performed in this study, statewide vehicle class distribution factors and axle load spectra should be used instead of default values in the MEPDG software. Default or user-defined values for other traffic inputs, except for annual average daily truck traffic, should be used unless specific information is obtained. It is also recommended that the statewide traffic inputs be updated every three years unless no significant changes are observed in the future.

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CHAPTER 1 INTRODUCTION

1. PROBLEM STATEMENT

Arkansas currently designs pavements using the 1993 Edition of the *AASHTO Guide for the Design of Pavement Structures* (hereinafter referred to as the *1993 Guide*) (*1*). Procedures for designing a new pavement contained in the *1993 Guide* have remained essentially unchanged since at least 1986. The *1993 Guide* has been considered outdated because of significant changes in traffic, materials, construction practices, and other parameters that affect pavement performance. Therefore, a new Mechanistic-Empirical Pavement Design Guide (MEPDG) has been developed under National Cooperative Highway Research Program (NCHRP) Project 1-37A. Pavement design procedures recommended for use in MEPDG represent a total departure from those procedures currently used. MEPDG features mechanistic pavement design principles and procedures – a radically different approach than the empirical approach used in the current *1993 Guide*. Among significant improvements, the mechanistic-empirical pavement design procedures require new traffic inputs for estimating the magnitude, configuration and frequency of the loads that are applied throughout the pavement design life.

State agencies typically collect several types of traffic data using different traffic data collection devices, such as static weight stations, automatic traffic recorders (ATR), automatic vehicle classifiers (AVC), and weigh-in-motion (WIM) scales. Currently, state agencies convert the collected traffic data into equivalent single axle loads (ESALs) that are required by the *1993 Guide*. In the *1993 Guide*, ESAL is a function of equivalent axle load factors (EALFs) that are affected by pavement type, drainage condition, and pavement failure condition.

MEPDG is different from the *1993 Guide*. It requires the same traffic data for the pavement type (flexible or rigid) and design type (new or rehabilitated). The typical traffic data required for MEPDG are as follows (*2*):

- Annual truck traffic volume
- Vehicle (truck) operation speed
- Truck traffic direction and lane distribution factors
- Vehicle (truck) class distribution
- Axle load distribution factors
- Axle and wheel base configurations
- Tire characteristics and inflation pressure
- Truck lateral distribution factor
- Truck traffic growth factors

For implementation of MEPDG in Arkansas, this research is to document the required traffic inputs for MEPDG, investigate the availability and quality of data relating to those inputs, develop a procedure for initially obtaining those inputs, create a program that allows for the continuous (or periodic) update of typical input values, and give a designer guidance for using/specifying those inputs. This research effort links closely with current traffic measurement efforts in the Arkansas State Highway and Transportation Department (AHTD).

2. RESEARCH OBJECTIVES

The primary global objective for this research is to provide Arkansas design professionals guidance in selecting realistic traffic inputs for use in MEPDG. This guidance includes information relating to the sensitivity of the design analysis to variations of input values. The secondary global objective involves the development of a program or plan to continuously measure and update the sensitive traffic inputs. A number of specific objectives to be met in this study have been identified. A listing of specific objectives follows:

- *Completely document traffic inputs*. MEPDG moves from the current traffic input (Equivalent Single Axle Load – ESAL) to a *load-spectra* system of inputs, in which specific truck types, axle loads, and hourly/daily/monthly volumes are required.
- *Completely document and characterize current AHTD traffic measurement capabilities*. Variables to be considered include volume of truck traffic, classification distributions, axle type and weight distributions within the traffic stream, and volume distributions over time.
- *Identify useful AHTD traffic data and areas of data insufficiency.* Based on the documented requirements of MEPDG and the data available under current AHTD practices, data sets are identified that currently fit into MEPDG traffic modules, as well as data sets that may yield useful information with some post-measurement manipulation. In addition, deficiencies in current AHTD data are identified.
- *Develop traffic input values specifically for Arkansas*. Using the traffic data available under the current AHTD practices, some of the required traffic inputs are developed. This task also provides a detailed procedure that allows for continuously updating of typical input values and refining those estimates into a robust data set. It is emphasized that the research does not seek to actually *measure* traffic inputs – the research simply seeks to develop a *program or methodology* for measuring the given input(s).

- *Develop recommendations regarding traffic input sensitivity.* MEPDG requires a significant number of traffic input values to perform a design analysis. With such a complex design/analysis system, certain inputs "affect" the ultimate design to a larger extent than others. This objective seeks to identify those inputs most "critical" to a successful design, and those for which "default" values may be used with confidence. Most sensitive traffic inputs are recommended for continuously or periodically update by AHTD.

3. REPORT ORGANIZATION

Chapter 2 describes the traffic data required for the pavement design procedures in the 1993 Guide and MEPDG. It also presents monitoring devices and programs used by state highway agencies to collect traffic data for pavement design purposes.

Chapter 3 reviews the traffic inputs required for the MEPDG software. In addition, the current practices for collecting traffic data used in Arkansas are briefly discussed. Based on the reviews, a strategic plan for development of statewide traffic inputs is presented. The traffic data provided by the Technical Services of AHTD for this study are evaluated. Finally, "good" traffic data are used to develop the statewide traffic inputs.

Chapter 4 presents two sensitivity analyses. One is to illustrate the effect of under-calibrated and over-calibrated WIM data on the design. The other is to investigate if the developed and the corresponding default traffic inputs are significantly different. If not, the default traffic inputs should be used for the design.

Chapter 5 presents the significant findings in this study. This chapter also includes recommendations for implementation of the study results in the future.

CHAPTER 2 LITERATURE REVIEW

1. TRAFFIC INPUTS FOR PAVEMENT DESIGN GUIDES

Traffic is one of the most important inputs in pavement design. Traffic data are required for estimating the magnitude, configuration and frequency of the loads that are applied throughout the pavement design life. The equivalent single axle load (ESAL) approach has been used for traffic characterization in the empirical methods of pavement design -- the *1993 Guide* -- for many years. However, the load equivalency concept is not necessary for MEPDG because variable loads can be considered separately in the new design process. This section provides an overview of the traffic characterization processes for the pavement design.

1.1. Traffic Inputs for Empirical Pavement Design Guide

In the *1993 Guide*, the mixed traffic of single- or multiple-axle loads is converted to an equivalent number of repetitions of a standard axle load, which is the 18-kip (80-kN) single-axle load. An axle load can be converted to a number of standard axle loads using an equivalent axle load factor (EALF), which is defined in Equation 2.1.

$$EALF = \frac{W_{t18}}{W_{tx}} \quad (2.1)$$

where:

$EALF$ = equivalent axle load factor

W_{tx} = number of x-axle load applications at the end of time t

W_{t18} = number of 18-kip (80-kN) single-axle load applications to time t

The total number of passes of the standard axle load during the design period, which is defined as the equivalent single-axle load (ESAL), can be determined using Equation 2.2. The ESAL is the only traffic parameter required for the design using the *1993 Guide* (*3*).

$$ESAL = \sum_{i=1}^{m} EALF_i n_i \tag{2.2}$$

where:

$ESAL$ = equivalent single-axle load

$EALF_i$ = EALF for the ith axle load group

n_i = number of passes of the ith axle load group during design period

m = number of axle load groups

The EALF is dependent on several variables, such as pavement type, structural capacity, failure condition, and type of distress (*1*,*2*). The EALF is commonly determined based on the empirical equations developed from the American Association of State Highway Officials (AASHO) Road Test in the 1960s. Since then, trucks have been designed to carry heavier loads and use higher tire pressures. These changes in truck design significantly influence the pavement performance. As a function of EALFs, the ESAL is currently not a good traffic input for pavement design. The new mechanistic-empirical pavement design methods do not use a single ESAL value in the design but considers the effect of each load group individually.

1.2. Traffic Inputs for Mechanistic-Empirical Pavement Design Guide

For the mechanistic-empirical pavement design procedures, the required traffic data are the same for the pavement type (flexible or rigid) and design type (new or rehabilitated). The

MEPDG procedures require the full axle-load spectrum data for each axle type, instead of the equivalent axle load (*2*).

Three types of traffic data are typically collected by state agencies -- vehicle counts, automatic vehicle classification (AVC), and weigh-in-motion (WIM) data. Vehicle counts are the number of vehicles counted over a period of time, while AVC data report the number of vehicles by vehicle type counted over a period of time. WIM data provide the number and configuration of axles observed within a series of load groups. These data are utilized to estimate both historical and future traffic levels for new pavement and rehabilitation design purposes.

The traffic data collection for MEPDG should follow the practices outlined in the *Traffic Monitoring Guide* (TMG) (*4*). State agencies that currently collect traffic data according to the TMG would meet the traffic characterization requirements for MEPDG. However, in some situations, agencies may not properly collect detailed traffic data to accurately characterize historical and future traffic for the pavement design. Thus, the level of detail of available traffic data is considered in determining the reliability of the pavement design using a hierarchical approach. Three levels of traffic inputs (Levels 1 through 3) are defined in MEPDG based on the amount of traffic data available. Level 1 represents the highest level of knowledge of past and future traffic characteristics for design purposes, and Level 3 is the least accurate traffic input level.

1.2.1. Level 1

Level 1 is considered the most accurate because it requires a very good knowledge of historical axle load spectra, classification, and volume data at or near the project site, which refers to a roadway segment near the design location with no influencing intersecting roadways.

1.2.2. Level 2

Level 2 is the intermediate traffic input level. It requires a very good knowledge of design traffic volume and vehicle classification. Level 2 uses the statewide/regional axle load spectra, instead of the site specific axle load spectra required for Level 1. The analyses of regional axle load spectra for each truck class must be completed externally by design agencies.

1.2.3. Level 3

Level 3 is the least accurate input level in MEPDG. It requires only estimates of average annual daily traffic (AADT) and truck percentage with no site-specific knowledge of traffic characteristics at the design location. An estimate of traffic inputs based on local experience is also considered in Level 3 (*2*).

It is anticipated that Levels 2 and 3 are the most commonly used for both new pavement and rehabilitation designs (*2*). Table 1 summarizes four main sources of traffic data required for each of the three hierarchical input levels in MEPDG. Detailed traffic inputs required for MEPDG are presented later in this report.

2. TRAFFIC DATA COLLECTION FOR PAVEMENT DESIGN GUIDES

This section briefly describes the current traffic data collection technologies and data reporting programs for pavement design purposes. A data collection plan is designed to identify changes in traffic patterns as they occur over time. A statewide traffic collection plan usually consists of permanent, continuously operating data collection sites and short duration data collection efforts (*4*). Permanent data collection sites provide continuous count summaries containing precise seasonal measurements of traffic characteristics at the monitored locations. However, the permanent sites are expensive to install, operate and maintain. Thus, short duration counts (for several days) are needed on roadways throughout the state. These short duration counts are then used with the traffic patterns measured at the permanent collection sites to estimate annual traffic conditions.

TABLE 1. Main Sources of Traffic Data for Three Hierarchical Input Levels (*2*)

Data Sources		**Input Level**		
		1	**2**	**3**
Traffic Load/Volume Data	WIM Data – Site/Segment Specific	X		
	WIM Data – Regional Default Summaries		X	
	WIM Data – National Default Summaries			X
	AVC Data – Site/Segment Specific	X		
	AVC Data – Regional Default Summaries		X	
	AVC Data – National Default Summaries			X
	Vehicle Counts – Site/Segment Specific	X	X	X
	Traffic Forecasting and Trip Generation Models	X	X	X

State highway agencies should establish well-designed, efficient traffic monitoring programs that can obtain, summarize and distribute traffic data collected by other agencies and programs within the state, such as Long Term Pavement Performance (LTPP) project. In addition, the programs should optimize the use of traffic monitoring equipment that can often provide more than one type of data at a time. Table 2 presents the types of data can be provided by different traffic data collection devices (*4*).

TABLE 2. Types of Data Provided by Traffic Data Collection Devices (*4*)

Type of Data	WIM Scale	Vehicle Classifier	Volume Counter
Axle and/or Vehicle Weight	X		
Volume by Type of Vehicle	X	X	
Volume of Vehicle	X	X	X

2.1 Continuous Count Programs

State highway agencies usually have continuous count programs to help establish seasonal, daily and hourly traffic characteristics for a variety of design, operation and management purposes. Most continuous count programs collect traffic data using three types of traffic collection devices – automatic traffic recorders (ATR), automatic vehicle classifiers (AVC), and weigh-in-motion (WIM) scales.

2.1.1 Automatic Traffic Recorders

Automatic traffic recorders are used to provide continuous traffic data at selected locations. Automatic traffic recorders are typically road tubes, which are essentially air switches that record load applications. ATR data are usually hourly traffic volumes by lane. The data are then analyzed to provide statistics relative to the traffic volume for design purposes, as follows (*4*):

- Annual average daily traffic at the site (AADT)
- Annual average weekday traffic at the site (AAWDT)
- Seasonal adjustment factors
- Day-of-week adjustment factors
- Lane/directional distribution factors
- Growth factors

The above factors are used to adjust short duration counts to AADT. ATR stations are often selected based on the importance of the monitoring sites or the locations that provide an accurate measure of traffic activity for specific categories of roads.

2.1.2 Automatic Vehicle Classifiers

Due to the importance of truck volume and load information for design purposes, continuously monitoring volume by vehicle class becomes necessary. Automatic vehicle classifiers are used to detect and classify vehicles based on vehicle characteristics, such as the number and type of axles, vehicle length, or vehicle weight. The Federal Highway Administration (FHWA) has developed a 13-vehicle axle-based category scheme, as shown in Table 3, to help state agencies in classification of vehicles.

The most common data collection technologies for continuous vehicle classifiers use in-pavement sensors based on dual-inductance loops or piezoelectric cables. A newer technology uses sensors that are not physically placed in the roadway itself, but it monitors traffic from above or beside the road (*5*).

TABLE 3. FHWA Vehicle Classification (*4*)

Vehicle Class	Description
1	Motorcycles
2	Passenger Cars
3	Other Two-Axle, Four-Tire Single Unit Vehicles
4	Buses
5	Two-Axle, Six-Tire, Single-Unit Trucks
6	Three-Axle Single-Unit Trucks
7	Four or More Axle Single-Unit Trucks
8	Four or Fewer Axle-Single-Trailer Trucks
9	Five-Axle Single-Trailer Trucks
10	Six or More Axle Single-Trailer Trucks
11	Five or Fewer Axle Multi-Trailer Trucks
12	Six-Axle Multi-Trailer Trucks
13	Seven or More Axle Multi-Trailer Trucks

Axle-based vehicle classifiers that make use of the FHWA classification scheme utilize an algorithm to interpret axle spacing information to categorize vehicles into 13 classes. However, axle spacing characteristics and the number of vehicle categories can be varied from state to state. Thus, it is up to each agency to utilize an alternative scheme based on the FHWA classification system, which meets its own needs. The continuous vehicle classification sites allow the monitoring of changes in truck traffic characteristics by classification over time, as follows (*4*):

- Annual average daily truck traffic at the site (AADTT)
- Seasonal and day-of-week traffic patterns for trucks
- Direction, lane and growth factors for trucks

2.1.3 Weigh-in-Motion Scales

Weigh-in-motion (WIM) devices provide the most extensive traffic data, including volume, classification, and axle/weight data. WIM devices measure transient tire forces that are utilized later to determine static axle weights using computer algorithms. Current WIM technologies require in-pavement sensors for permanently mounted systems which reduce dynamic vehicle motion and impact force on sensors. This results in more accurate weight measurements and longer sensor life. Bending plates, hydraulic load cells, piezoceramic cables, piezopolymer cables, and piezoquartz sensors are typical WIM types for continuous counts (*5*).

Each sensor technology has its own strengths and weaknesses. Performance of any WIM system is dependent on environment and site conditions. WIM sites cannot be selected in a purely random fashion because a WIM system only works accurately on a flat, smooth, and strong pavement. Specific requirements for selecting a WIM site are presented elsewhere (*6*).

2.2 Short Duration Count Programs

State highway agencies establish short count programs to provide up-to-date traffic data for a wide geographic coverage of roadways. Unlike continuous counts occurs at the same locations over time, the short count program is normally used portable devices and revised each year based on the agency design, operation, and maintenance plans. Short duration counts are most commonly collected for periods of 24 or 48 hours, although seven consecutive days are used as many as possible (*5*).

Vehicle classification and WIM devices for short duration counts currently use portable sensors or mats placed on top of the roadway surface. The advantages and disadvantages of the technologies used for short count systems are discussed in detail elsewhere (*5*).

Since the short count data only represent the traffic conditions in a short time period, the data may not represent "normal design" conditions for that roadway segment. The short count data are then adjusted based on the adjustment factors obtained from the continuous count program. The procedure for adjusting short count data to obtain traffic estimates for design purposes are presented in TMG (*4*).

In summary, each state highway agency can select traffic monitoring programs and equipment whose cost and data accuracy are suitable for design and maintenance purposes. In general, data collection practice should include several basic steps (*5*):

- Identify user requirements
- Determine location and system requirements
- Manage the equipment installation
- Implement a data collection and quality assurance program
- Conduct maintenance and calibration of equipment

2.3 Use of Long-Term Pavement Performance Data

The Long-Term Pavement Performance (LTPP) program is a national research effort studying the causes of pavement deterioration and the effects of different pavement design and maintenance methods. The LTPP database maintained continuous vehicle classification and WIM data at specific LTPP test sites throughout the United States. In the development of MEPDG, analyses of traffic data maintained in the LTPP database for 134 sites were conducted to determine suitable traffic default values (*7*). Data from the LTPP sites in a state can be included in the statewide traffic monitoring program. They can be particularly useful in developing statewide/regional traffic inputs for various roadways within the state.

However, the use of LTPP database has limitations. Many LTPP data collection sites are not where a state would prefer to collect vehicle classification and WIM data as part of its statewide traffic monitoring program (*4*). In addition, a substantial amount of traffic data was missed for many of the LTPP data collection sites (*7*). In spite of their limitations, the LTPP data should be summarized and added to the state traffic database that is available for many design and analysis purposes, especially for development of the traffic inputs for MEPDG.

CHAPTER 3 DEVELOPMENT OF TRAFFIC INPUTS FOR MEPDG

1. INPUTS REQUIRED FOR TRAFFIC CHARACTERIZATION IN MEPDG

MEPDG requires four basic categories of traffic data for the structural pavement design (*2*):

- Truck traffic volume – base year information
- Truck traffic volume adjustment factors
  - Monthly adjustment
  - Class distribution
  - Hourly distribution
  - Traffic growth
- Axle load distribution factors
- General traffic inputs
  - Number axles/trucks
  - Axle configuration
  - Wheel base

The information required for developing the traffic inputs and the corresponding default values provided in the MEPDG software are briefly described in the following sections. A detailed discussion of these inputs can be found elsewhere (*2*).

1.1 Traffic Volume – Base Year Information

In order to determine the traffic loading for a pavement design, the following base year information is required:

- Two-way annual average daily truck traffic (AADTT)
- Percent of trucks in design direction

- Number of lanes in the design direction
- Percent of trucks in design lane
- Vehicle (truck) operational speed.

1.1.1 Two-Way Annual Average Daily Truck Traffic

Two-way AADTT is the annual average daily volume of heavy vehicles, including classes 4 through 13 in the traffic stream. It is normally derived from WIM, AVC, or vehicle count data. For Level 1 traffic inputs, AADTT is site-specific information, while it is regional/statewide information for Level 2. For Level 3, AADTT is estimated based on the annual average daily traffic and an estimate of the truck percentage, which can be estimated based on local experience. It is recommended that the average AADTT for the last three years prior to the base year be used for the design (*2*).

1.1.2 Number of Lanes in Design Direction

This information should be determined prior to the structural design of pavement. A full description of methodologies for determining the number of lanes for the pavement under design can be found elsewhere (*8*,*9*).

1.1.3 Percent Trucks in Design Direction

This information is commonly referred to as the directional distribution factor (DDF). The DDF should represent the predominant type of truck using the roadway. The DDF can be determined from WIM, AVC, or vehicle count data. If detailed information is not available to determine the DDF for the pavement under design, the DDF for the most common truck type (i.e., Class 9) is used. The MEPDG software provides a default DDF of 55 percent for Interstates, which was computed using the LTPP data (*2*).

1.1.4 Percent Trucks in Design Lane

This input is commonly referred to as the lane distribution factor (LDF), which describes the distribution of truck traffic between lanes in the design direction. Like the DDF, the LDF should represent the predominant type of truck in the design direction. The LDF can be determined from WIM, AVC, or vehicle count data. If the site specific or statewide/regional LDF is not available, the default values recommended for use based on the most common type of truck (i.e., Class 9) are as follows (*2*):

- Single-lane roadways in one direction, LDF = 1.00
- Two-lane roadways in one direction, LDF = 0.90
- Three-lane roadways in one direction, LDF = 0.60
- Four-lane roadways in one direction, LDF = 0.45

1.1.5 Vehicle Operational Speed

This information should be determined prior to the structural design of pavement. Detailed methodologies used to determine the operational speed can be found elsewhere (*8*,*9*).

1.2 Traffic Volume Adjustment Factors

The base-year AADTT must be adjusted using the following traffic volume adjustment factors, and each factor is briefly described in this section:

- Monthly adjustment factors

- Vehicle class distribution factors
- Hourly truck distribution factors
- Traffic growth factors

1.2.1 Monthly Adjustment Factors

Truck traffic monthly adjustment factors (MAF) specify the monthly variation of the annual truck traffic for a given truck class. The monthly adjustment factors are dependent on the design location and the local economy. While the truck traffic distribution can be varied every year, they are assumed to be constant over the entire design period in MEPDG (*2*). There are three input levels for MAF. Level 1 requires site specific inputs, while Level 2 requires regional/statewide inputs. Level 3 uses the default values or is based on local experience. Based on the traffic counts by class obtained from WIM, AVC, or vehicle count data, the monthly adjustment factors can be calculated using Equation 3.1 (*2*).

$$MAF_i = \frac{AMDTT_i}{\frac{1}{12}\sum_{i=1}^{12} AMDTT_i} \qquad (3.1)$$

where:

MAF_i = monthly adjustment factor for month i

$AMDTT_i$ = average monthly daily truck traffic for month i

i = month of the year

The sum of MAF for all months for a vehicle class must equal 12. If no information is available, an even or equal distribution (i.e., 1.0 for all months for all vehicle classes) can be used (*2*). The MEPDG software allows designers to directly input or import MAF from a file. However, the input file is currently not a text file. Thus, it is recommended that the site specific and regional MAF be directly input in the software and then save to a file using the "Export MAF to File" function. This file can be imported into the software for the design later.

1.2.2 Vehicle Class Distribution Factors

Vehicle class distribution factors (CDF) specify the percentage of each truck class (Classes 4 through 13) within the AADTT for the base year. The traffic information used to develop CDF is based on site specific WIM, AVC, or vehicle counts for Level 1, regional/statewide traffic classification counts for Level 2, and national classification counts for Level 3. The vehicle class distribution factors can be determined using Equation 3.2. The sum of CDF for all classes should equal 100.

$$CDF_j = \frac{AADTT_j}{AADTT} \qquad (3.2)$$

where:

CDF_j = vehicle class distribution factor for vehicle class j

$AADTT_j$ = annual average daily truck traffic for class j

$AADTT$ = annual average daily truck traffic for all classes

If site specific and statewide/regional information is not available, the default CDF for a roadway design can be selected based on the roadway functional class and a truck traffic classification (TTC) group that describes the traffic stream expected on the roadway (*2*). Designers must choose the default vehicle class distribution factors corresponding to the TTC that most closely describes the design traffic stream for the roadway under design. Table 4 shows the roadway functional classification system used in the LTPP database.

TABLE 4. Roadway Functional Classification in LTPP Database (*4*)

Code	Roadway Functional Classification
01	Rural Principal Arterial – Interstate
02	Rural Principal Arterial – Other
06	Rural Minor Arterial
07	Rural Major Collector
08	Rural Minor Collector
09	Rural Local System
11	Urban Principal Arterial – Interstate
12	Urban Principal Arterial – Other Freeways and Expressways
14	Urban Principal Arterial – Other
16	Urban Minor Arterial
17	Urban Collector
18	Urban Local System

The NCHRP 1-37A researchers found that the roadway functional classifications did not properly present the distribution of truck traffic on the roadway. Therefore, the TTC was introduced to divide roadways into sections that have a similar composition of trucks (Classes 4 through 13). Seventeen truck traffic classification groups were defined for pavement structural design purposes (*2*). General descriptions of the seventeen TTCs are presented in Table 5.

TABLE 5. General Descriptions of Truck Traffic Classifications (*2*)

TTC	Description
1	Major Single-Trailer Truck Route (Type I)
2	Major Single-Trailer Truck Route (Type II)
3	Major Single- and Multi- Trailer Truck Route (Type I)
4	Major Single-Trailer Truck Route (Type III)
5	Major Single- and Multi- Trailer Truck Route (Type II)
6	Intermediate Light and Single-Trailer Truck Route (I)
7	Major Mixed Truck Route (Type I)
8	Major Multi-Trailer Truck Route (Type I)
9	Intermediate Light and Single-Trailer Truck Route (II)
10	Major Mixed Truck Route (Type II)
11	Major Multi-Trailer Truck Route (Type II)
12	Intermediate Light and Single-Trailer Truck Route (III)
13	Major Mixed Truck Route (Type III)
14	Major Light Truck Route (Type I)
15	Major Light Truck Route (Type II)
16	Major Light and Multi-Trailer Truck Route
17	Major Bus Route

The seventeen TTC groups are developed based on the distribution of buses, single-unit trucks, single-trailer trucks, and multi-trailer trucks grouped from different types of trucks as follows:

- Buses (vehicle Class 4)

- Single-unit trucks (vehicle Classes 5, 6, and 7)
- Single-trailer trucks (vehicle Classes 8, 9, and 10)
- Multi-trailer trucks (vehicle Classes 11, 12 and 13)

The last three major truck categories were developed primarily around vehicle Classes 5, 9, and 13. These three vehicle classes showed the greatest variability that significantly influenced truck traffic streams (*2*). Tables 6 presents the truck traffic classification criteria based on the four major vehicle categories (i.e., buses, single-unit trucks, single-trailer trucks, and multi-trailer trucks). Table 7 shows the suggested guidance for selecting appropriate TTCs for different highway functional classifications.

1.2.3 Truck Hourly Distribution Factors

Hourly distribution factors (HDF) are used to adjust truck volume throughout the day. Development of HDF for Level 1 requires site specific hourly truck traffic data from WIM, AVC, or vehicle count stations. It requires regional/statewide data for Level 2 and national data or local experience for Level 3. The MEPDG software provides the default HDF values derived from the LTPP traffic database (*2*). The hourly data can be used to determine HDFs using Equation 3.3. The sum of HDF for 24-hour period should equal 100.

$$HDF_i = \frac{HATT_i}{\sum_{j=1}^{24} HATT_j} \times 100 \tag{3.3}$$

where:

HDF_i = Hourly distribution factor for *ith* one-hour time period

$HATT_i$ = Hourly average truck traffic for *ith* one-hour time period

TABLE 6. Truck Traffic Classification Criteria (*2*)

Buses	Multi-Trailer	Single-Trailer and Single-Unit Trucks	TTC
Low to None (<2%)	Relatively High Amount of Multi-Trailer Trucks (>10%)	Predominantly single-trailer trucks	5
		High percentage of single-trailer trucks, but some single-unit trucks	8
		Mixed truck traffic with a higher percentage of single-trailer trucks	11
		Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks	13
		Predominantly single-unit trucks	16
	Moderate Amount of Multi-Trailer Trucks (2-10%)	Predominantly single-trailer trucks	3
		Mixed truck traffic with a higher percentage of single-trailer trucks	7
		Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks	10
		Predominantly single-unit trucks	15
Low to Moderate (>2%)	Low to None (<2%)	Predominantly single-trailer trucks	1
		Predominantly single-trailer trucks, but with a low percentage of single-unit trucks	2
		Predominantly single-trailer trucks with a low to moderate amount of single-unit trucks	4
		Mixed truck traffic with a higher percentage of single-trailer trucks	6
		Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks	9
		Mixed truck traffic with a higher percentage of single-unit trucks	12
		Predominantly single-unit trucks	14
Bus Route (>25%)	Low to None (<2%)	Mixed truck traffic with about equal single-unit and single-trailer trucks	17

TABLE 7. Truck Traffic Classification Criteria (*2*)

Highway Functional Classifications	Applicable TCC Groups
Principal Arteries – Interstate and Defense Routes	1,2,3,4,5,8,11,13
Principal Arteries – Intrastate Routes, including Freeways and Expressways	1,2,3,4,6,7,8,9,10,11,12,14,16
Minor Arteries	4,6,8,9,10,11,12,15,16,17
Major Collectors	6,9,.12,14,15,17
Minor Collectors	9,12,14,17
Local Routes and Streets	9,12,14,17

1.2.4. Traffic Growth Factors

Traffic growth factors at a specific site can be estimated using continuous counts or short duration counts collected over several years. Three different traffic growth functions, as shown in Table 8, are allowed in the MEPDG software to compute the growth or decay in truck traffic over time. The software also allows users to input different growth rate and growth function for different truck classes.

TABLE 8. Traffic Growth Function (*2*)

Function	Model
No Growth	$AADTT_x = 1.0 \times AADTT_{BY}$
Linear Growth	$AADTT_x = GR \times AGE + AADTT_{BY}$
Compound Growth	$AADTT_x = AADTT_{BY} \times GR^{AGE}$

where $AADTT_x$ is the annual average daily truck traffic at age X, GR is the growth rate, and $AADTT_{BY}$ is the base year annual average daily truck traffic.

1.3 Axle Load Distribution Factors

The axle load distribution factors represent the percentage of the total axle applications within each load interval for a specific axle type (single, tandem, tridem, and quad) and vehicle class (Classes 4 through 13). The axle load distributions or spectra can be only determined from WIM data. For Level 1, the requirement data are site specific, while they are statewide/regional data for Level 2. The load spectra for Levels 1 and 2 can be imported from prepared text files. For Level 3, the default values determined from the LTPP database are provided in the MEPDG software.

Analyses of the LTPP WIM data showed that the differences between year-to-year and month-to-month load spectra were not significant. Thus, for the MEPDG, axle load spectra can be normalized on an annual basis (*2*). However, the MEPDG software allows users to vary the axle load spectra monthly.

The following load distribution information is required for the MEPDG (*2*):

- Axle load distribution for each axle type for each load interval:
    - Single axles – 3,000 lb to 40,000 lb at 1,000-lb intervals
    - Tandem axles – 6,000 lb to 80,000 lb at 2,000-lb intervals
    - Tridem and quad axles – 12,000 lb to 102,000 lb at 3000-lb intervals
- For each axle type, load distribution is required for each month (January through December) and truck class (Class 4 through 13).

1.4 General Traffic Inputs

The general traffic inputs include the information listed below. The default values for the general traffic inputs were determined from the LTPP database (*2*).

- Mean wheel location: The distance from the outer edge of the wheel to the pavement marking. The default value is 18 inches.
- Traffic wander standard deviation: The standard deviation of the lateral traffic wander. The default value is 10 inches.
- Design lane width: The actual traffic land width. The default value is 12 ft.
- Number of axle types per truck class: the average number of axles for each axle type (single, tandem, tridem, and quad) for each truck class (Class 4 through 13). The default values based on the LTPP database are presented elsewhere (*2*).
- Axle configuration: The inputs needed to describe the configurations of the typical tire and axle loads.
- Wheelbase: The inputs describing the details of the vehicle wheelbase.
- Tire dimension and inflation pressures. The default hot inflation pressure in the MEPDG software is 120 psi.

These data are used in the calculations of traffic loading for determining pavement responses (*2*). The default values provided for the general traffic inputs are recommended if more accurate data are not available.

1.5 Strategic Plan for Traffic Characterization

Based on the requirements for traffic inputs, the following strategic plan for developing traffic inputs for implementation of MEPDG in Arkansas is proposed as follows:

- Traffic inputs using the site specific values
  - Annual average daily truck traffic
- Traffic inputs using the regional/statewide values

   - Monthly distribution factors
   - Vehicle class distribution factors
   - Hourly truck distribution factors
   - Axle load distribution factors (Axle load spectra)
- Traffic inputs using the default or user-defined values
   - Traffic growth factors
   - Directional distribution factors
   - Lane distribution factors
   - Other general traffic inputs

The following sections present the development process of the four regional/statewide traffic inputs and recommendations for other inputs.

2. ARKANSAS TRAFFIC MONITORING PROGRAM

The traffic monitoring program in Arkansas is currently performed and managed by the Technical Services of Arkansas State Highway and Transportation Department (AHTD). The Technical Services provides traffic data for various purposes, such as transportation and traffic analyses, pavement and bridge designs, and environmental studies. The Technical Services is also responsible for reporting traffic data to the FHWA and LTPP program.

In general, the traffic monitoring program in Arkansas is developed based on the guidelines in FHWA's Traffic Monitoring Guide (TMG) published in May 2001. Currently, the Technical Services performed two traffic count programs: (1) continuous count program, and (2) short-duration count program. For the continuous count program, the Technical Services operates 79 automated traffic data collection sites, as shown in Figure 1. Of the 79 automated sites, 55 data collection sites are the weigh-in-motion (WIM). The WIM stations are used to continuously collect traffic volume, vehicle classification and vehicle weight. All WIM sites in Arkansas are using piezoelectric sensors. The WIM sites are calibrated every three years. The calibration is performed following the guidelines in FHWA's Traffic Monitoring Guide (*4*).

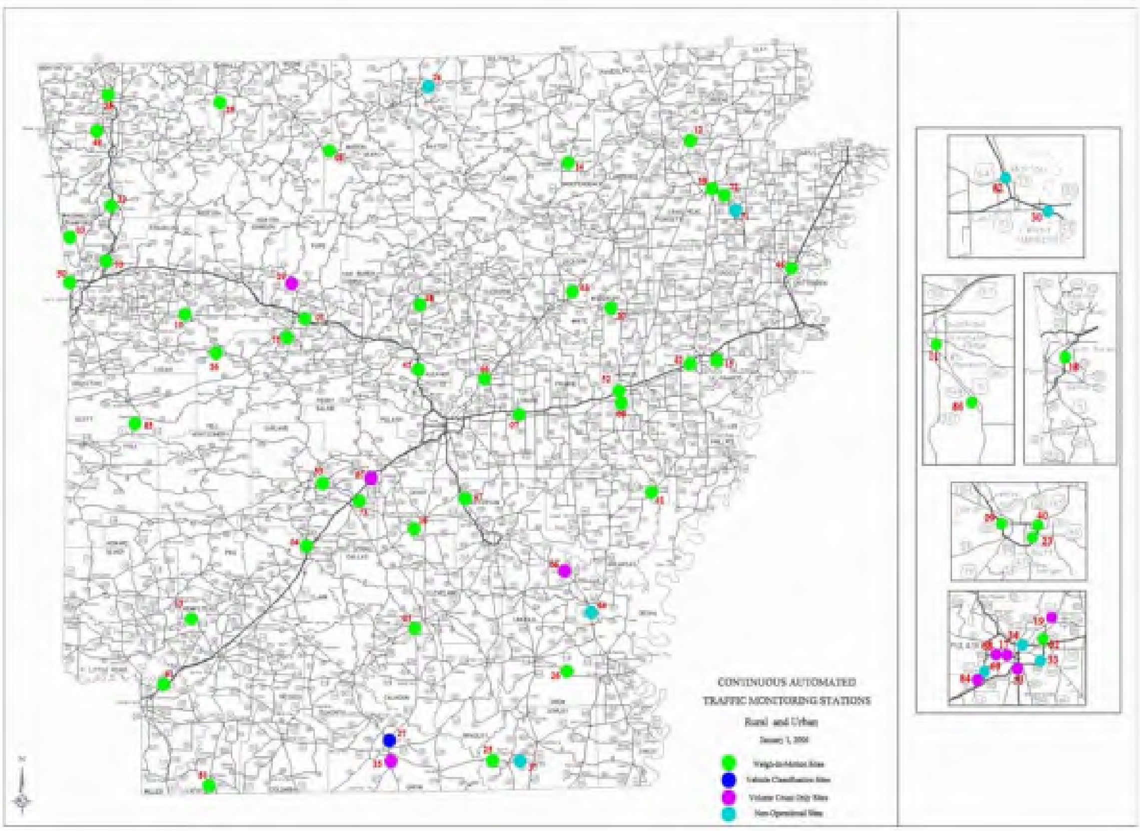

FIGURE 1. Automated Traffic Data Collection Sites in Arkansas

3. TRAFFIC CHARACTERIZATION FOR MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE

Based on the strategic plan for development of traffic inputs for implementation of MEPDG in Arkansas, the following statewide traffic inputs are developed based on the available traffic data collected in Arkansas:

- Monthly distribution factors
- Vehicle class distribution factors
- Hourly truck distribution factors
- Axle load distribution factors

3.1 Selection of WIM Sites for MEPDG Traffic Characterization

For this study, the traffic data from the 55 WIM sites collected from 2003 through 2005 were provided by the Technical Services. Two FHWA's file formats were used: (1) the vehicle classification record (C-Card), "ssyy.CLA"; and (2) the vehicle weight record (W-Card), "ssyy.WGT" (*4*). Each vehicle classification file contains one-month record of hourly traffic volume by vehicle class. Each vehicle weight file contains one-month record of passing vehicles with their axle weights and axle spacings. Table 9 presents the format of vehicle classification record, and Table 10 shows the format of vehicle weight record.

The automated vehicle classification and weight data that were available each month from 2003 through 2005 are tabulated in Appendix A. In order to develop the traffic inputs for the new MEPDG, the only WIM stations which provide enough traffic data for 12 month of the year (i.e., from January through December) were selected. Among the 55 WIM sites, the data from many sites were not available several months a year, as shown in Appendix A.

Only 25 WIM sites provided 12-month data and were selected. Table 11 lists 18 selected WIM sites in rural areas, and Table 12 shows other 7 WIM sites in urban areas.

TABLE 9. Vehicle Classification Record (*4*)

Field	Columns	Length	Description
1	1	1	Record Type
2	2-3	2	FIPS State Code
3	4-9	6	Station ID
4	10	1	Direction of Travel Code
5	11	1	Lane of Travel
6	12-13	2	Year of Data
7	14-15	2	Month of Data
8	16-17	2	Day of Data
9	18-19	2	Hour of Data
10	20-24	5	Total Volume
11	25-29	5	Class 1 Count
12	30-34	5	Class 2 Count
13	35-39	5	Class 3 Count
14	40-44	5	Class 4 Count
15	45-49	5	Class 5 Count
16	50-54	5	Class 6 Count
17	55-59	5	Class 7 Count
18	60-64	5	Class 8 Count
19	65-69	5	Class 9 Count
20	70-74	5	Class 10 Count
21	75-79	5	Class 11 Count
22	80-84	5	Class 12 Count
23	85-89	5	Class 13 Count

TABLE 10. Truck Weight Record (*4*)

Field	Columns	Length	Description
1	1	1	Record Type
2	2-3	2	FIPS State Code
3	4-9	6	Station ID
4	10	1	Direction of Travel Code
5	11	1	Lane of Travel
6	12-13	2	Year of Data
7	14-15	2	Month of Data
8	16-17	2	Day of Data
9	18-19	2	Hour of Data
10	20-21	2	Vehicle Class
11	22-24	3	Open
12	25-28	4	Total Weight of Vehicle
13	29-30	2	Number of Axles
14	31-33	3	A-axle Weight
15	34-36	3	A-B Axle Spacing
16	37-39	3	B-axle Weight
17	40-42	3	B-C Axle Spacing
18	43-45	3	C-axle Weight
19	46-48	3	C-D Axle Spacing
20	49-51	3	D-axle Weight
21	52-54	3	D-E Axle Spacing
22	55-57	3	E-axle Weight
23	58-60	3	E-F Axle Spacing
24	61-63	3	F-axle Weight
25	64-66	3	F-G Axle Spacing
26	67-69	3	G-axle Weight
27	70-72	3	G-H Axle Spacing
28	73-75	3	H-axle Weight
29	76-78	3	H-I Axle Spacing
30	79-81	3	I-axle Weight
31	82-84	3	I-J Axle Spacing
32	85-87	3	J-axle Weight
33	88-90	3	J-K Axle Spacing
34	91-93	3	K-axle Weight
35	94-96	3	K-L Axle Spacing
36	97-99	3	L-axle Weight
37	100-102	3	L-M Axle Spacing
38	103-105	3	M-axle Weight

TABLE 11. WIM Sites Active in 12 Consecutive Months in Rural Areas

Map ID	Station	F/C	Route	Location
Interstate 01				
70	170064	01	I-540	Newberry Castle Road Overpass (Alma, Crawford)
07	430037	01	I-40	East of S.H. 31 Interchange (Lonoke, Lonoke)
61	460006	01	I-30	At C.R. C-63 Overpass (Texarkana, Miller)
52	481524	01	I-40	West of U.S. 49 (Brinkley, Monroe)
01	580236	01	I-40	East of S.H. 331 (Russellville, Pope)
42	680025	01	I-40	At C.R. F-10 Overpass (Forrest City, St Francis)
Principle Arterial 02				
05	071813	02	US 79	North of U.S. 167 (Thornton, Calhoun)
48	230001	02	US 65	South of S.H. 124 (Damascus, Faulkner)
12	281983	02	US 412	East of Cache River Bridge (Light, Greene)
49	720034	02	US 412	West of S.H. 112 (Tonitown, Washington)
63	730068	02	US 67	At S.H. 258 Overpass (Bald Knob, White)
Minor Arterial 06				
03	171651	06	SH 59	North of Natural Dam (Natural Dam, Crawford)
13	290002	06	US 278	South of S.H. 332 (Ozan, Hemstead)
20	740035	06	US 64	West of S.H. 17 (Patterson, Woodruff)
36	750010	06	SH 10	East of County Road 537 (Havana, Yell)
Major Collector 07				
60	480037	07	US 70	East of S.H. 17 (Brinkley, Monroe)
14	670027	07	SH 115	East of U.S. 167 (Cave City, Sharp)
15	680032	07	SH 50	West of S.H. 38 (Madison, St Francis)

TABLE 12. WIM Sites Active in 12 Consecutive Months in Urban Areas

Map ID	Station	F/C	Route	Location
Interstate 11				
82	180002	11	I-55	South of U.S. 64 (Marion, Crittenden)
09	350314	11	I-530	North of S.H. 190 (Pine Bluff, Jefferson)
Other Freeways and Expressways 12				
40	350215	12	US 65	North of S.H. 15 (Pine Bluff, Jefferson)
66	430038	12	US 67	South of S.H. 89 (Cabot, Lonoke)
11	460286	12	SH 245	South of U.S. 82 (Texarkana, Miller)
02	600870	12	SH 440	South of S.H. 161 (Rixey, Pulaski)
Collector 17				
23	350512	17	I-530	Frontage Road North of US 65 (Pine Bluff, Jefferson)

The traffic data records from the 25 sites were converted from raw WIM data. The records have not been checked for data quality. Thus, the data are evaluated in the next section.

3.2 Quality Control Checks for Traffic Data

Several publications have reported that the traffic data collected from the automated traffic collection sites often have errors, especially the data collected from the WIM sites which use temperature-dependent piezoelectric sensors (*5*,*7*). A recent research in Washington reported that only 11 WIM sites of a total of 52 WIM stations operated in the state of Washington could provide the traffic data that passed the quality control checks (*10*). Therefore, the traffic records used in this research project, which have not been checked for data quality, are evaluated using the quality control checks recommended in the LTPP and FHWA publications (*4,11*). These evaluation procedures are briefly described and performed in the following sections.

3.2.1 Quality Control Checks for Vehicle Classification Data

There are four steps which should be taken to evaluate automated vehicle classification (AVC) data (*11*). The first step is to compare the manual classification counts and the hourly AVC data. The absolute difference between the manual counts and the hourly AVC data should be less than five percent for each of the primary vehicle categories (*11*). The primary vehicle categories are varied based on the roadway functional classification and the design purpose. For MEPDG, the primary vehicle categories that significantly influence traffic loading are vehicle Classes 5, 9, and 13 (*2*).

The second step is to check the number of Class 1 (motorcycles). If a significant number of motorcycles are reported, the equipment may mistakenly record trailers separated from tractors, and the last tandem is recorded as a motorcycle because of its short spacing. The evaluation procedure recommended that the number of Class 1 should be less than five percent unless their presence is noted (*11*).

The third step is to check the reported number of unclassified vehicles. The number of unclassified vehicles should be less than five percent of the vehicles recorded (*11*). If more than five percent of recorded vehicles are unclassified, the equipment may have axle sensing malfunctions that prevent the equipment from measuring all of the appropriate axle pulses.

Finally, the current truck percentages by class are compared with the corresponding historical percentages to determine if significant changes in vehicle mix have occurred. One important thing to look for is the unexpected changes of similar vehicle classes, such as vehicle Classes 8 and 9 (*11*).

For this study, the manual vehicle classification counts were not available, so the first evaluation step was not performed. For the second evaluation step, the percent of Class 1 (motorcycles) was calculated for every station each month. The percent of Class 1 was less than five percent for every station. Thus, there was no evidence showing that the equipment at the 25 WIM sites mistakenly recorded trailers separated from tractors. Unclassified vehicles were not found in the traffic data provided for this study, so evaluation step 3 was not performed.

The last evaluation step for the automated vehicle classification data was performed as follows:

- Determined the number of trucks by class for each month (January through December) using the available vehicle classification data from 2003 through 2005.
- Calculated the normalized class distribution for each month using Equation 3.4

$$MCDF_{ij} = \frac{AMDTT_{ij}}{\sum_{j=4}^{13} AMDTT_{ij}} \tag{3.4}$$

where:

$MCDF_{ij}$ = monthly class distribution factor for month i and truck class j

$AMDTT_{ij}$ = average monthly daily truck traffic for month i and class j

- Plot the normalized class distributions for 12 months, as shown in Appendix B.
- Based on the distribution plot, compared the normalized class distribution for each month to determine if unexpected changes in vehicle mix had occurred. Data in the

months which had unexpected changes due to the malfunctions of equipment were discarded.

- If the remaining data for that station did not represent the 12 different months (i.e., January through December), the station was not included for further analyses.

A computer program was developed following the abovementioned procedure to evaluate the automated vehicle classification data contained in the C-card files provided by AHTD. Detailed evaluation of the classification data collected from the 25 WIM sites are presented in Appendix B. There were three cases observed during the evaluation process, as explained below.

- Case 1: Accepted all classification data from a station. The normalized class distribution curves were consistent. No unexpected change in the vehicle distribution was found in the data.
- Case 2: Partially accepted classification data from a station. Initially, the normalized class distribution curves were not consistent. Further analyses were required to verify and discard the invalid data. Finally, the data collected from the station were partially accepted.
- Case 3: Excluded all classification data from a station. The normalized class distribution curves were not consistent. After verifying and discarding the invalid data, the remaining data do not represent 12 months (i.e., January through December), which is necessary to determine the monthly adjustment factors. The station is excluded for further analyses.

An example of Case 1 is station 481524. Figure 2 presents the normalized class distribution curves for station 481524. The distribution curves were consistent with historical data and throughout 12 months. Thus, all vehicle classification data available from station 481524 were accepted for further analyses.

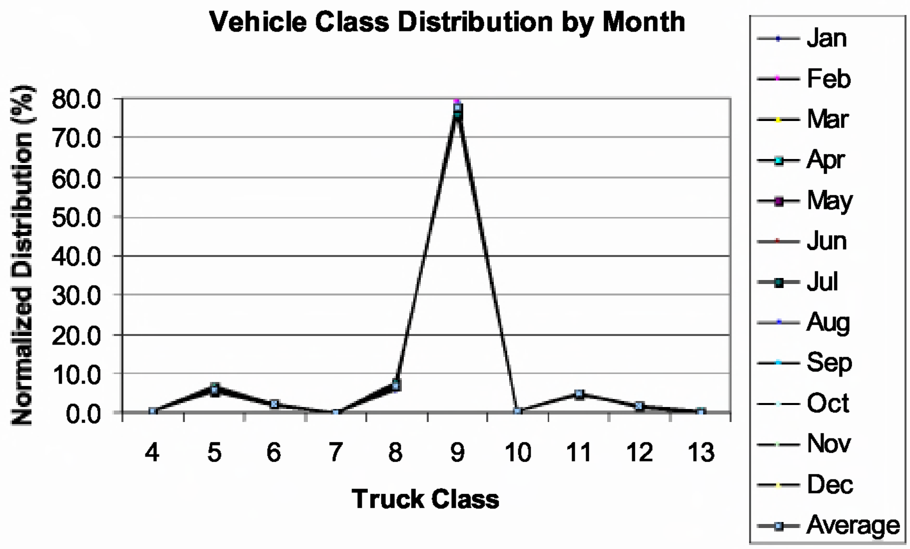

FIGURE 2. Normalized Class Distribution for Station 481524 (I-40, Brinkley)

Station 430037 is an example of Case 2. The normalized class distribution curves are presented in Figure 3. Some unexpected changes in distribution between Classes 8 and 9 and between Classes 5 and 6 were found in December 2004, and January and February 2005. After the data collected in these months were discarded, the curves were consistent with the historical data and throughout 12 months, as presented in Figure 4. Thus, the adjusted dataset was accepted for further analyses.

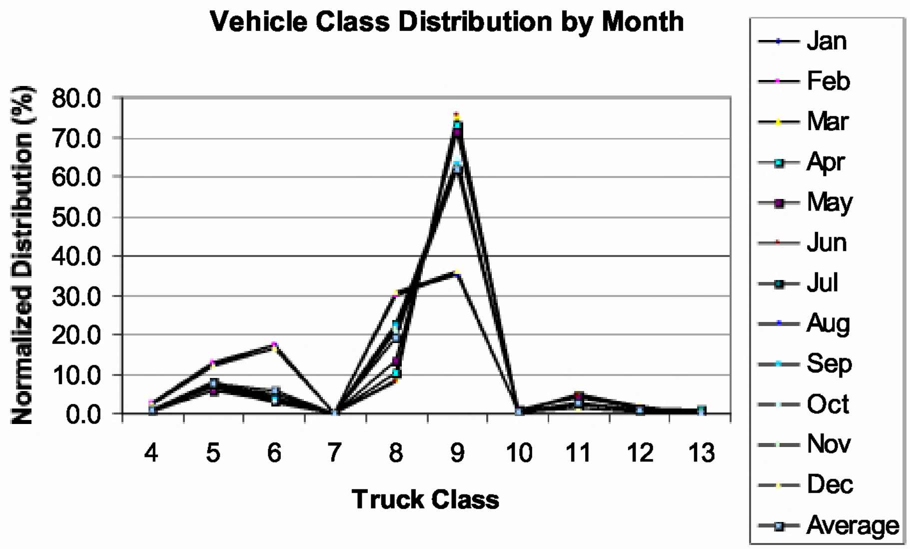

FIGURE 3. Normalized Class Distribution for Station 430037 (I-40, Lonoke)

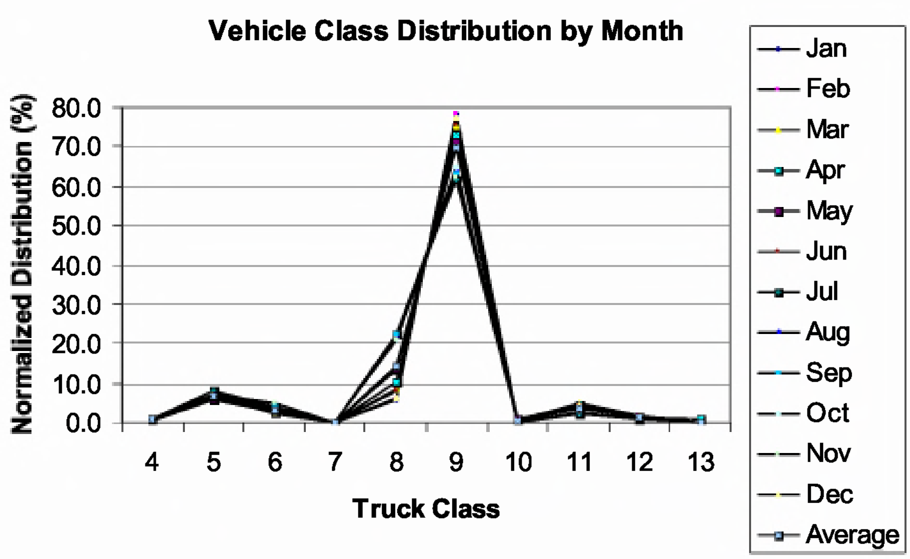

FIGURE 4. Adjusted Normalized Class Distribution for Station 430037

Among the 25 WIM stations, only station 350215 was not included for further analyses -- Case 3. The normalized class distribution curves for Station 350215 showed some unexpected changes in distribution between Classes 8 and 9 in April and September, as presented in Figure 5. After discarding the suspected data, the remaining data were not sufficient to represent 12 months (i.e., January through December), so this station was not included for further analyses.

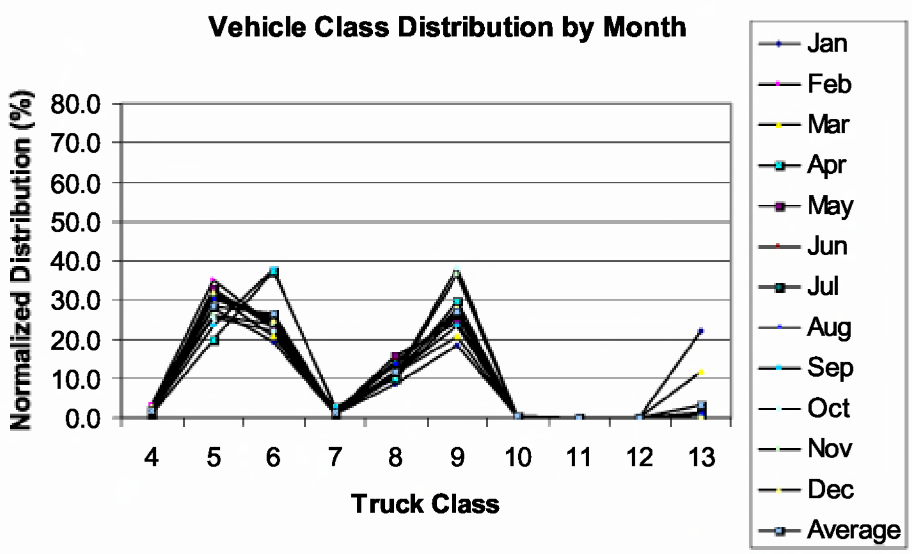

FIGURE 5. Normalized Class Distribution for Station 350215 (US 65, Pine Bluff)

The results of quality control checks for the automated vehicle classification data are summarized in Table 13. There are 17 stations in Case 1, 7 stations in Case 2, and only 1 station in Case 3. Table 14 summarizes unexpected changes in the vehicle classification data for those stations in Case 2. The unexpected changes are often occurred in the winter or summer months. This problem may be due to the significant effect of temperature on performance of the piezoelectric sensors of WIM devices. For most cases, the unexpected changes in distribution are between Classes 8 and 9. In one case, the number of Class 1 units is significantly increased in one month. The problems observed in this study are similar to those reported in the literature (*11*,*12*).

TABLE 13. Evaluation of Automated Vehicle Classification Data

Evaluation Case	Station(s) in Each Case
Case 1: Accepted all classification data from a station	17 stations: 460006, 481524, 580236, 071813, 281983, 720034, 730068, 171651, 290002, 740035, 480037, 670027, 680032, 180002, 430038, 460286, 350512
Case 2: Partially accepted classification data from a station	7 stations: 170064, 430037, 680025, 230001, 750010, 350314, 600870
Case 3: Excluded all classification data from a station	1 station: 350215

TABLE 14. Months with Unexpected Changes in Class Distribution

Station	Month(s) with Unexpected Changes in Class Distribution
170064	Sep. 2004: Unexpected changes in distribution between truck Classes 8 and 9
430037	Dec. 2004 – Feb. 2005: Unexpected changes in distribution between truck Classes 5, 6, 8 and 9
680025	Mar. 2005 – Apr. 2005: Unexpected changes in distribution between truck Classes 8 and 9
230001	Sep. 2004: Unexpected increase in the volume of Class 1 (704 motorcycles)
750010	Jul. 2004 – Aug. 2004: Unexpected changes in distribution between truck Classes 8 and 9
350314	Sep. 2004 and Jan. 2005 – April 2005: Unexpected changes in distribution between truck Classes 4, 5, 6, 8 and 9
600870	Jan. 2004: Unexpected changes in distribution between truck Classes 8 and 9
350215	Apr. 2003 and Sep. 2003: Unexpected changes in distribution between truck Classes 8 and 9

3.2.2 Quality Control Checks for Vehicle Weight Data

One of the most important data that a WIM system collects is vehicle weight. The weight data must also be checked after the automated vehicle classification data were evaluated as described in the previous section. There are several methods proposed for evaluating the weight data accuracy, and they are briefly described in this section. Among the proposed methods, the evaluation methods used by LTPP and TMG are adopted to perform the quality control checks for vehicle weight data in this study. Finally, the evaluation results are presented.

Dahlin reported in the early 1990's that the steer axle weight of Class 9 vehicles could be used to monitor the accuracy of WIM weight data because the average steer axle weight for a sample of 30 Class 9 vehicles should fall within a certain range related to the vehicle gross weight (*13*). If the average steer axle weight was out of the expected range, the WIM scale should be recalibrated.

The relationship between steer axle weight and gross axle weight was investigated by Southgate in the late 1990's based on the data obtained from a static weight station in Kentucky (*14*). He stated that the relationship was not precise. Instead, he found a relationship between the steer axle weight and the spacing between the steer axle and the lead drive axle. This relationship was suggested to use within the upper limit based on the 12-kip limit load for a steering axle and the lower limit based on the truck manufacturers' minimum specifications. Southgate proposed an evaluation procedure based on this relationship for verifying if the recorded WIM data were reasonable.

Nichols later investigated both evaluation methods in his study (*15*). He reported that the method based on the steer axle weight and gross vehicle weight relationship was less robust than the method using the steer axle weight and axle spacing relationship. Both relationships varied based on the vehicle mix and were not sensitive enough to detect small drifts for early detection of sensor failure. Instead of using these methods, Nichols proposed the use of the steer axle weight and the weight variation between the left and right wheels. This method was referred to as the left-right residual. He suggested that the left-right residual be used for statistical process control to detect subtle calibration drifts.

The use of front axle weight for calibration purposes is also proposed in other evaluation methods which are presented in several documents published by FHWA (*4*), LTPP program (*11*), and the Minnesota Department of Transportation (*16*). The procedures presented in these documents are similar. The procedures use statistical parameters applied to the following data to monitor the weight data from a WIM scale (*4*).

- The front axle and drive tandem weights of Class 9 trucks
- The gross vehicle weight distribution of Class 9 trucks

The FHWA and LTPP evaluation procedures recommend two basic steps be taken to evaluate recorded vehicle weight data (*4,11*). First, the front axle and drive tandem axle weights of Class 9 trucks are checked. Although the front axle is heavier when a truck is loaded, the front axle weight should be between 8,000 and 12,000 lb. If most of the recorded front axle weights of Class 9 trucks are less than 7,000 lb., the WIM scale should be recalibrated. The drive tandems of a fully loaded Class 9 truck should be between 30,000 and 36,000 lb. These limits are based on the extensive analyses of vehicle weight data in the LTPP database (*4,11*)

The next step is to check the gross vehicle weights of Class 9 trucks. This step requires a histogram plot of the gross vehicle weights of Class 9 trucks using a 4,000-lb.

increment. The histogram plot should have two peaks for most sites. One represents unloaded Class 9 trucks and should be between 28,000 and 36,000 lb. The second peak represents the most common loaded vehicle condition at that site, this varies with the type of commodity commonly being carried on the road and the legal weight limits for Class 9 trucks in the state. Based on the LTPP data, the loaded trucks weigh between 72,000 and 80,000 lb (*4,11*).

For most sites, the height of these peaks may be seasonally changed, but the location of the two peaks is fairly constant over time. If both peaks shifted in the same direction from their locations based on historical data, the scale is most likely out of calibration. If the loaded peak shifted and the other peak correctly located, the site should be reviewed using additional information, including the types of commodities carried by Class 9 trucks and the load distribution right after the site was last calibrated. Another statistical parameter should be reviewed is the number of vehicles over the legal weight limit (for the state of Arkansas, the legal weight limit is 80,000 lb.), especially the number of Class 9 vehicles over 100,000 lb. If the percentage of overweight vehicles is high, the scale calibration should be checked.

For this study, the quality control checks for the weight data are performed following the procedure recommended by LTPP and FHWA (*4,11*). The W-Card files provided by AHTD were used in this evaluation. A computer program was developed to generate the following four plots from the data collected at each station:

- A histogram plot of gross vehicle weights of Class 9 trucks using a 4,000-lb. increment
- A histogram plot of front axle weights of Class 9 trucks using a 1,000-lb. increment
- A plot of average front axle weights for unloaded, partially loaded, and fully loaded Class 9 trucks

- A plot of average drive tandem axle weights for unloaded, partially loaded, and fully loaded Class 9 trucks

In order to generate the aforesaid plots, the computer program was developed following the steps described below:

- Opened a W-Card file (One file contains weight data from all active WIM stations throughout the state of Arkansas in one month)
- Found the range containing all weight data from a specific station
- Found the rows recording the weight data of Class 9 trucks
- Counted the number of records for generating each plot:
  - For a histogram plot of gross vehicle weights, counted the number of trucks that fall in between each 4,000-lb. weight bin
  - For a histogram plot of front axle weights, counted the number of front axles that fall in between each 1,000-lb. weight bin
  - For a plot of average front axle weights, determined the average weights of front axles corresponding to unloaded trucks (less than 36,000 lb.), partially loaded trucks (between 36,000 and 72,000 lb.), and fully loaded trucks (more than 72,000 lb.)
  - For a plot of average drive tandem axle weights, calculated the average weights of drive tandem axles corresponding to unloaded trucks (less than 36,000 lb.), partially loaded trucks (between 36,000 and 72,000 lb.), and fully loaded trucks (more than 72,000 lb.)
- Finally, the plots were generated

The plots for each station are presented in Appendix C. Based on the plots, the evaluation process was performed following FHWA and LTPP's procedure (*4*,*11*). Detailed evaluation of the weight data from each station is included in Appendix C. Examples of "good" and "bad" weight datasets are described below.

Figures 6 through 9 show the plots of "good" weight data collected at Station 170064. The data from this station were considered "good" and included for further analyses in this study based on the following evaluation. The expected limits used in the evaluation process are from the LTPP and FHWA procedure (*4*,*11*)

- The distribution curves of gross vehicle weights in Figure 6 had two peaks within the expected ranges of 32,000±4,000 lb. and 76,000±4,000 lb. Most trucks were expected to be either fully loaded or empty. This was an ideal situation.
- In figure 7, most of the front axles weighed between 8,000 and 12,000 lb. The peaks were about 10,000 lb. Figure 8 shows that the average front axle weights of Class 9 trucks were close to 10,000 lb. every month. The front axle was heavier when the truck was loaded. However, the average front axle weights for Class 9 trucks for each loading situation (unloaded, partially loaded, and fully loaded) were all within the expected range of 10,000±2,000 lb. These evidences indicated that the WIM scale was properly calibrated.
- Finally, the average drive tandem axle weights were within the expected range of 33,000±3,000 lb.
- The plots did not reveal any problem with the weight data. Thus, the data set from this station was included for further analyses.

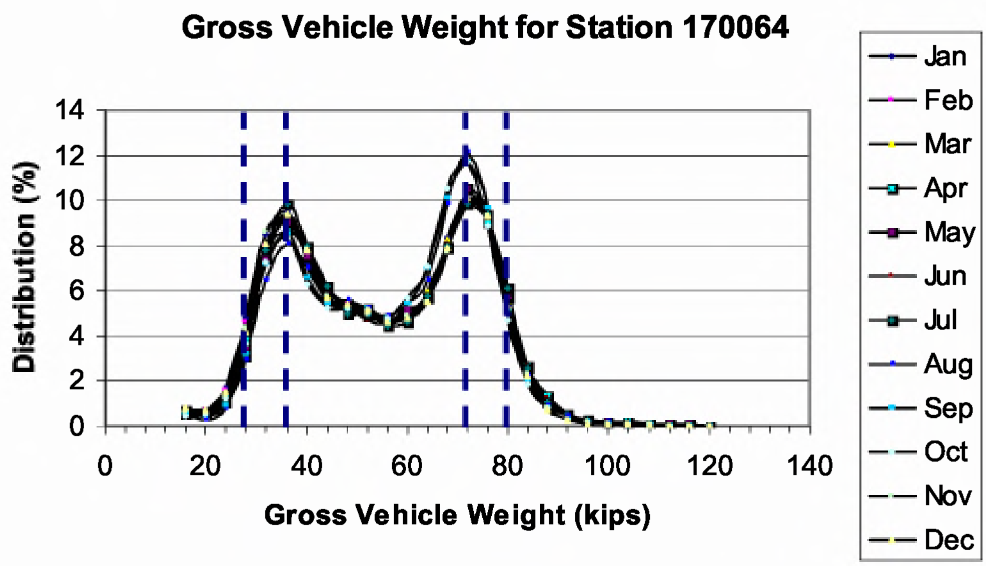

FIGURE 6. Gross Vehicle Weight Distributions for Station 170064 (I-540, Alma)

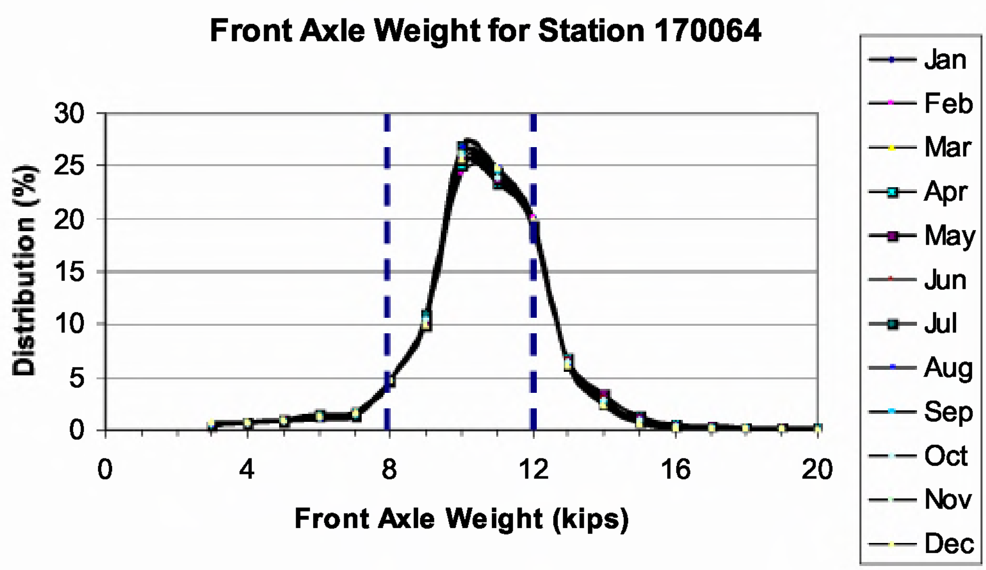

FIGURE 7. Front Axle Weight Distributions for Station 170064

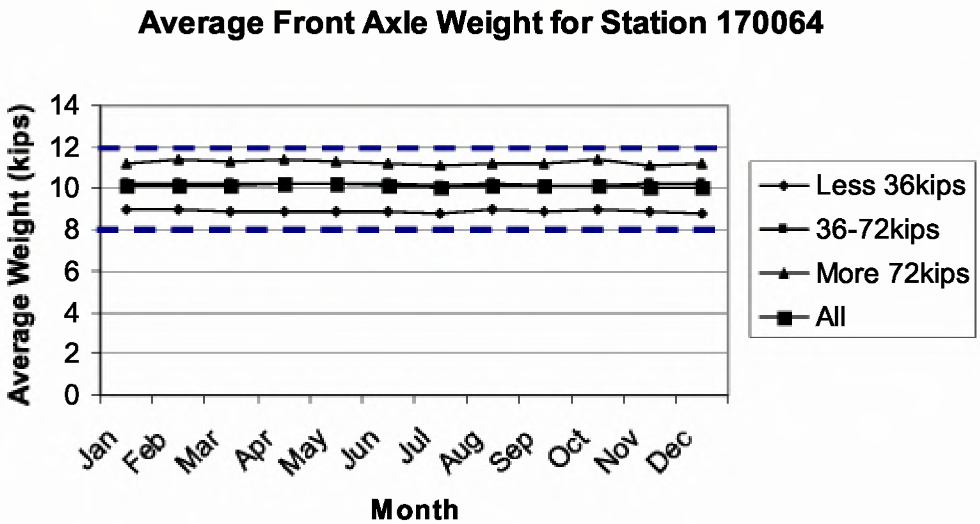

FIGURE 8. Average Front Axle Weights for Station 170064

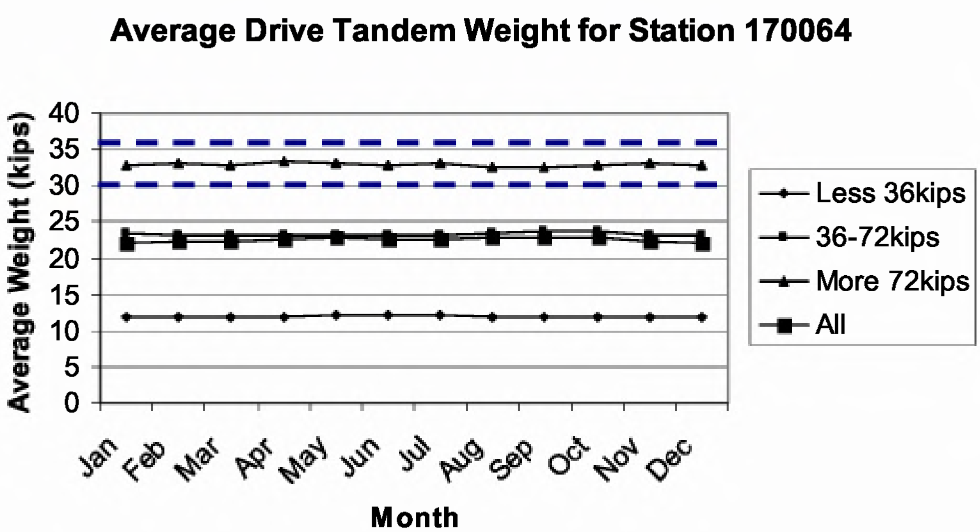

FIGURE 9. Average Drive Tandem Axle Weights for Station 170064

If the plots of weight data from a station, like those for Station 170064, did not reveal any problems, the weight data from that station were included for further analyses. If the plots for a station indicated problems that influence the data accuracy, the weight data were not included, and the WIM scale should be recalibrated immediately. The problems varied from station to station, but four general failure cases were observed in the evaluation process.

- Case 1: Fluctuated Data. When a WIM scale failed, the weight data collected from that station were fluctuated. Figure 10 show an example of Case 1 failure for the weight data from Station 680032. Compared to Figures 6, the data in Figure 10 were fluctuated. Figure 11 also revealed the scale failure. The front axle weights were not consistent. It was obvious that the WIM scale was failed, and the calibration should be checked immediately. Other examples of Case 1 failure are shown in the plots from Stations 680025 and 670027 in Figures 12 and 13, respectively.

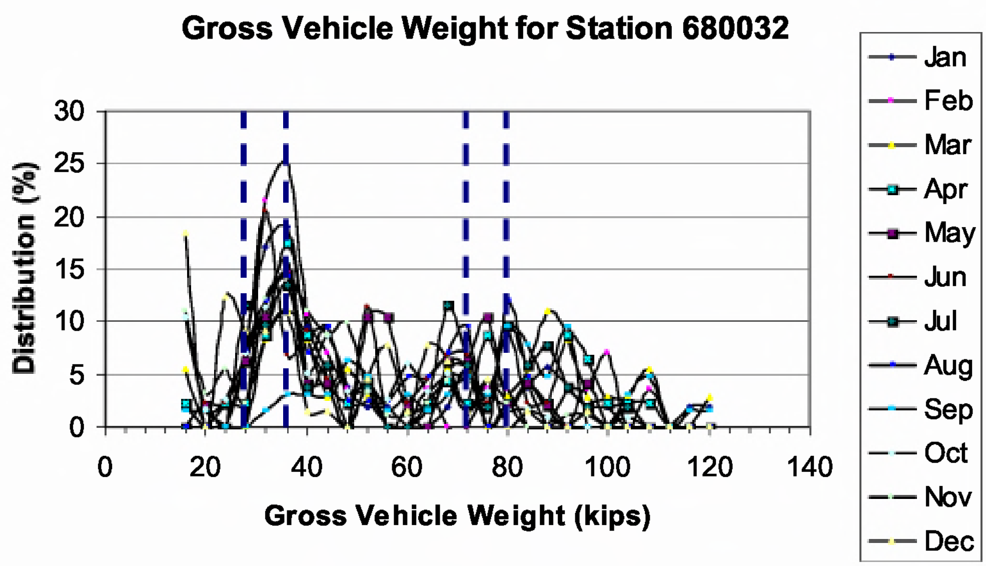

FIGURE 10. Gross Weight Distributions for Station 680032 (Madison, St Francis)

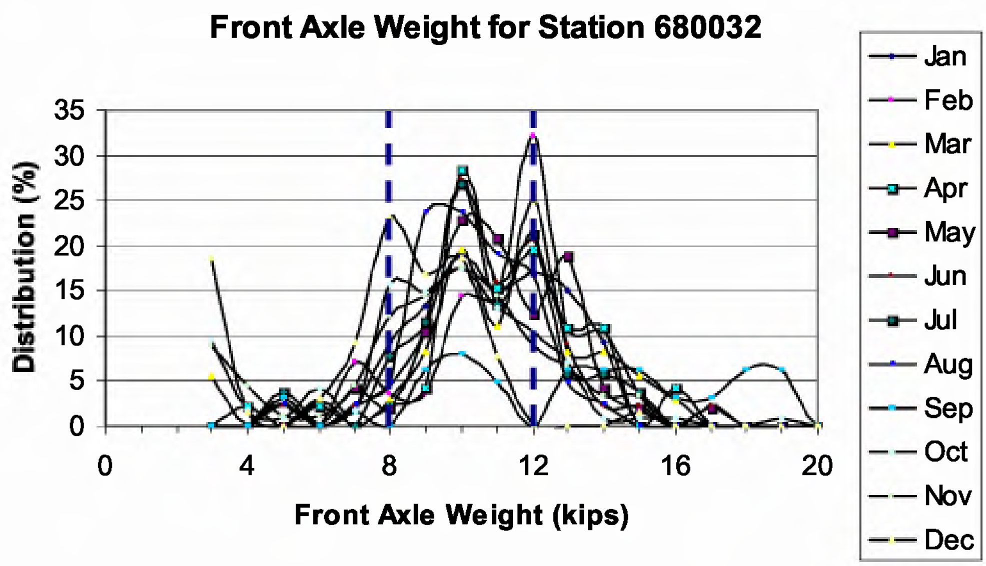

FIGURE 11. Front Axle Weight Distributions for Station 680032

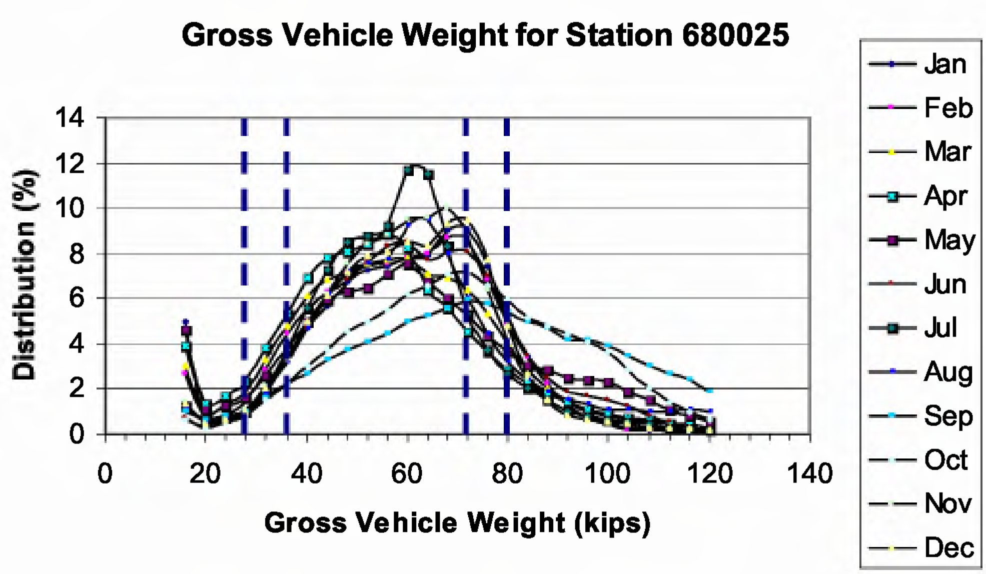

FIGURE 12. Gross Weight Distributions for Station 680025 (Forrest City, St Francis)

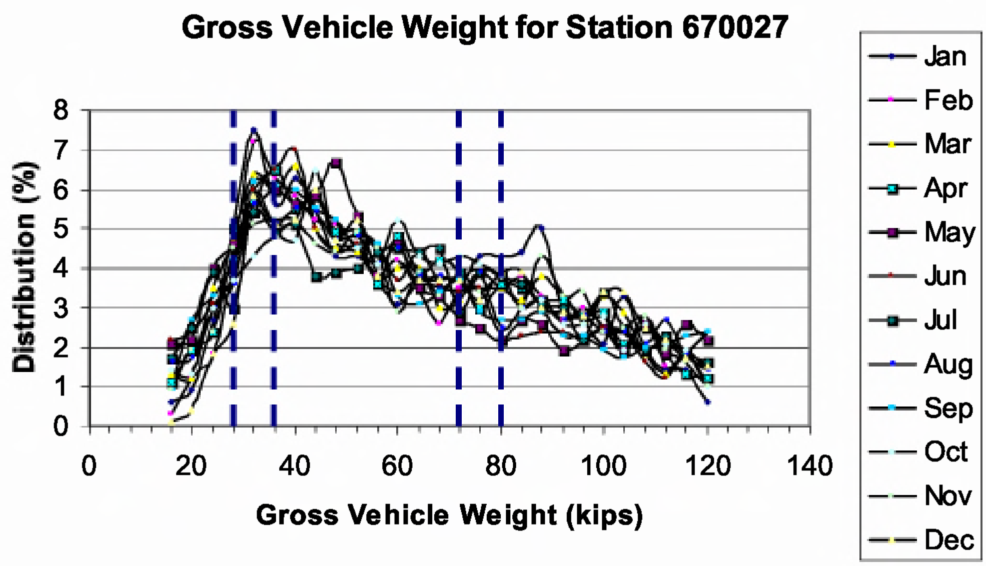

FIGURE 13. Gross Weight Distributions for Station 670027 (Cave City, Sharp)

- Case 2: One Peak Shifted. The peaks representing unloaded trucks were at the expected location, but the peaks representing loaded trucks were shifted either to the left or right. Figure 12, which presents the weight data from Station 350215, shows an example of this case. For this case, another graph should be used to evaluate the weight data, and a plot of average front axle weights could be useful. Figure 15 shows such a plot for the weight data from Station 350215. The average front axle weights for different loading situations (unloaded, partially loaded, and fully loaded) were fluctuated month to month. Parts of the curves lied outside the expected range of 10,000±2,000 lb. Compared to Figure 8, Figure 13 reveals some problems with the data from Station 350215. Thus, the weight data from this station were not included for further analyses.

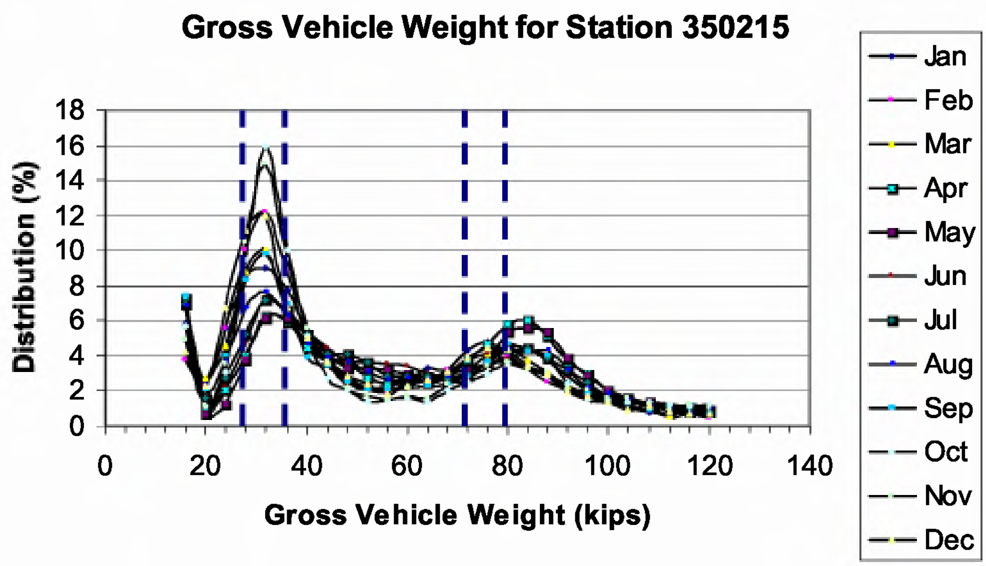

FIGURE 14. Gross Weight Distributions for Station 350215 (Pine Bluff, Jefferson)

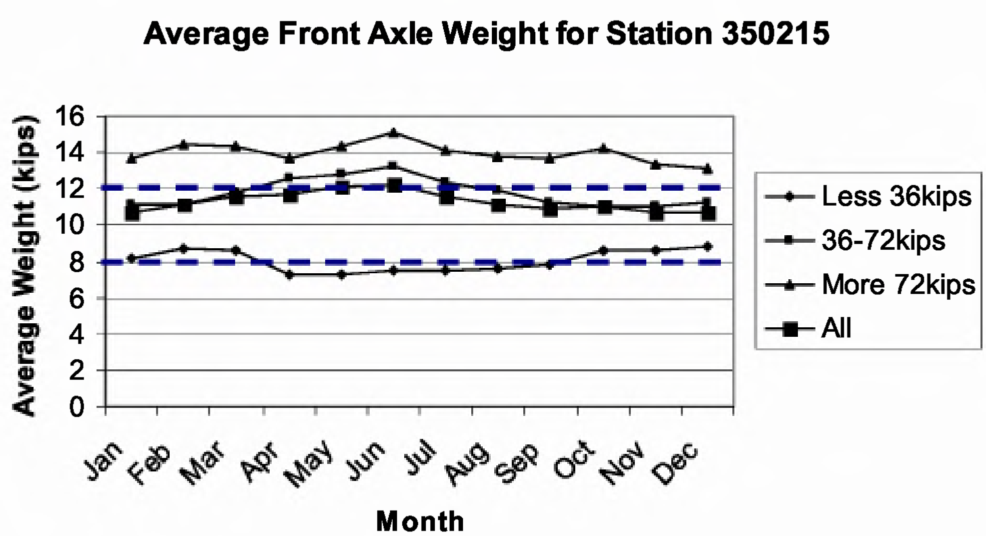

FIGURE 15. Average Front Axle Weights for Station 350215

- Case 3: Two Peaks Shifted. A WIM scale is linearly calibrated. Thus, if the two peaks representing unloaded and loaded trucks are shifted to the same direction, the scale is likely out of calibration. An example of Case 3 is shown in Figure 16. The two peak locations were shifted to the right. Thus, the scale was likely over-calibrated, and the weight data from this station were not included for further analyses.

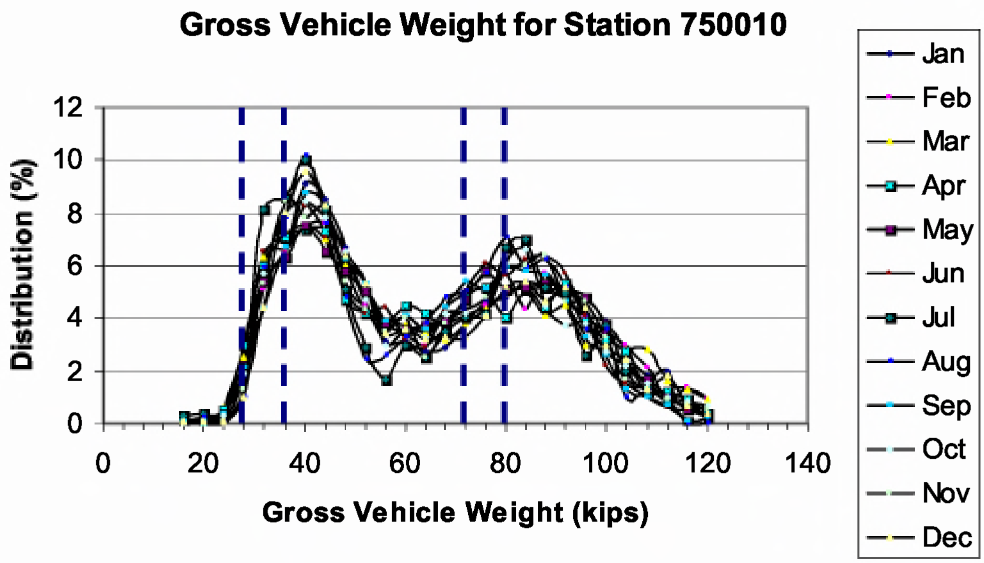

FIGURE 16. Gross Weight Distributions for Station 750010 (Havana, Yell)

- Case 4: Overweight Trucks. When the number of overweight Class 9 trucks, especially over 100,000-lb., increases significantly, the scale is likely out of calibration. Figure 17 shows an example of Case 4 failure of the WIM scale at Station 730068. The number of Class 9 trucks over 100,000 lb. significantly increased several months during the winter. To evaluate the weight data from this station, a plot of the average front axle weights, as shown in Figure 18, were generated. Compared to Figure 8, Figure 18 shows some problems happened at Station 730068. Thus, the weight data were not accurate and should not be included for further analyses.

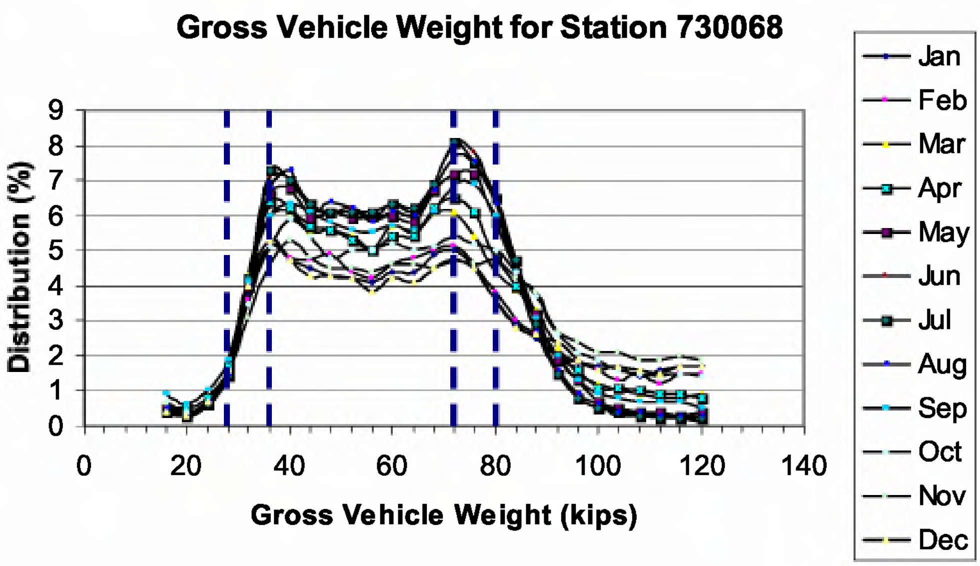

FIGURE 17. Gross Weight Distributions for Station 730068 (Bald Knob, White)

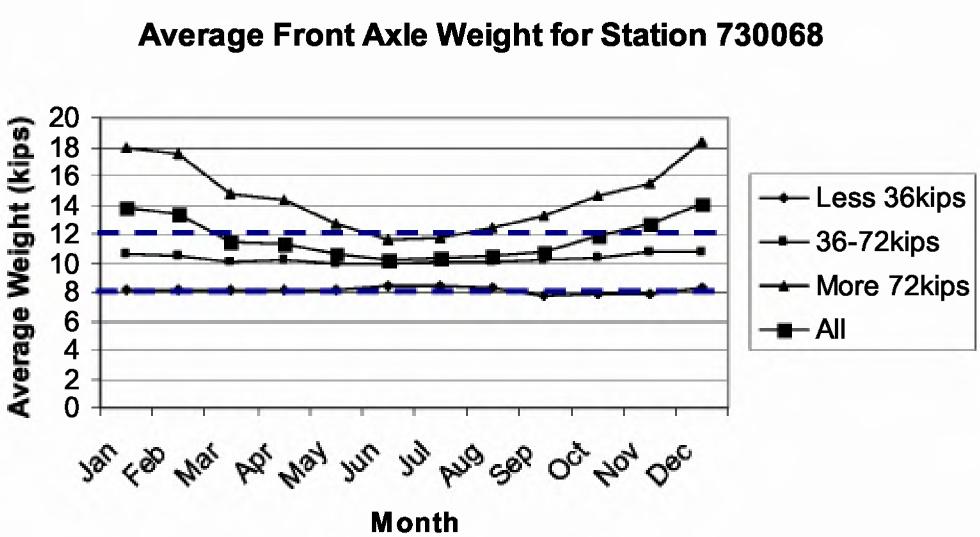

FIGURE 18. Average Front Axle Weights for Station 730068

Table 15 summarizes the evaluation results of weight data. The weight data from 25 stations are evaluated. The weight data from ten stations are considered "good", 14 stations considered "bad", and one station not evaluated. Ten "good" datasets are selected for further analyses.

TABLE 15. Summary of Weight Data Evaluation

Evaluation Result	Station
"Good" Weight Data	10 stations: 170064, 460006, 580236, 071813, 230001, 720034, 740035, 480037, 430038, 600870
Case 1: Inconsistency	5 stations: 680025, 281983, 670027, 680032, 180002
Case 2: One Peak Shifted	4 stations: 430037, 481524, 350215, 460286
Case 3: Two Peaks Shifted	4 stations: 171651, 290002, 750010, 350314
Case 4: Overweight Trucks Increase	1 station: 730068

3.3 Development of Traffic Inputs

The WIM data that passed the quality control checks in the previous section are used to develop traffic inputs for MEPDG. Development of the traffic inputs is a data reduction process. The procedure divides a massive traffic dataset into groups. Each group is manipulated to provide one or a set of traffic inputs. The analysis is intensive, and it can only be handled using computer programs. The following sections describe the computer programs developed for this study and the analyses performed to develop traffic inputs.

3.3.1 Computer Programs for Development of Traffic Inputs

Since a WIM scale records the information of every vehicle passing the sensors, the amount of data collected at a WIM station is significant. For this study, FHWA's C-Card and W-Card formats were used, and the formats are described in Tables 9 and 10. One file contained classification or weight data from all WIM stations that were active in a specific month in Arkansas. There were 55 WIM stations operated in Arkansas from 2003 through 2005. One file contained up to nine million records. It was impossible to handle the data reduction process manually. First, *Trafload*, a computer program developed under NCHRP Project 1-39 for generating traffic inputs for MEPDG, was tried. The program was able to import the classification data in C-Card files. However, the software could not read the W-Card files provided by AHTD. The file format was checked carefully, and no error was found. The software error is unknown. Thus, it was decided that the *trafload* software not be used in this project.

For this study, two computer programs were developed to reduce the data and generate the traffic inputs for MEPDG. One program, named "CLASS.xls" was for handling classification data, and the other, named "WEIGHT.xls" is for vehicle weight data.

The "CLASS.xls" program used for development of the volume adjustment factors was developed following the steps described below:

- Opened a C-Card file (One file contained classification data from all active WIM stations throughout the state of Arkansas in one month)
- Found the range containing all weight data from a specific station
- Counted the number of records using different filters to determine the following information for one month:

- Traffic volume and the number of days counted
- Traffic volume in each direction
- Traffic volume in outside lanes
- Traffic volume by classification
- Traffic volume for each hour

- Summarized the monthly information in the previous step and determined the following traffic volume inputs for the station:
  - Two-way annual average daily traffic (AADT)
  - Percent of truck traffic (Class 4 through 13)
  - Two-way annual average daily truck traffic (AADTT)
  - Percent of trucks in each direction
  - Percent of trucks in outside lanes
- Determined the following volume adjustment factors for the station:
  - Monthly adjustment factors
  - Vehicle class distribution factors
  - Hourly distribution factors

The "WEIGHT.xls" program used for development of the axle load spectra was programmed following the steps described below:

- Opened a W-Card file (One file contained weight data from all active WIM stations throughout the state of Arkansas in one month)
- Found the range containing all weight data from a specific station
- Counted the number of axles in each weight bin for different vehicle classes using the following load intervals

    - Single axles – 3,000 lb to 40,000 lb at 1,000-lb intervals
    - Tandem axles – 6,000 lb to 80,000 lb at 2,000-lb intervals
    - Tridem and quad axles – 12,000 lb to 102,000 lb at 3000-lb intervals
- Summarized the monthly axle load distribution in the previous step and determined the axle load spectra for the site
- Finally saved the axle load spectra to a file which could be read automatically into the MEPDG software

The two programs can be used to develop the traffic inputs for a specific site. The inputs can be used for Level 1 in the MEPDG software. Examples of the traffic inputs determined using the two programs are presented in this section.

Table 16 shows the traffic inputs for the base year manipulated from the classification data collected at Station 460006. Tables 17 through 19 show the volume adjustment factors, such as monthly adjustment factors, vehicle class distribution factors, and hourly distribution factors, which were determined from the data collected at the same station. Tables 20 through 22 show examples of the load spectra for single, tandem, and tridem axles determined from the weight data collected at Station 460006. The axle load spectra can be saved to a text file which can be imported into the MEPDG software. The information is ready to use for Level 1 traffic inputs in MEPDG. In order to develop the regional/statewide traffic inputs for Level 2, further analyses are needed. Development of Level 2 traffic inputs for Arkansas is presented in the following sections.

TABLE 16. Traffic Volume – Base Year Information (Station 460006)

Parameter	Level 1 Input
Annual Average Daily Traffic (AADT)	24,315
Percent of Trucks (Classes 4 through 13)	41.0
Annual Average Daily Truck Traffic (AADTT)	9975
Percent of Trucks in each Direction (EB/WB)	49.3/50.7
Percent of Trucks in Outside Lane	86.7

TABLE 17. Level 1 Monthly Adjustment Factors for Station 460006

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
Jan	1.03	0.87	0.86	1.60	0.57	0.90	0.76	0.95	0.96	0.65
Feb	1.10	0.87	0.93	0.39	0.58	1.00	0.96	1.02	1.05	0.85
Mar	1.10	1.09	1.19	0.44	0.72	1.06	0.93	1.04	1.04	0.86
Apr	0.47	0.67	0.38	0.90	1.31	1.05	0.94	0.92	0.91	0.92
May	0.96	1.06	1.12	0.67	0.67	1.02	1.12	0.99	1.00	1.32
Jun	0.93	1.08	1.09	0.90	0.74	0.95	1.01	0.94	0.93	0.76
Jul	0.94	1.13	1.07	0.07	0.99	0.93	1.05	0.95	0.99	1.27
Aug	1.09	1.04	1.16	0.29	1.41	1.04	1.20	1.00	1.00	1.59
Sep	1.28	1.05	1.15	0.07	1.56	1.01	1.11	1.05	0.99	1.32
Oct	1.19	1.09	1.10	1.87	1.69	1.05	1.19	1.09	1.07	1.05
Nov	0.97	1.07	1.06	1.61	1.21	1.13	0.99	1.16	1.14	0.87
Dec	0.92	0.99	0.89	3.19	0.55	0.88	0.72	0.90	0.92	0.54

TABLE 18. Level 1 Vehicle Class Distribution Factors for Station 460006

Vehicle Class	Annual Distribution
Class 4	1.1
Class 5	10.2
Class 6	16.0
Class 7	0.0
Class 8	5.3
Class 9	61.2
Class 10	0.4
Class 11	4.2
Class 12	1.5
Class 13	0.1

TABLE 19. Level 1 Hourly Distribution Factors for Station 460006

Hour	Annual Distribution
0	2.7
1	2.6
2	2.4
3	2.4
4	2.4
5	2.6
6	3.1
7	3.7
8	4.4
9	4.8
10	5.1
11	5.2
12	5.4
13	5.5
14	5.6
15	5.7
16	5.7
17	5.5
18	5.2
19	4.8
20	4.5
21	4.1
22	3.6
23	3.1

TABLE 20. Level 1 Single Axle Load Spectra for Station 460006

A. Load	Vehicle Class									
(lb)	4	5	6	7	8	9	10	11	12	13
3000	0.847	9.975	0.805	0.000	7.339	0.233	0.288	0.259	0.315	3.114
4000	2.159	25.699	2.537	1.899	16.349	1.018	1.143	1.022	1.293	6.353
5000	2.058	15.103	2.277	0.633	10.265	0.767	1.181	1.698	2.151	4.712
6000	3.077	12.456	3.343	1.266	10.742	1.216	2.279	3.083	4.048	6.062
7000	4.603	8.871	5.555	2.532	10.373	2.825	6.588	4.528	6.143	6.124
8000	5.801	5.472	9.427	3.165	7.994	6.895	11.737	5.842	8.439	5.792
9000	10.829	5.272	20.482	12.025	8.545	20.720	23.164	10.702	15.547	7.806
10000	10.423	3.283	18.180	7.595	5.368	23.507	18.461	9.869	13.596	6.311
11000	13.028	3.255	16.313	15.823	4.975	24.940	17.522	11.376	14.498	7.017
12000	9.925	2.036	6.610	14.557	3.027	10.168	7.519	8.183	8.761	5.377
13000	10.400	2.034	3.961	10.759	2.974	4.332	4.165	9.601	8.265	5.024
14000	6.455	1.347	1.789	8.228	2.000	1.033	1.537	7.160	4.795	4.443
15000	5.891	1.356	1.611	10.759	2.091	0.556	1.015	7.904	4.342	5.356
16000	3.389	0.844	1.054	4.430	1.315	0.297	0.545	5.145	2.327	3.695
17000	2.871	0.818	1.074	1.899	1.375	0.288	0.553	4.999	1.854	4.609
18000	1.675	0.515	0.731	0.633	0.870	0.185	0.371	2.820	0.959	3.488
19000	1.622	0.441	0.803	1.266	0.825	0.182	0.401	2.320	0.745	3.425
20000	0.904	0.251	0.538	0.000	0.543	0.115	0.212	1.165	0.398	1.931
21000	0.863	0.231	0.601	0.000	0.533	0.112	0.250	0.878	0.323	1.578
22000	0.654	0.158	0.503	0.000	0.438	0.094	0.167	0.474	0.246	1.432
23000	0.473	0.096	0.335	0.000	0.284	0.061	0.144	0.229	0.153	0.727
24000	0.395	0.100	0.376	0.000	0.307	0.064	0.167	0.174	0.139	0.706
25000	0.264	0.062	0.237	0.000	0.195	0.047	0.068	0.097	0.105	0.436
26000	0.289	0.066	0.230	1.899	0.208	0.050	0.083	0.085	0.111	0.955
27000	0.161	0.038	0.146	0.633	0.140	0.036	0.061	0.057	0.066	0.602
28000	0.184	0.037	0.143	0.000	0.167	0.041	0.083	0.058	0.070	0.436
29000	0.110	0.029	0.090	0.000	0.123	0.025	0.045	0.039	0.057	0.208
30000	0.106	0.032	0.080	0.000	0.122	0.029	0.061	0.047	0.056	0.332
31000	0.094	0.020	0.042	0.000	0.078	0.020	0.023	0.031	0.036	0.374
32000	0.101	0.021	0.041	0.000	0.107	0.022	0.023	0.032	0.039	0.436
33000	0.055	0.013	0.022	0.000	0.066	0.017	0.015	0.023	0.026	0.187
34000	0.062	0.014	0.024	0.000	0.060	0.019	0.015	0.024	0.024	0.228
35000	0.046	0.011	0.012	0.000	0.047	0.013	0.015	0.017	0.019	0.249
36000	0.062	0.013	0.010	0.000	0.055	0.016	0.045	0.018	0.019	0.104
37000	0.039	0.011	0.008	0.000	0.044	0.014	0.023	0.016	0.015	0.062
38000	0.018	0.007	0.004	0.000	0.016	0.013	0.008	0.010	0.009	0.021
39000	0.037	0.008	0.004	0.000	0.021	0.014	0.008	0.009	0.006	0.083
40000	0.014	0.002	0.002	0.000	0.013	0.010	0.008	0.007	0.003	0.145
41000	0.014	0.001	0.000	0.000	0.006	0.004	0.008	0.002	0.002	0.062

TABLE 21. Level 1 Tandem Axle Load Spectra for Station 460006

A. Load	Vehicle Class									
(lb)	4	5	6	7	8	9	10	11	12	13
6000	0.742	0.000	0.788	0.000	8.700	0.426	0.307	0.000	0.137	2.625
8000	1.655	0.000	2.937	0.000	15.555	1.404	0.750	0.000	0.687	5.868
10000	2.356	0.000	4.444	0.000	14.123	2.699	1.199	0.000	2.179	5.927
12000	3.158	0.000	5.634	0.000	13.883	4.124	1.957	0.000	2.652	4.866
14000	4.014	0.000	6.492	0.000	10.921	5.933	4.505	0.000	3.760	5.220
16000	4.075	0.000	6.036	0.000	8.014	6.578	8.771	0.000	5.841	4.807
18000	4.878	0.000	6.116	0.000	6.469	7.434	8.628	0.000	9.992	6.075
20000	5.441	0.000	6.251	0.000	4.918	7.722	8.418	0.000	13.903	5.692
22000	5.983	0.000	6.448	0.000	3.976	7.585	7.376	0.000	15.565	5.102
24000	7.307	0.000	7.153	0.000	3.012	7.458	8.313	0.000	14.082	5.662
26000	8.705	0.000	8.354	0.000	2.226	7.810	8.163	0.000	11.471	5.397
28000	11.097	0.000	8.757	0.000	1.683	8.599	7.699	0.000	7.717	5.927
30000	11.472	0.000	7.905	0.000	1.312	8.704	7.706	0.000	4.636	6.901
32000	9.390	0.000	6.101	0.000	0.971	7.637	6.897	0.000	2.354	6.104
34000	6.667	0.000	4.204	0.000	0.747	5.813	5.502	0.000	1.496	5.662
36000	4.259	0.000	2.829	0.000	0.605	3.835	3.966	0.000	0.822	4.689
38000	2.649	0.000	1.841	0.000	0.426	2.278	3.036	0.000	0.576	3.539
40000	1.536	0.000	1.338	0.000	0.374	1.277	1.852	0.000	0.435	2.713
42000	1.113	0.000	1.103	0.000	0.340	0.797	1.274	0.000	0.382	1.563
44000	0.746	0.000	0.769	0.000	0.266	0.442	0.825	0.000	0.238	0.973
46000	0.579	0.000	0.618	0.000	0.260	0.294	0.540	0.000	0.217	0.678
48000	0.428	0.000	0.539	0.000	0.185	0.220	0.397	0.000	0.160	0.796
50000	0.322	0.000	0.478	0.000	0.165	0.164	0.322	0.000	0.145	0.649
52000	0.289	0.000	0.405	0.000	0.132	0.131	0.270	0.000	0.109	0.383
54000	0.212	0.000	0.355	0.000	0.142	0.105	0.187	0.000	0.090	0.354
56000	0.196	0.000	0.325	0.000	0.101	0.085	0.187	0.000	0.082	0.354
58000	0.155	0.000	0.284	0.000	0.093	0.071	0.172	0.000	0.065	0.236
60000	0.139	0.000	0.258	0.000	0.089	0.061	0.142	0.000	0.042	0.177
62000	0.094	0.000	0.222	0.000	0.070	0.052	0.142	0.000	0.032	0.147
64000	0.090	0.000	0.191	0.000	0.067	0.043	0.127	0.000	0.031	0.118
66000	0.061	0.000	0.184	0.000	0.035	0.038	0.075	0.000	0.019	0.177
68000	0.053	0.000	0.156	0.000	0.031	0.034	0.052	0.000	0.031	0.236
70000	0.037	0.000	0.128	0.000	0.029	0.030	0.060	0.000	0.010	0.147
72000	0.024	0.000	0.118	0.000	0.038	0.029	0.030	0.000	0.013	0.059
74000	0.020	0.000	0.087	0.000	0.012	0.023	0.037	0.000	0.010	0.059
76000	0.008	0.000	0.062	0.000	0.011	0.021	0.015	0.000	0.000	0.059
78000	0.033	0.000	0.044	0.000	0.009	0.019	0.052	0.000	0.011	0.029
80000	0.008	0.000	0.035	0.000	0.006	0.017	0.022	0.000	0.004	0.029
82000	0.012	0.000	0.012	0.000	0.003	0.007	0.022	0.000	0.006	0.000

TABLE 22. Level 1 Tridem Axle Load Spectra for Station 460006

A. Load	Vehicle Class									
(lb)	4	5	6	7	8	9	10	11	12	13
12000	0.000	0.000	0.000	0.000	0.000	0.000	3.063	0.000	0.000	0.000
15000	0.000	0.000	0.000	0.633	0.000	0.000	8.399	0.000	0.000	0.000
18000	0.000	0.000	0.000	1.899	0.000	0.000	10.890	0.000	0.000	0.000
21000	0.000	0.000	0.000	1.266	0.000	0.000	8.312	0.000	0.000	0.000
24000	0.000	0.000	0.000	1.266	0.000	0.000	6.534	0.000	0.000	0.000
27000	0.000	0.000	0.000	1.899	0.000	0.000	6.722	0.000	0.000	0.000
30000	0.000	0.000	0.000	1.266	0.000	0.000	6.322	0.000	0.000	0.000
33000	0.000	0.000	0.000	4.430	0.000	0.000	7.505	0.000	0.000	0.000
36000	0.000	0.000	0.000	8.861	0.000	0.000	8.477	0.000	0.000	0.000
39000	0.000	0.000	0.000	12.025	0.000	0.000	6.973	0.000	0.000	0.000
42000	0.000	0.000	0.000	15.823	0.000	0.000	6.612	0.000	0.000	0.000
45000	0.000	0.000	0.000	18.354	0.000	0.000	5.233	0.000	0.000	0.000
48000	0.000	0.000	0.000	12.025	0.000	0.000	4.199	0.000	0.000	0.000
51000	0.000	0.000	0.000	9.494	0.000	0.000	2.907	0.000	0.000	0.000
54000	0.000	0.000	0.000	3.797	0.000	0.000	2.343	0.000	0.000	0.000
57000	0.000	0.000	0.000	1.899	0.000	0.000	1.512	0.000	0.000	0.000
60000	0.000	0.000	0.000	0.633	0.000	0.000	1.003	0.000	0.000	0.000
63000	0.000	0.000	0.000	0.000	0.000	0.000	0.635	0.000	0.000	0.000
66000	0.000	0.000	0.000	0.633	0.000	0.000	0.431	0.000	0.000	0.000
69000	0.000	0.000	0.000	0.000	0.000	0.000	0.415	0.000	0.000	0.000
72000	0.000	0.000	0.000	1.266	0.000	0.000	0.353	0.000	0.000	0.000
75000	0.000	0.000	0.000	0.633	0.000	0.000	0.235	0.000	0.000	0.000
78000	0.000	0.000	0.000	0.633	0.000	0.000	0.165	0.000	0.000	0.000
81000	0.000	0.000	0.000	0.000	0.000	0.000	0.141	0.000	0.000	0.000
84000	0.000	0.000	0.000	0.000	0.000	0.000	0.102	0.000	0.000	0.000
87000	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.000	0.000	0.000
90000	0.000	0.000	0.000	1.266	0.000	0.000	0.078	0.000	0.000	0.000
93000	0.000	0.000	0.000	0.000	0.000	0.000	0.102	0.000	0.000	0.000
96000	0.000	0.000	0.000	0.000	0.000	0.000	0.078	0.000	0.000	0.000
99000	0.000	0.000	0.000	0.000	0.000	0.000	0.094	0.000	0.000	0.000
102000	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.000	0.000	0.000

3.3.2 Development of Regional/Statewide Traffic Inputs

"Good" classification data from 24 stations and "good" weight data from 10 stations were used to develop the regional/statewide traffic inputs. The two programs described in the previous section were used to develop Level 1 inputs for these stations. The Level 1 inputs were further analyzed to provide the regional/statewide traffic inputs for Arkansas. This section presents the analysis processes.

Traffic Volume – Base Year Information

Tables 23 and 24 summarize the traffic volume inputs determined using classification data from the 24 WIM stations. The information in Tables 23 and 24 was not used to develop the regional/statewide traffic volume inputs. It is recommended that the traffic volume inputs be site specific, as discussed in the strategic plan for development of the MEPDG traffic inputs for Arkansas. The traffic volume inputs for a design project can be provided by the Technical Services. The database is updated every year and covers almost all functional classes throughout the state.

The directional distribution factors (DDF) shown in Tables 23 and 24 are mostly between 50 and 53 percent. MEPDG recommends a default DDF of 55 percent be used based on the LTPP data. The ranges of lane distribution factors (LDF) shown in Tables 23 and 24 are as follows:

- One-lane in each direction, LDF is 1.00.
- Two-lane in each direction, LDF is between 0.6 and 0.9, compared to the default LDF of 0.9.
- Three-lane in each direction, LDF is 0.4, compared to the default LDF of 0.6.

TABLE 23. Traffic Volume Information for Roadways in Rural Areas

Station	Route	AADT	Percent Truck	AADTT	Direction	%Truck/ Direction	No. Lanes	%Truck/ O. Lane
Interstate 01								
170064	I-540	20,358	22.5	4,587	NB/SB	51.8/48.2	4	82.2
430037	I-40	32,037	47.2	15,119	EB/WB	49.7/50.3	4	80.6
460006	I-30	24,484	41.4	10,125	EB/WB	49.1/50.9	4	86.8
481524	I-40	31,163	51.3	16,000	EB/WB	49.1/50.9	4	79.4
580236	I-40	25,561	32.0	8,186	EB/WB	50.4/49.6	4	85.3
680025	I-40	29,196	49.9	14,560	EB/WB	50.3/49.7	4	78.2
Principle Arterial 02								
071813	US 79	7,843	18.6	1,460	NB/SB	51.0/49.0	4	66.8
230001	US 65	8,240	12.6	1,039	NB/SB	49.4/50.6	4	76.0
281983	US 412	3,037	25.2	765	EB/WB	50.5/49.5	4	64.6
720034	US 412	19,163	15.6	2,990	EB/WB	50.5/49.5	4	71.6
730068	US 67	8,644	23.1	1,996	NB/SB	51.6/48.4	4	91.0
Minor Arterial 06								
171651	SH 59	1,214	18.0	218	NB/SB	46.8/53.2	2	100.0
290002	US 278	2,399	16.6	398	EB/WB	48.8/51.2	2	100.0
740035	US 64	4,891	21.4	1,048	EB/WB	49.7/50.3	2	100.0
750010	SH 10	1,734	15.5	269	EB/WB	50.4/49.6	2	100.0
Major Collector 07								
480037	US 70	2,970	20.2	601	EB/WB	49.3/50.7	2	100.0
670027	SH 115	1,523	14.5	221	NB/SB	53.9/46.1	2	100.0
680032	SH 50	900	5.8	52	EB/WB	53.7/46.3	2	100.0

TABLE 24. Traffic Volume Information for Roadways in Urban Areas

Station	Route	AADT	Percent Truck	AADTT	Direction	%Truck / Direction	No. Lanes	%Truck / O. Lane
Interstate 11								
180002	I-55	41960	39.3	16481	NB/SB	49.1/50.9	4	62.9
350314	I-530	24505	13.0	3190	NB/SB	50.3/49.7	4	79.3
Other Freeways and Expressways 12								
430038	US 67	32813	11.7	3853	NB/SB	51.1/48.9	4	79.6
460286	SH 245	13036	18.4	2397	NB/SB	52.7/47.3	4	86.1
600870	SH 440	19881	16.0	3181	EB/WB	49.6/50.4	6	38.2
Collector 17								
350512	I-530	10	20.5	2	NB/SB	27.4/72.6	2	100

Volume Adjustment Factors

The following three volume adjustment factors are developed in this study:

- Vehicle class distribution
- Monthly distribution
- Hourly distribution

Vehicle Class Distribution Factors

Vehicle class distributions for each station were determined using the “CLASS.xls” program. Only annual vehicle class distribution was developed because the monthly vehicle class distributions are not significantly different. This can be verified by reviewing the monthly vehicle class distribution plot for each station shown in Appendix B. Vehicle class distribution for highways having the same functional class was grouped together. Figures 19 through 24 show the vehicle class distribution for six functional classes in Arkansas.

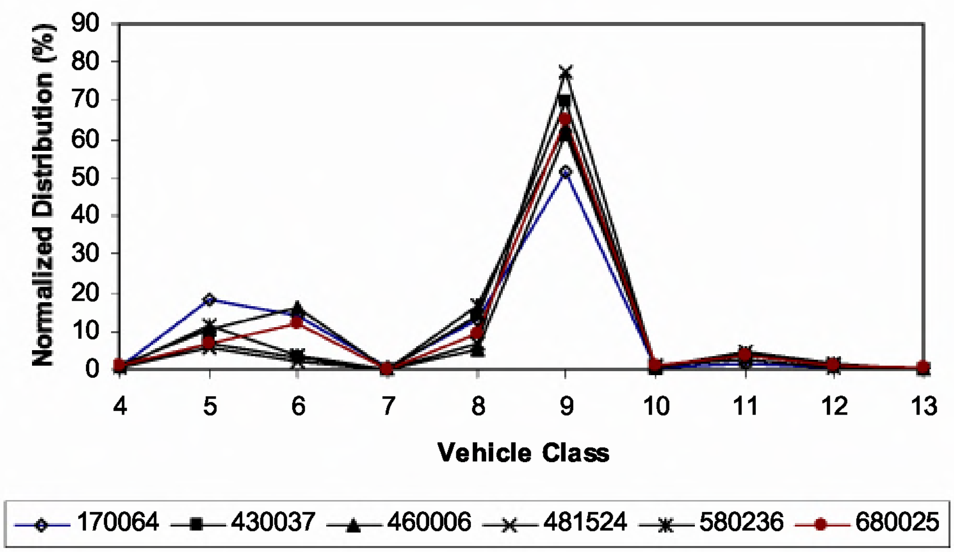

FIGURE 19. Vehicle Class Distribution for Functional Class 1

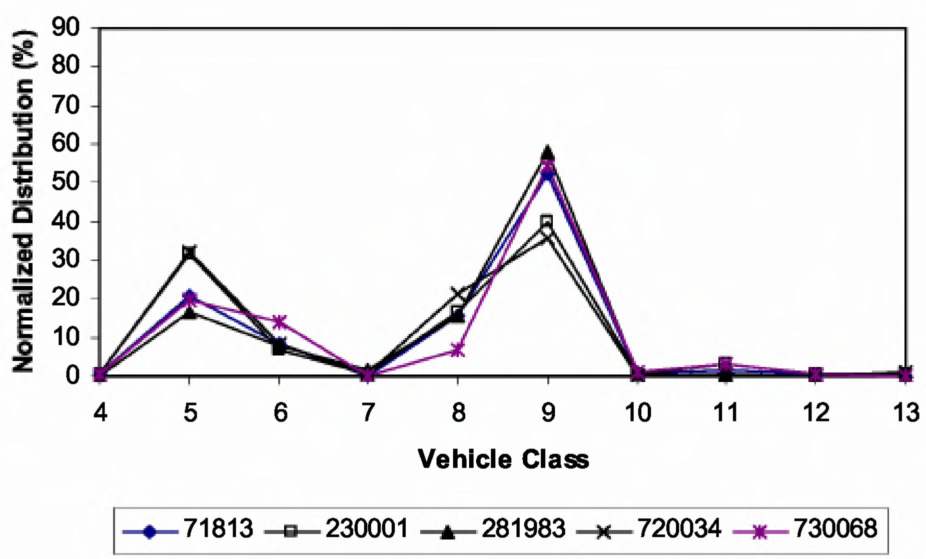

FIGURE 20. Vehicle Class Distribution for Functional Class 2

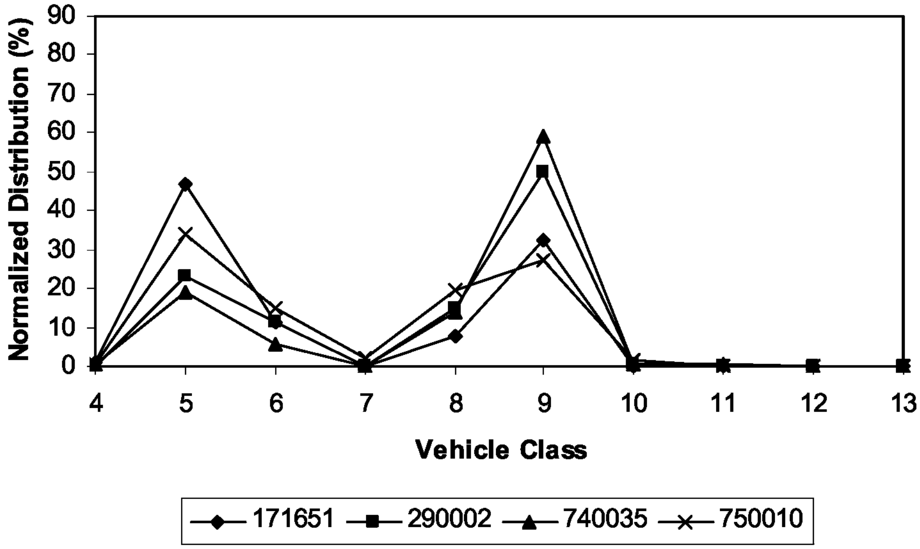

FIGURE 21. Vehicle Class Distribution for Functional Class 6

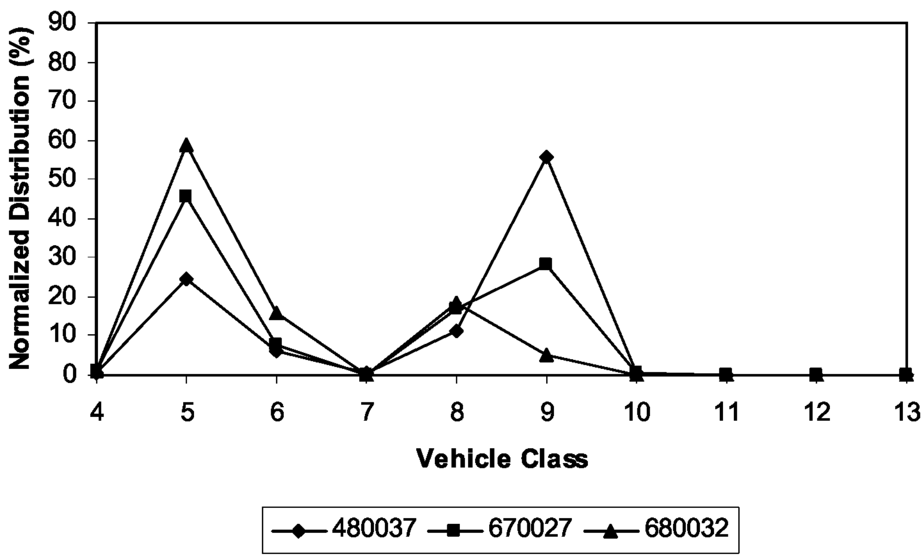

FIGURE 22. Vehicle Class Distribution for Functional Class 7

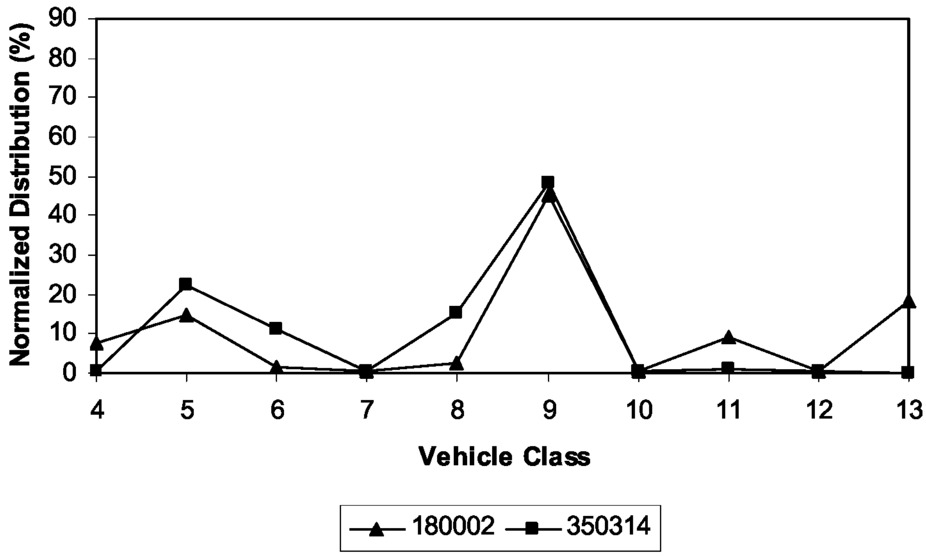

FIGURE 23. Vehicle Class Distribution for Functional Class 11

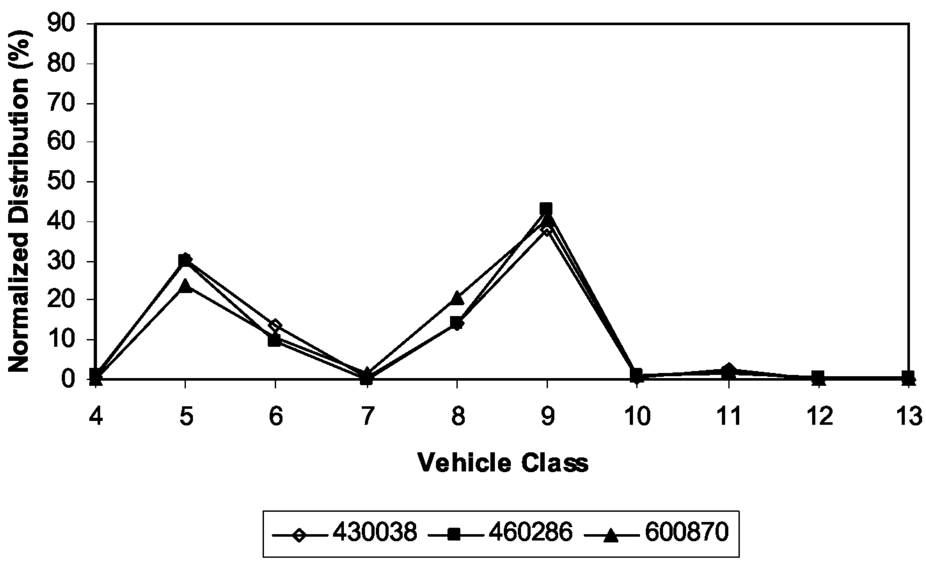

FIGURE 24. Vehicle Class Distribution for Functional Class 12

The above figures show that roadways within the same functional classification may not have similar distributions. Variation of vehicle class distributions for facilities within a functional classification was also reported in the literature (*2*,*17*). Thus, it is not recommended that vehicle class distributions be grouped based on their functional classification. A new method was proposed to group vehicle class distributions using seventeen truck traffic classification (TTC) groups (*2*). The TTC system is based on the distribution of four truck groups: buses, single-unit trucks, single-trailers, and multi-trailers. Guidelines for TTC grouping are presented in Table 6.

Vehicle class distribution for each station was then classified using the TTC system. Table 25 shows the vehicle lass distributions for each functional classification in this study. The vehicle class distributions within the same truck traffic classification were grouped together. Figures 25 through 31 show the vehicle class distributions for each truck traffic classification available in this study. The vehicle class distributions for the same TTC were in a good agreement. Each truck traffic classification in this study had a unique vehicle class distribution, except truck traffic classifications 6 and 7. Figure 32 compares the vehicle class distributions of TTC 6 and 7. The two vehicle class distributions were similar, so they were grouped together. The applicable vehicle class distributions for the truck traffic classifications available in Arkansas are summarized in Table 26. Significance of the developed vehicle classifications to the default values in the MEPDG software is evaluated in the next chapter.

TABLE 25. Truck Traffic Classification within Each Functional Classification

Station	Buses	Single-Units	Single-Trailers	Multi-Trailers	TTC
Functional Classification 1					
170064	0.5	32.4	64.9	2.3	7
430037	0.7	9.9	84.5	4.9	3
460006	1.1	26.2	66.9	5.8	7
481524	0.6	8.0	84.8	6.5	3
580236	0.3	14.9	81.1	3.7	3
680025	1.1	18.7	75.0	5.2	3
Functional Classification 2					
071813	0.3	29.2	68.8	1.8	6
230001	0.7	38.8	56.8	3.8	7
281983	0.2	25.8	73.9	0.1	6
720034	0.5	40.8	57.2	1.2	6
730068	0.5	33.8	61.8	3.8	7
Functional Classification 6					
171651	1.1	58.5	40.3	0.1	12
290002	0.2	34.2	65.5	0.1	6
740035	0.3	24.9	73.9	0.8	6
750010	0.3	51.1	48.4	0.1	9
Functional Classification 7					
480037	0.7	31.1	67.8	0.3	6
670027	1.0	53.5	45.4	0.0	9
680032	1.1	74.7	24.1	0.1	12
Functional Classification 11					
180002	7.6	16.9	48.3	27.3	13
350314	0.3	33.7	64.3	1.7	6
Functional Classification 12					
430038	0.3	44.5	52.7	2.5	10
460286	0.8	39.3	57.8	2.0	7
600870	0.1	35.6	61.8	2.5	7

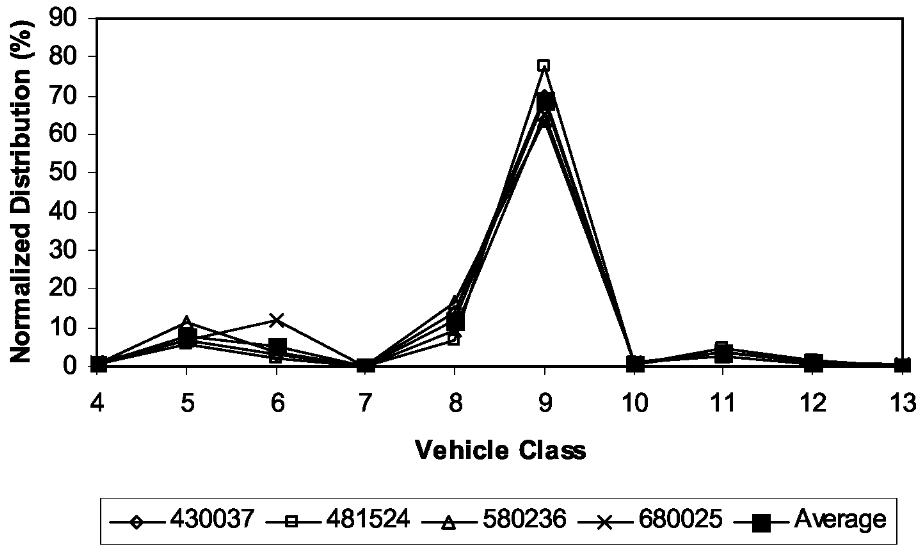

FIGURE 25. Vehicle Class Distribution for TTC 3

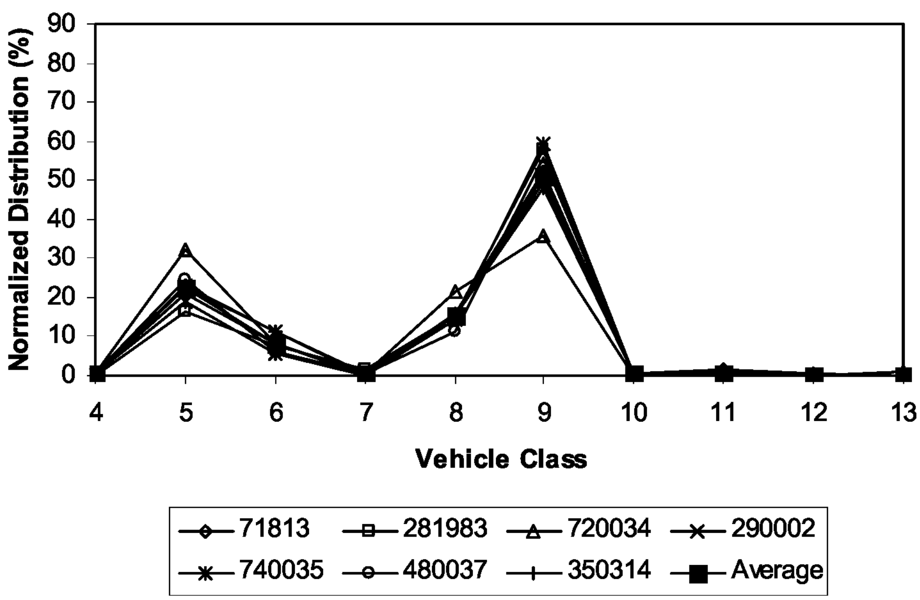

FIGURE 26. Vehicle Class Distribution for TTC 6

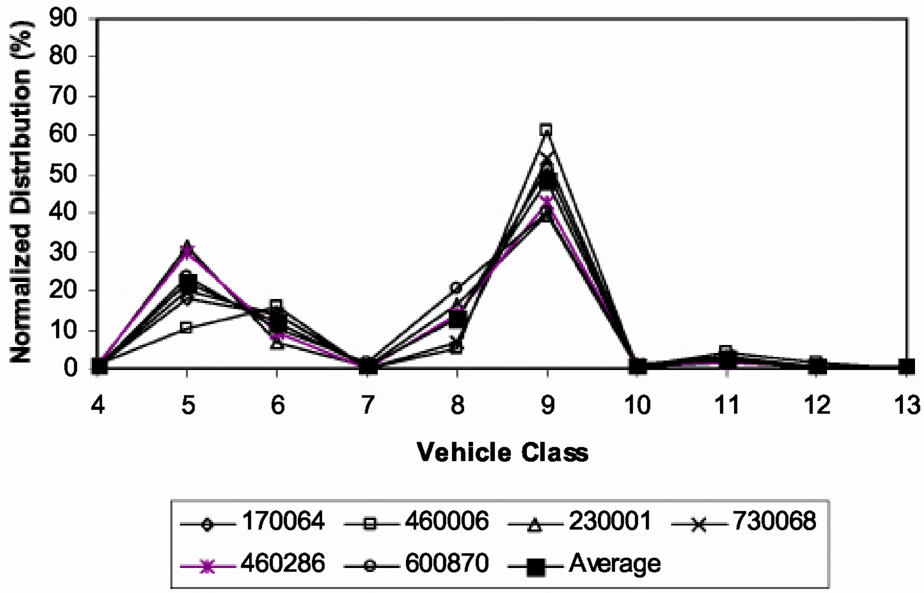

FIGURE 27. Vehicle Class Distribution for TTC 7

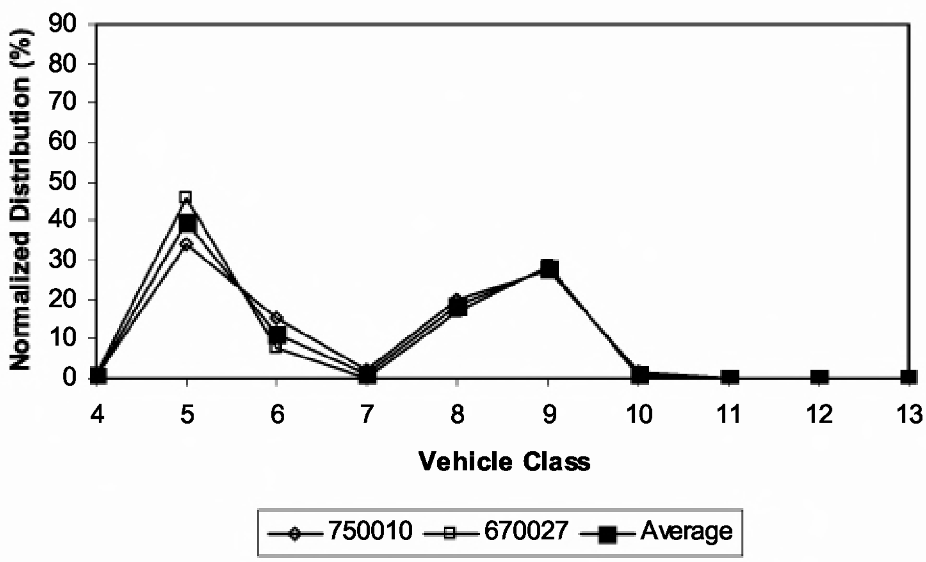

FIGURE 28. Vehicle Class Distribution for TTC 9

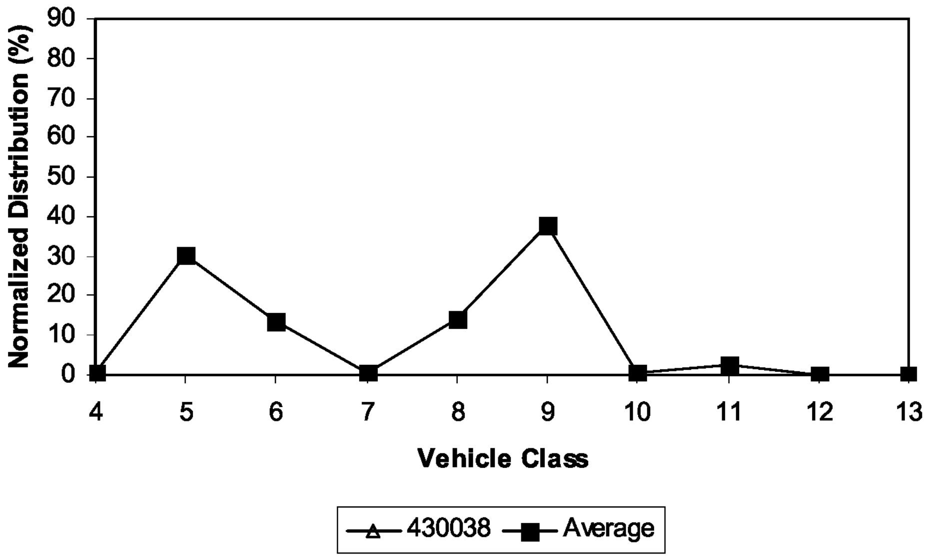

FIGURE 29. Vehicle Class Distribution for TTC 10

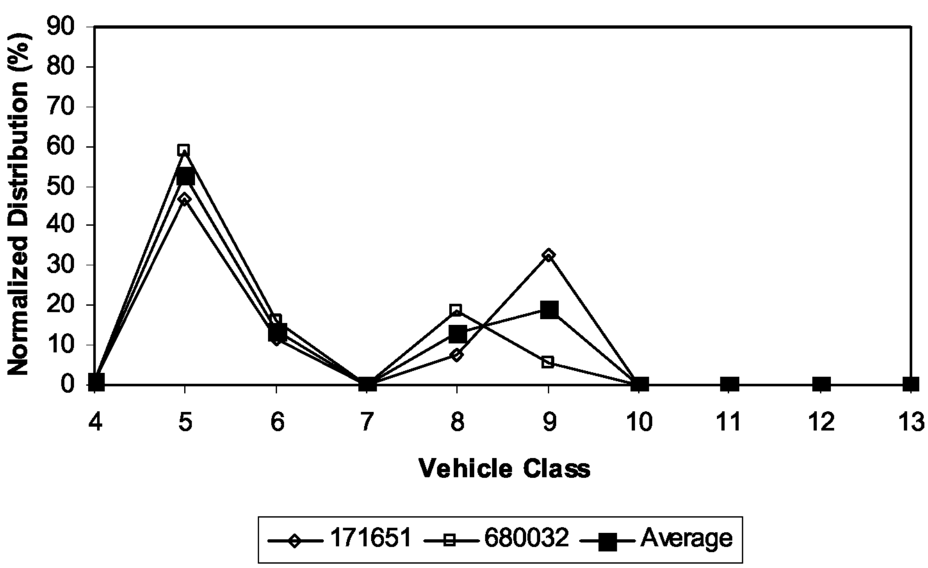

FIGURE 30. Vehicle Class Distribution for TTC 12

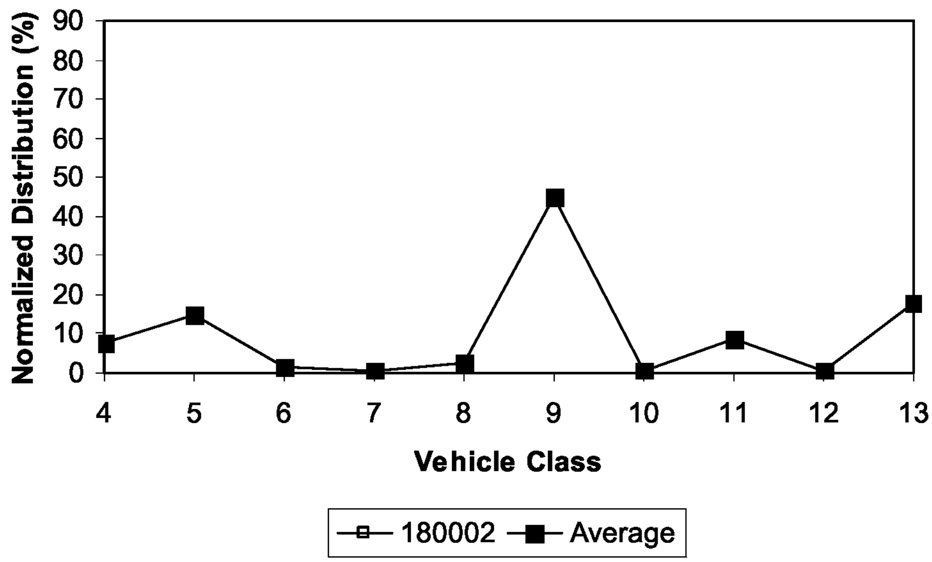

FIGURE 31. Vehicle Class Distribution for TTC 13

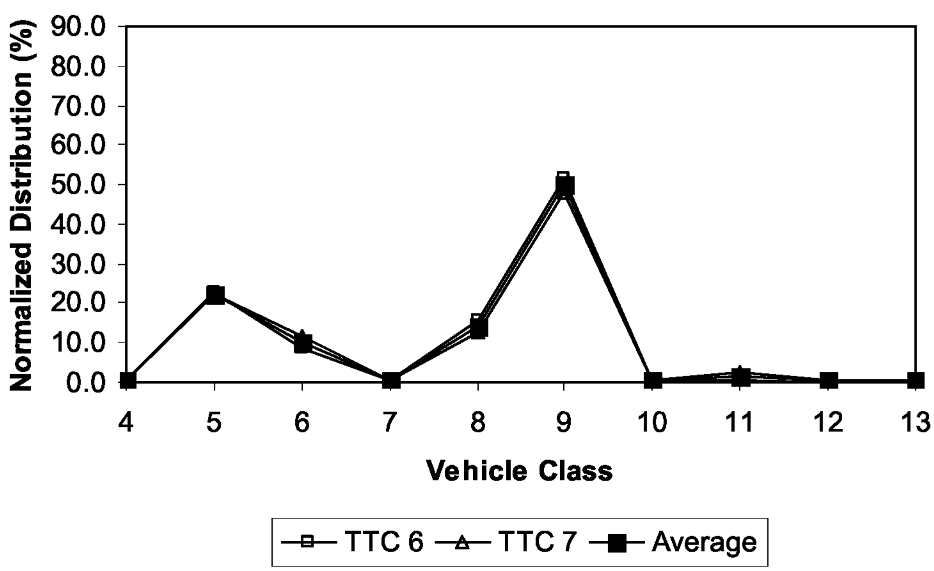

FIGURE 32. Vehicle Class Distribution for TTC 6 and 7

TABLE 26. Vehicle Class Distribution for Each Truck Traffic Classification

Class	TTC 3	TTC 6,7	TTC 9	TTC 10	TTC 12	TTC 13	Avg.
4	0.7	0.5	0.7	0.3	1.1	7.6	1.8
5	7.7	22.4	39.9	30.3	52.8	15	28.0
6	5.2	9.9	11.4	13.8	13.7	1.5	9.2
7	0.0	0.4	1.0	0.4	0.1	0.4	0.4
8	11.7	14.2	18.2	14.4	13.2	2.5	12.4
9	69.0	49.9	27.9	37.9	18.9	45.2	41.5
10	0.6	0.6	0.9	0.4	0.2	0.6	0.5
11	3.7	1.5	0.0	2.4	0.1	8.9	2.8
12	1.2	0.3	0.0	0.1	0.0	0.3	0.3
13	0.2	0.3	0.1	0	0.1	18.1	3.1

Monthly Distribution Factors

Monthly distribution factors for each station were determined using the "CLASS.xls" program. The monthly distribution factors were developed for each vehicle class. As shown in Table 26, the number of vehicles in each class on a roadway was significantly different. Therefore, a weighted average of monthly distribution factors was determined for each station. The monthly distribution factors were grouped for each TTC group. Figures 33 through 38 present the monthly distribution factors for each TTC group. The average monthly distribution factors for the TTC groups are summarized in Table 27. The monthly distribution factors for each station are variable, but the average monthly distribution factors for each TTC group are more consistent and mostly between 0.9 and 1.1.

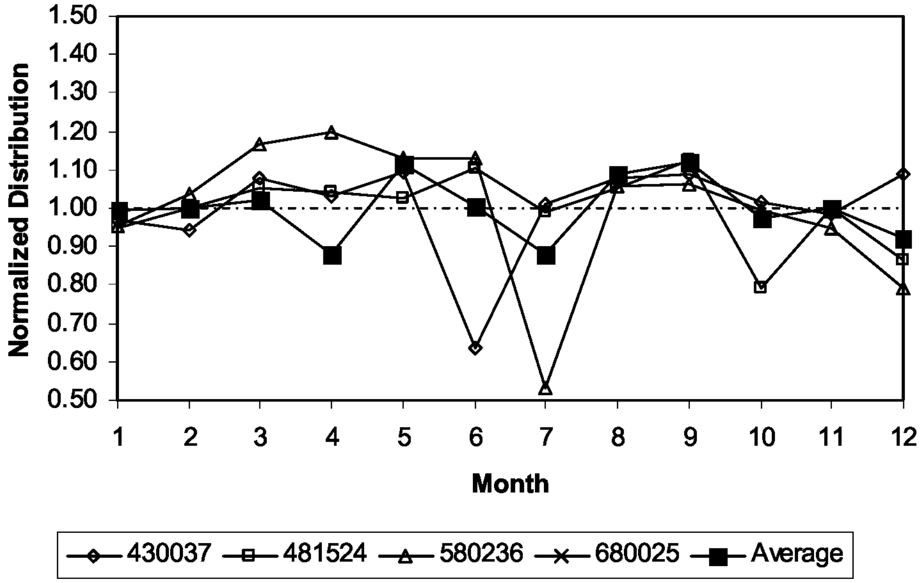

FIGURE 33. Monthly Distribution Factors for TTC 3

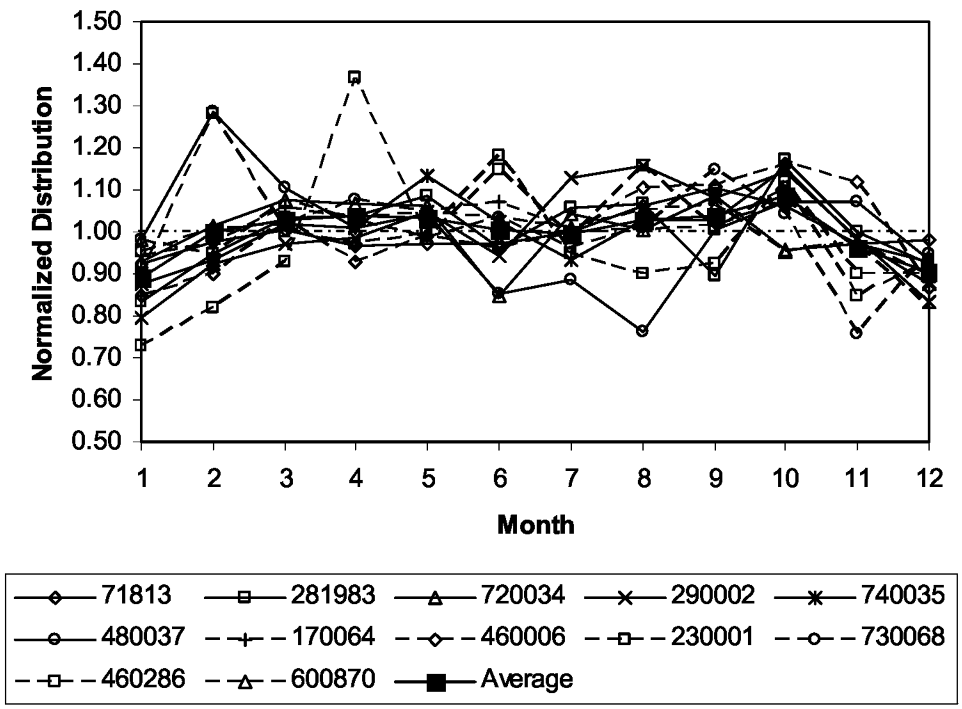

FIGURE 34. Monthly Distribution Factors for TTC 6 and 7

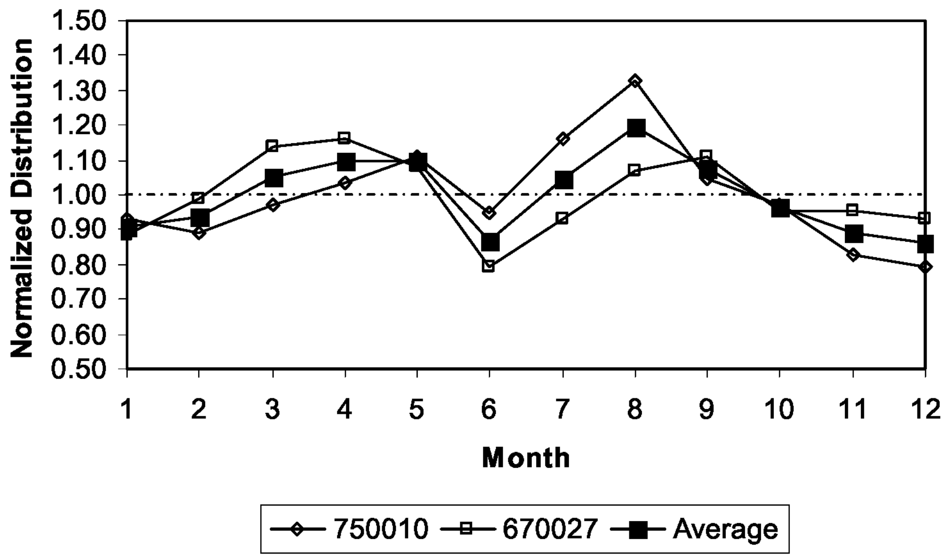

FIGURE 35. Monthly Distribution Factors for TTC 9

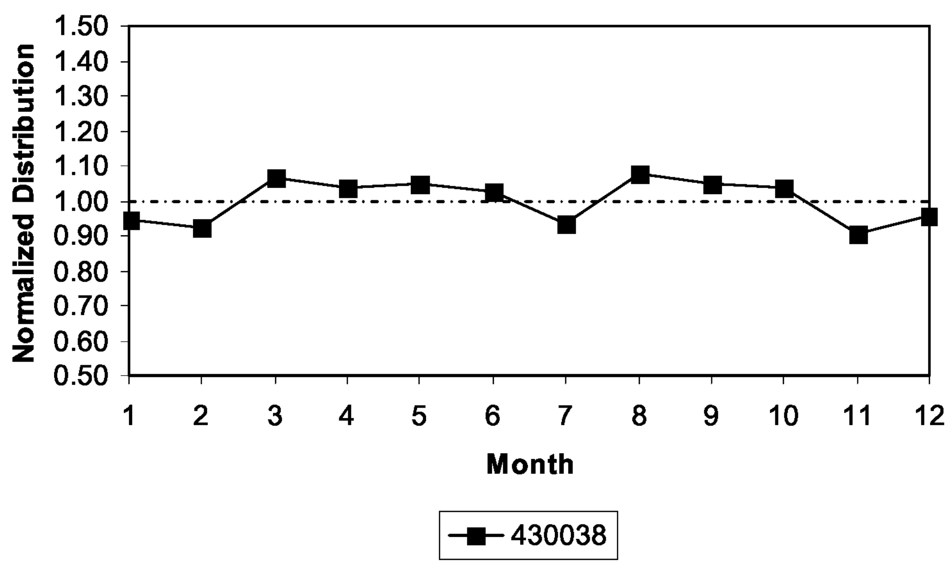

FIGURE 36. Monthly Distribution Factors for TTC 10

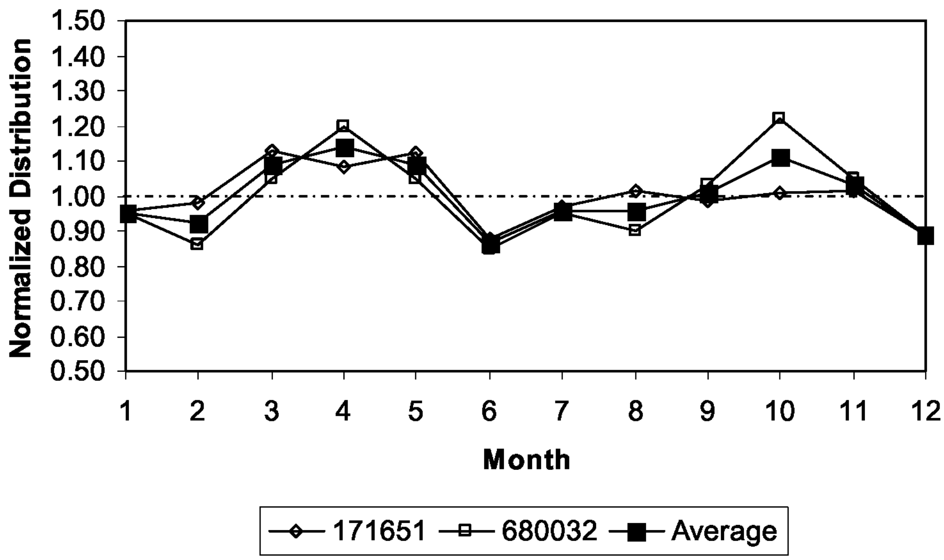

FIGURE 37. Monthly Distribution Factors for TTC 12

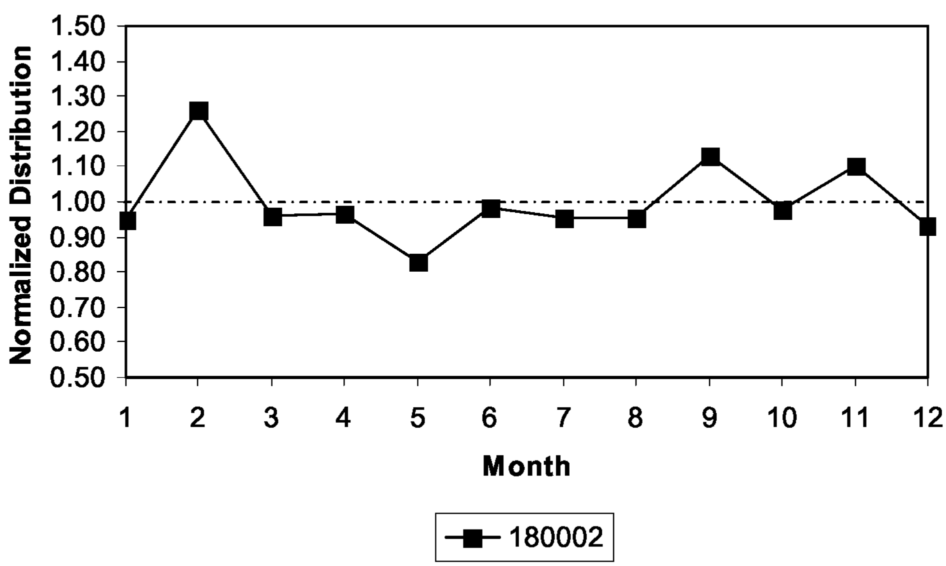

FIGURE 38. Monthly Distribution Factors for TTC 13

TABLE 27. Average Monthly Distribution Factors for TTC Groups

Month	TTC 3	TTC 6,7	TTC 9	TTC 10	TTC 12	TTC 13	Avg.	Default
1	0.99	0.89	0.91	0.94	0.95	0.95	0.94	1.00
2	1.00	1.00	0.94	0.92	0.92	1.26	1.01	1.00
3	1.02	1.03	1.05	1.07	1.09	0.96	1.04	1.00
4	0.88	1.04	1.10	1.04	1.14	0.97	1.03	1.00
5	1.11	1.03	1.09	1.05	1.09	0.83	1.03	1.00
6	1.01	1.00	0.87	1.02	0.86	0.98	0.96	1.00
7	0.88	1.00	1.05	0.94	0.96	0.95	0.96	1.00
8	1.09	1.03	1.20	1.08	0.96	0.95	1.05	1.00
9	1.12	1.04	1.08	1.05	1.01	1.13	1.07	1.00
10	0.97	1.08	0.96	1.04	1.11	0.98	1.03	1.00
11	1.00	0.96	0.89	0.90	1.03	1.10	0.98	1.00
12	0.92	0.90	0.86	0.96	0.89	0.93	0.91	1.00

Figure 39 presents a comparison of the average monthly distribution factors and the default factors in the MEPDG software. The monthly distribution factors for each truck traffic classification are different from the default values, but the overall average monthly distribution factors are close to the default values. In general, the truck distribution percentage is higher in couple months before the summer and Christmas. However, this trend is not clearly defined for all stations. Significance of the developed monthly distribution factors to the default values in the MEPDG software is evaluated in the next chapter.

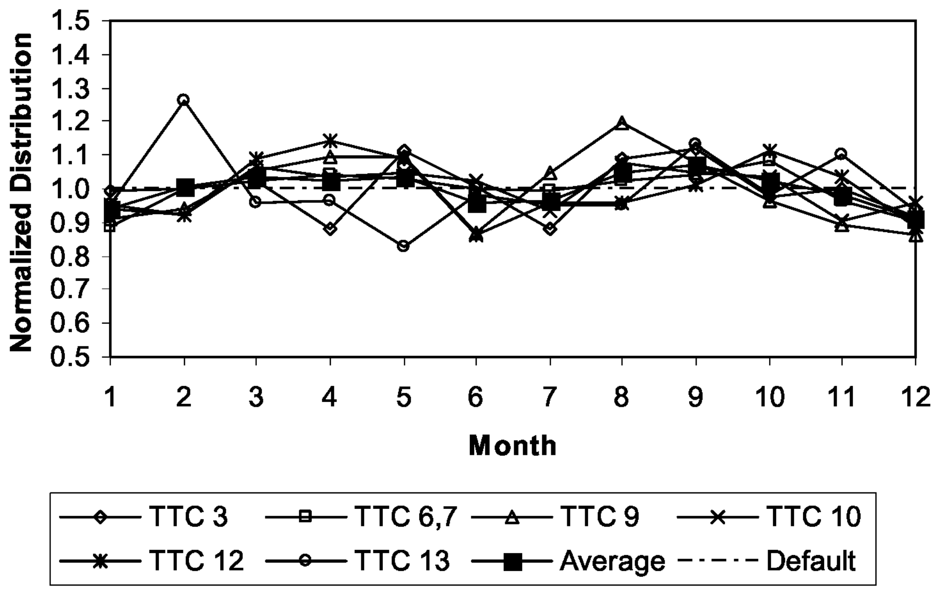

FIGURE 39. Average Monthly Distribution Factors for TTC Groups

Hourly Distribution Factors

Hourly distribution factors for each station were determined using the "CLASS.xls" program. The hourly distribution factors are developed based on monthly and annual classification data. The MEPDG software requires only annual hourly distribution factors. The hourly distribution factors were grouped based on the truck traffic classification. Figures 40 through 46 present the hourly distribution factors for each TTC group. The hourly distribution factors within the same TTC group are consistent. All TTC groups have a much greater traffic percentage from 6:00 a.m. to 7:00 p.m. Figure 47 summarizes the average hourly distribution factors for all TTC groups.

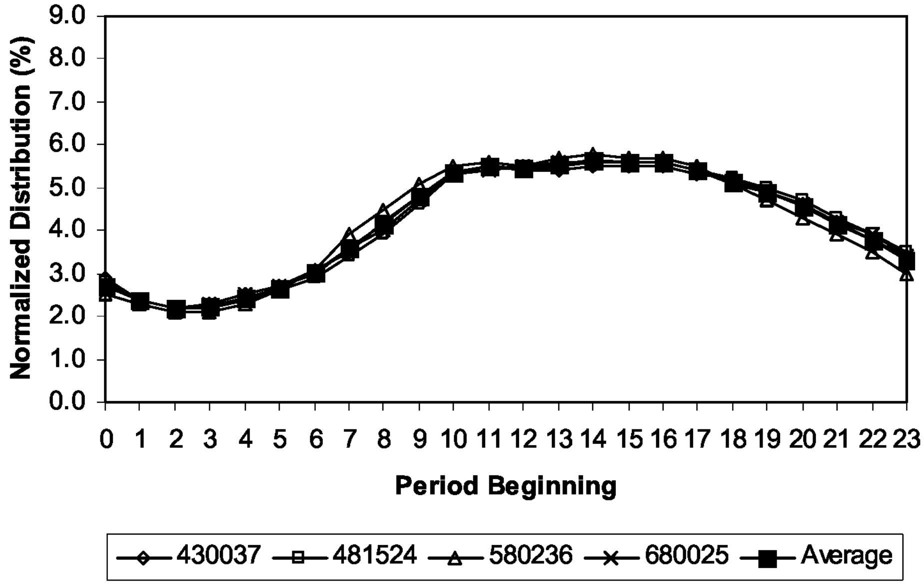

FIGURE 40. Hourly Distribution Factors for TTC 3

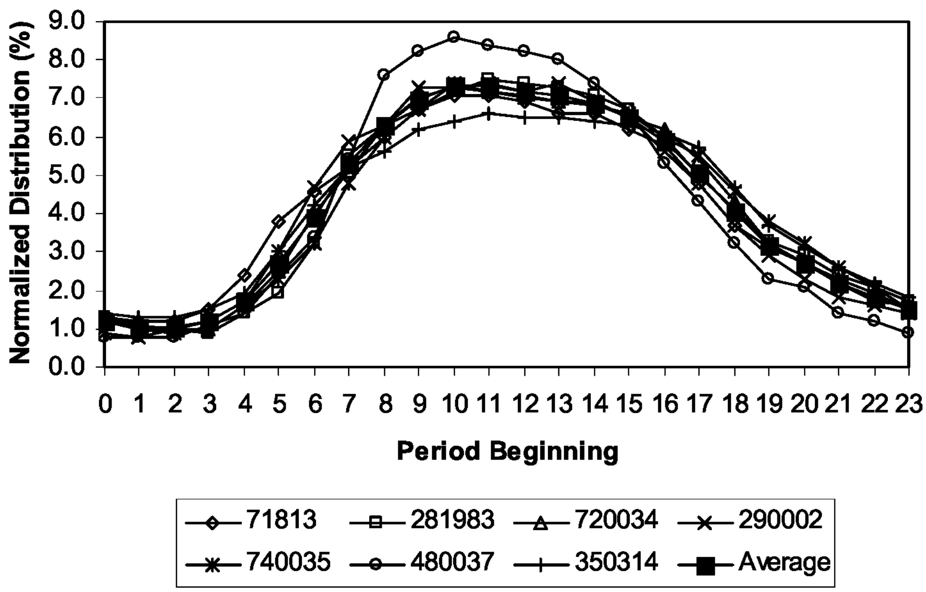

FIGURE 41. Hourly Distribution Factors for TTC 6

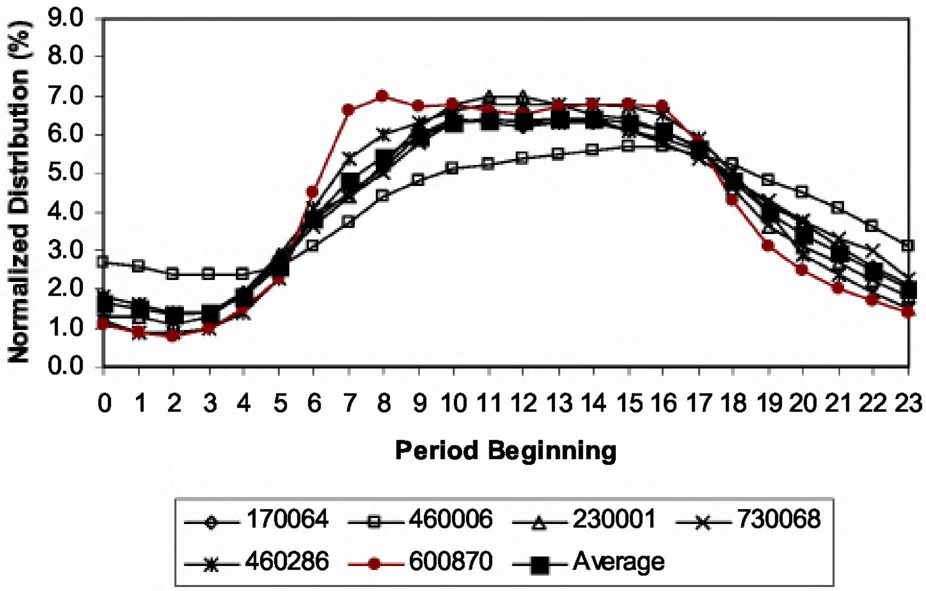

FIGURE 42. Hourly Distribution Factors for TTC 7

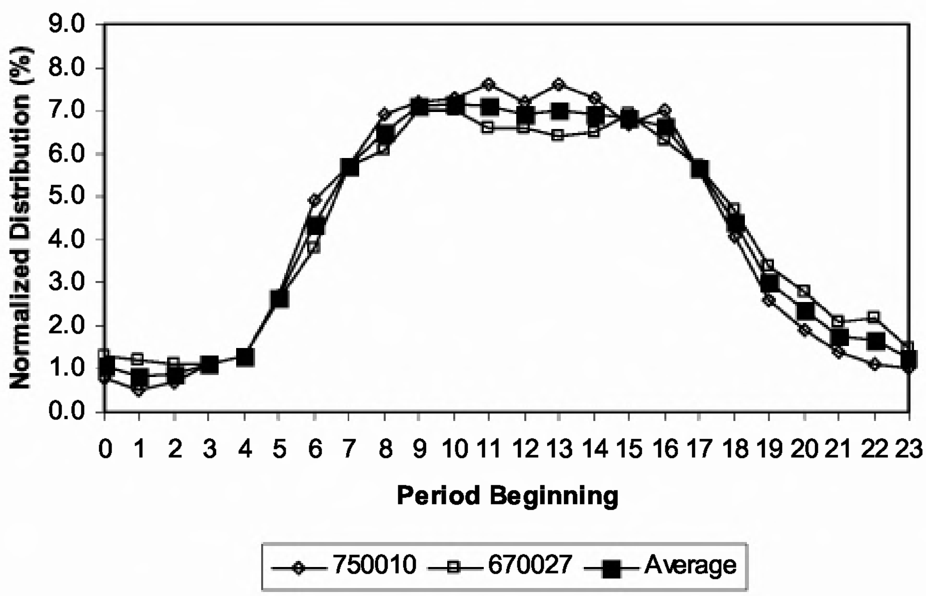

FIGURE 43. Hourly Distribution Factors for TTC 9

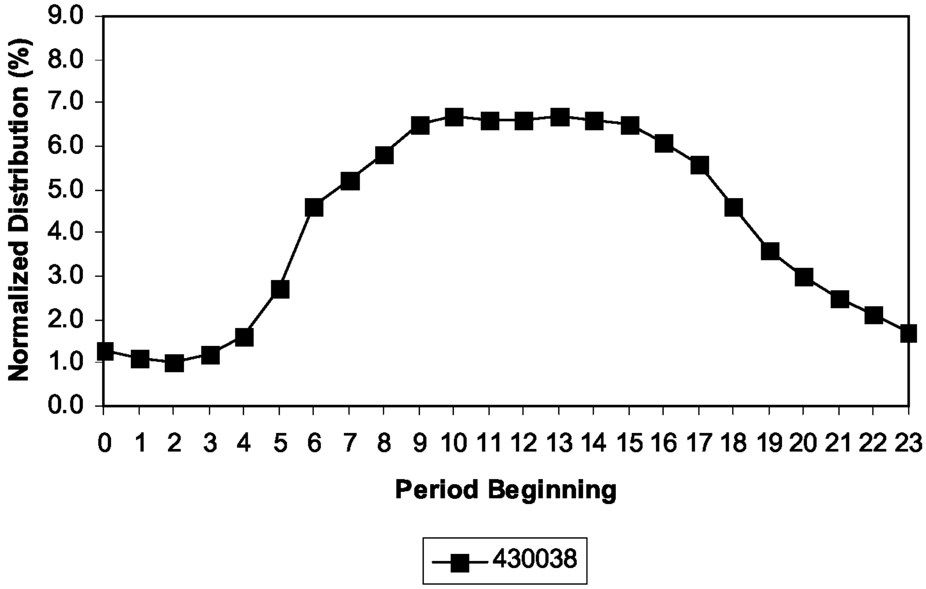

FIGURE 44. Hourly Distribution Factors for TTC 10

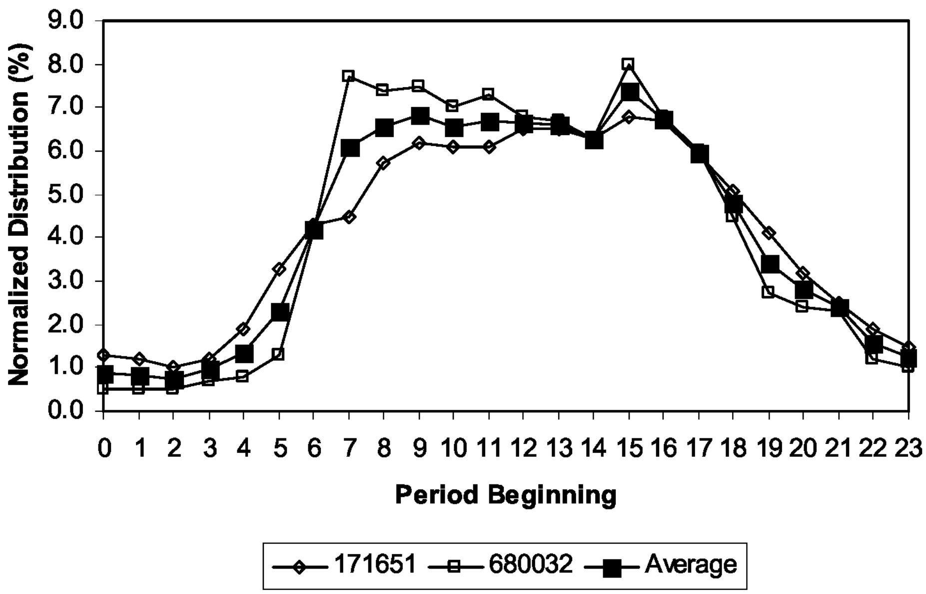

FIGURE 45. Hourly Distribution Factors for TTC 12

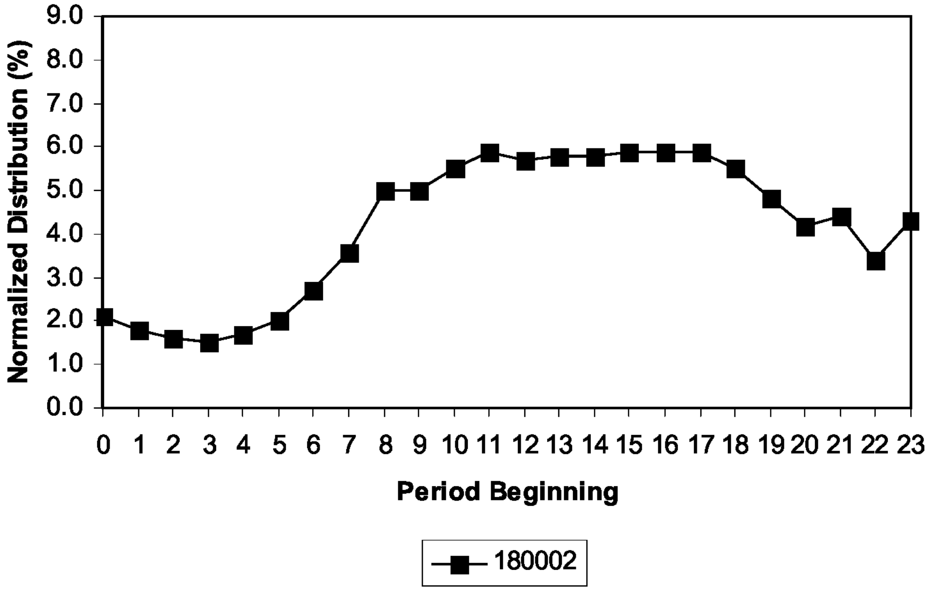

FIGURE 46. Hourly Distribution Factors for TTC 13

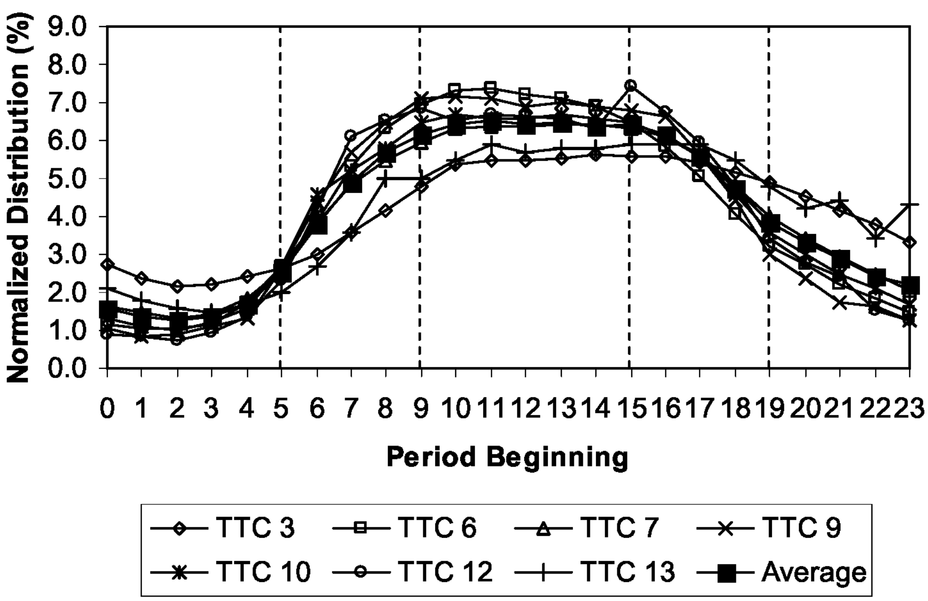

FIGURE 47. Average Hourly Distribution Factors for TTC Groups

In the MEPDG software, a day is divided into five time periods, as shown in Figure 47. The hourly distribution factors within each period are determined for use in the design. Table 28 presents the hourly distribution factors for each time periods and the corresponding default values. It is observed that the developed hourly distribution factors are different from the default values. Significance of the developed hourly classification factors to the default values in the MEPDG software is evaluated in the next chapter.

TABLE 28. Hourly Distribution Factors for TTC Groups

Time of Day	TTC 3	TTC 6	TTC 7	TTC 9	TTC 10	TTC 12	TTC 13	Avg.	Default
Midnight - 6 a.m	14.58	8.81	10.30	7.85	8.90	7.10	10.70	9.75	13.8
6 a.m. - 10 a.m.	15.58	22.47	20.10	23.65	22.10	23.70	16.30	20.56	20.0
10 a.m. - 4 p.m.	33.08	42.31	38.18	41.85	39.70	40.20	34.60	38.56	35.4
4 p.m. - 8 p.m.	21.03	18.16	20.57	19.70	19.90	20.90	22.10	20.34	18.4
8 p.m. - Midnight	15.80	8.21	10.88	7.00	9.30	8.00	16.30	10.79	12.4

Axle Load Distribution Factors

Axle load spectra for each station were developed using the "WEIGHT.xls" program. Development of axle load spectra for a roadway requires weight data from a WIM station on the roadway. As evaluated in the previous section, only ten WIM stations in Arkansas provided "good" weight data for developing the regional/statewide axle load spectra. The ten stations were divided into four TTC groups 3, 6, 7, and 10, as shown in Table 29. Primary vehicles at these stations are classes 5, 6, 8 and 9. These vehicles contribute over 90 percent of traffic flow, in which vehicle class 9 trucks contribute from 37.9 to 69.0 percent of truck traffic. Analyses presented in this section are based on the four vehicle classes, especially vehicle class 9.

TABLE 29. WIM Stations for Development of Axle Load Spectra

TTC	Stations	Primary VC and Distribution
3	580236	VC 5,6,8,9: 93.6 percent of traffic
6	071813, 720034, 740035, 480037	VC 5,6,8,9: 96.4 percent of traffic
7	170064, 460006, 230001, 600870	VC 5,6,8,9: 96.4 percent of traffic
10	430038	VC 5,6,8,9: 96.4 percent of traffic

Single Axle Load Spectra

Figures 48 through 51 show the vehicle class 9 single axle spectra for TTC groups 3, 6, 7 and 10. The load spectra were similar for all TTC groups. The VC 9 single load spectra for the TTC groups are all present in Figure 52 for comparison purposes. The peaks were within the expected range of 8,000 and 12,000 lb. Thus, it was reasonable to group the VC 9 single axle load spectra from the ten stations together. The average VC 9 single axle load spectra were determined and compared to the default values in the MEPDG software in Figure 53. The peak of the developed load spectra was slightly higher than that of the default spectra; otherwise they were very similar.

Figure 54 shows the VC 5 single axle load spectra for all TTC groups. The VC 5 single axle load spectra were very similar for all stations. Thus, they were grouped together. Figure 55 compares the developed and default single axle load spectra for Class 5. The axle load spectra were different for Class 5.

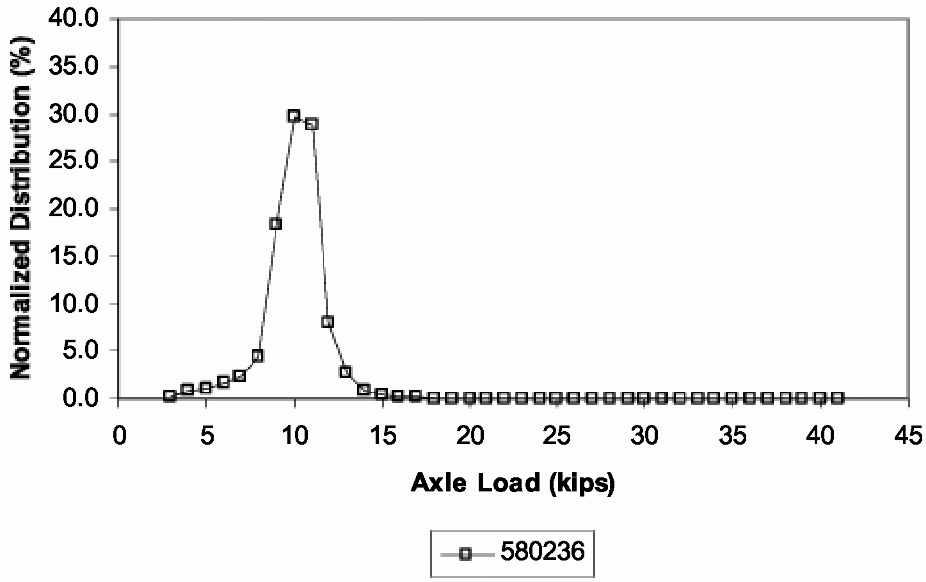

FIGURE 48. VC 9 Single Axle Load Spectra for TTC 3

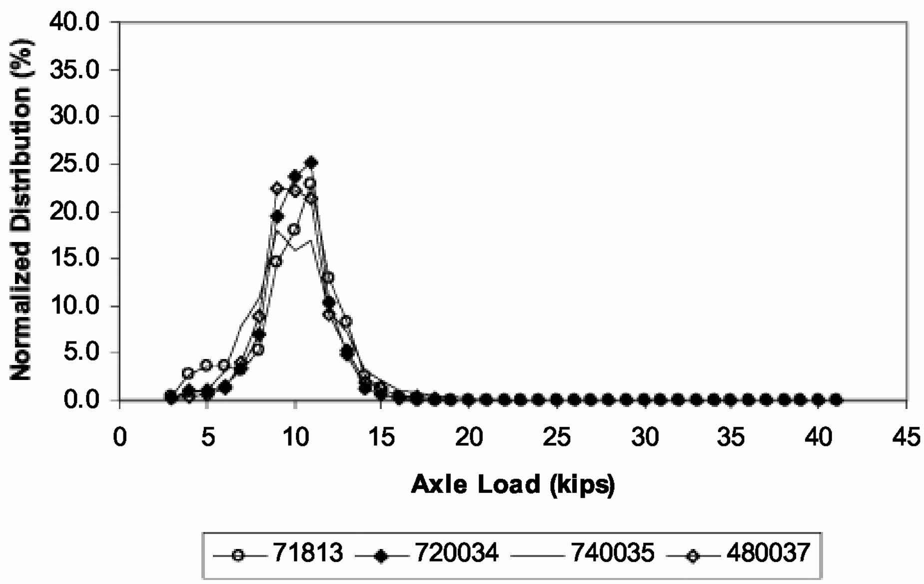

FIGURE 49. VC 9 Single Axle Load Spectra for TTC 6

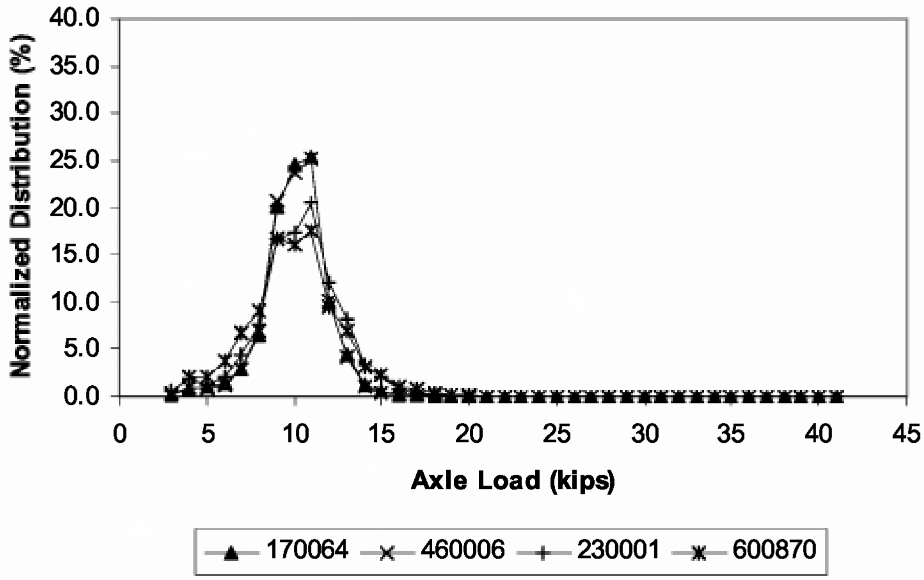

FIGURE 50. VC 9 Single Axle Load Spectra for TTC 7

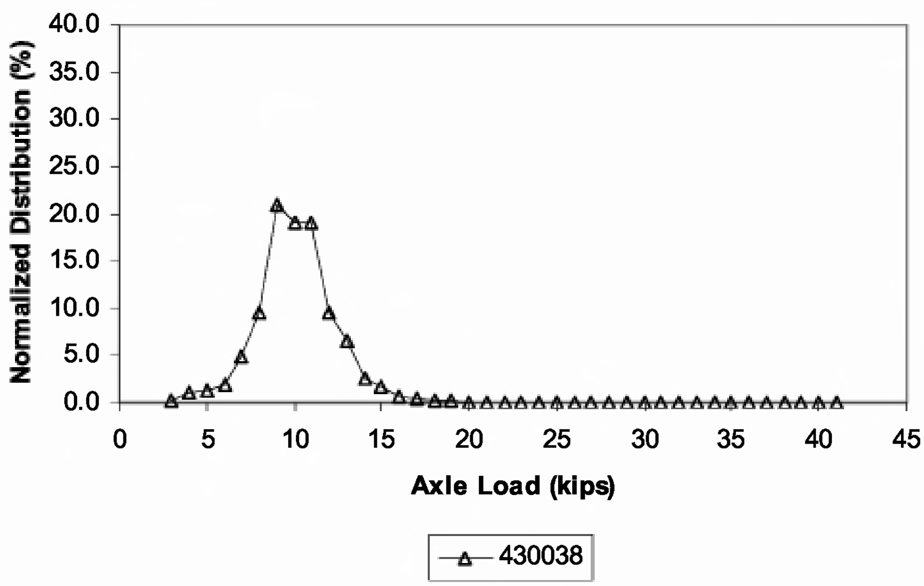

FIGURE 51. VC 9 Single Axle Load Spectra for TTC 10

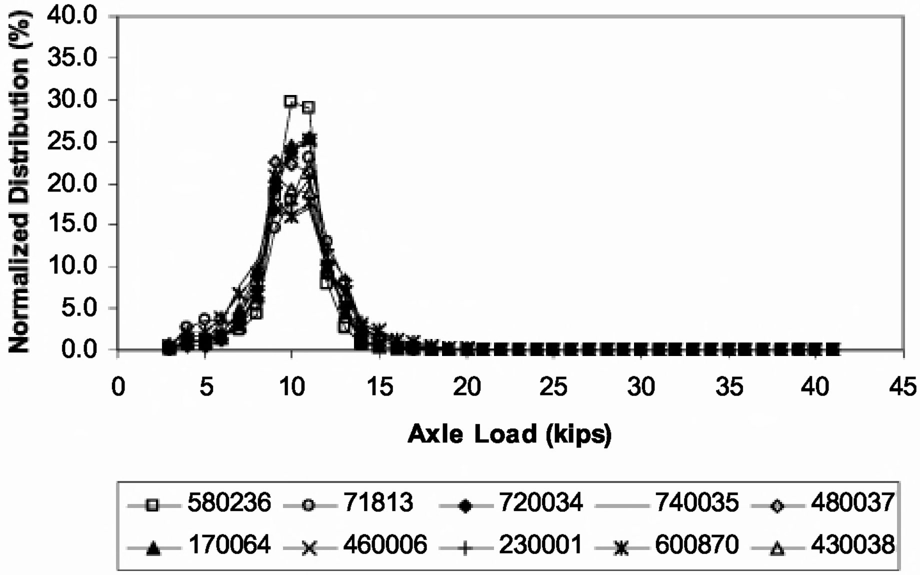

FIGURE 52. VC 9 Single Axle Load Spectra for TTC groups

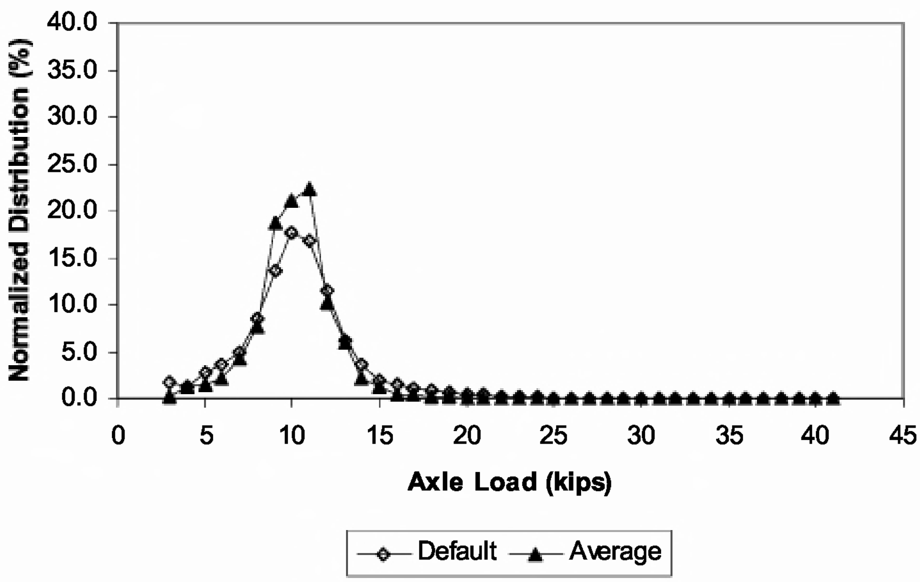

FIGURE 53. Statewide and Default VC 9 Single Axle Load Spectra

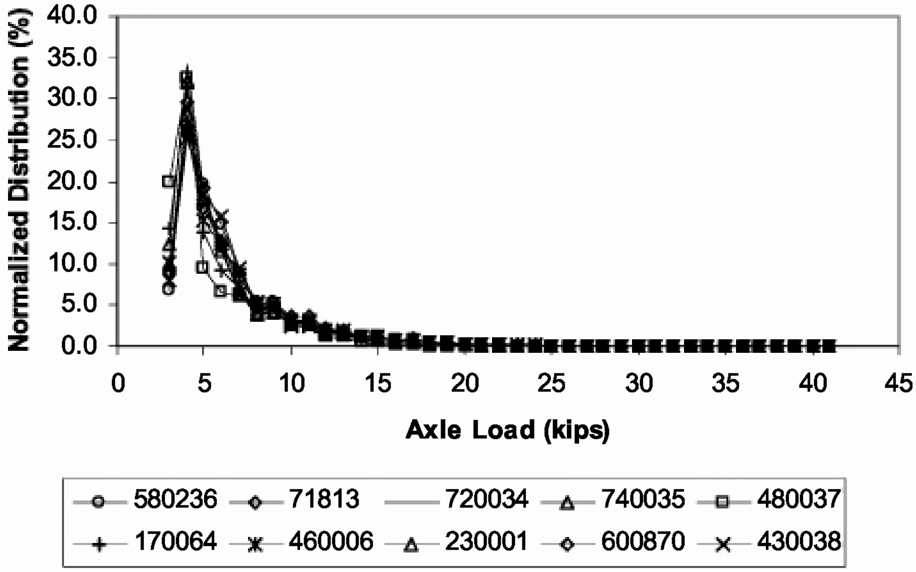

FIGURE 54. VC 5 Single Axle Load Spectra for TTC groups

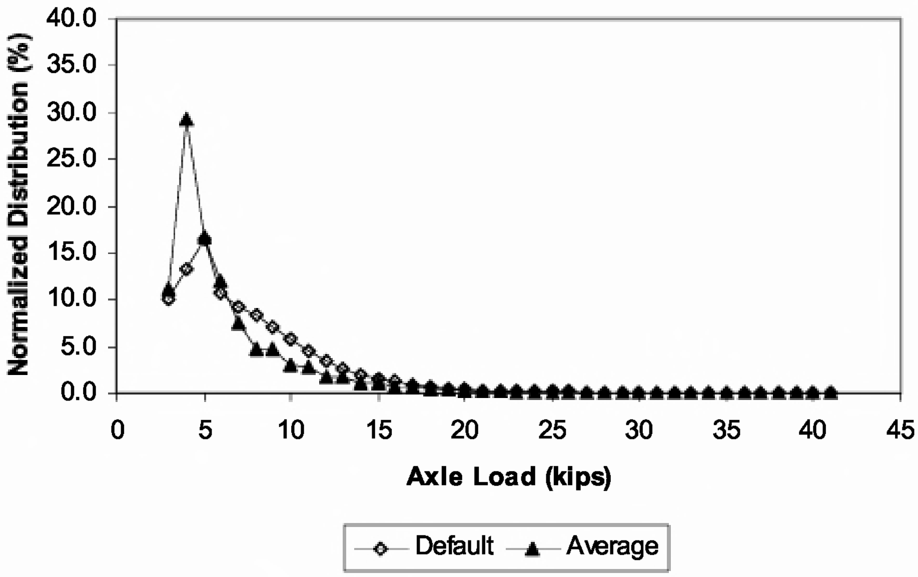

FIGURE 55. Statewide and Default VC 5 Single Axle Load Spectra

Single load spectra for other vehicle classes were determined in the same manner as for Classes 5 and 9. Based on the evaluation of single axle load spectra for vehicle classes 5 and 9, it was reasonable to group the axle load spectra from all stations for each vehicle class. Table 30 presents the statewide single axle load spectra. Significance of the developed single axle load spectra to the default values is evaluated in the next chapter.

Tandem Axle Load Spectra

Figure 56 presents the VC 9 tandem axle load spectra for all stations. It was shown that the tandem axle load spectra included several groups that shared common load distribution characteristics. Cluster analyses were performed to group the WIM stations based on their axle load spectra. As shown in the previous section, the truck traffic classification system was used successfully to group the WIM sites. Thus, the use of the TTC system was first investigated. Figures 58 and 59 present the VC 9 tandem axle load spectra for TTC groups 6 and 7. The axle load spectra in a TTC group were not in a good agreement. The TTC system was not a good method for grouping the axle load spectra.

Another cluster analysis was performed in this study. The axle load spectra were mathematically grouped based on the distribution curves. This grouping method is based on the observation that a distribution curve for VC 9 tandem axle load spectra should have two peaks: (1) one is for the tandem axles of unloaded VC 9 trucks, and (2) the other is for the tandem axles of loaded VC 9 trucks. Figures 59 through 61 show three groups of the tandem axle load spectra: (1) Two peaks, one peak for unloaded, and one peak for loaded VC trucks. A similar cluster analysis was also presented by Lu and Harvey (*18*).

TABLE 30. Statewide Single Axle Load Spectra

Ax. Load	Vehicle Class									
(lb)	4	5	6	7	8	9	10	11	12	13
3000	2.641	11.089	1.601	0.119	8.354	0.294	1.058	0.361	0.481	6.155
4000	6.976	29.213	3.982	0.566	19.658	1.313	3.705	1.545	2.602	10.304
5000	4.826	16.709	3.307	0.648	11.548	1.407	3.216	2.874	4.130	5.735
6000	5.517	11.963	4.627	1.542	9.931	2.202	4.082	6.806	10.036	6.908
7000	6.473	7.451	6.378	1.971	7.976	4.240	6.172	9.282	13.239	6.701
8000	6.186	4.667	8.287	2.792	6.091	7.592	8.285	9.211	12.182	6.324
9000	10.021	4.711	15.724	7.054	7.187	18.825	15.948	14.091	16.428	8.673
10000	8.636	2.970	14.774	8.952	5.042	21.041	14.930	10.435	11.665	5.102
11000	11.153	2.868	15.561	14.333	5.166	22.301	16.425	10.618	10.666	7.266
12000	7.798	1.725	8.505	13.091	3.440	10.116	9.422	7.004	5.755	4.097
13000	8.202	1.639	6.580	14.594	3.519	5.909	7.215	7.571	5.254	6.628
14000	5.464	1.014	3.130	10.271	2.271	2.105	3.269	5.018	2.471	3.535
15000	4.888	1.010	2.552	8.441	2.248	1.263	2.389	4.886	1.960	3.578
16000	2.802	0.619	1.346	5.271	1.430	0.529	1.109	2.967	0.999	3.367
17000	2.414	0.617	1.172	3.989	1.447	0.370	0.881	2.774	0.834	3.468
18000	1.422	0.376	0.629	1.807	0.907	0.170	0.438	1.517	0.396	2.493
19000	1.126	0.360	0.546	1.928	0.896	0.124	0.380	1.233	0.337	2.658
20000	0.679	0.221	0.312	0.686	0.569	0.064	0.228	0.614	0.155	1.250
21000	0.651	0.210	0.297	0.654	0.563	0.047	0.197	0.462	0.161	1.205
22000	0.542	0.153	0.191	0.380	0.436	0.030	0.149	0.274	0.069	1.262
23000	0.288	0.091	0.114	0.213	0.277	0.015	0.101	0.148	0.040	0.527
24000	0.325	0.089	0.103	0.170	0.255	0.014	0.089	0.104	0.042	0.588
25000	0.189	0.051	0.060	0.084	0.160	0.008	0.060	0.050	0.017	0.427
26000	0.126	0.051	0.058	0.187	0.155	0.007	0.070	0.048	0.012	0.508
27000	0.107	0.030	0.027	0.081	0.088	0.004	0.030	0.016	0.017	0.181
28000	0.120	0.026	0.030	0.048	0.090	0.004	0.020	0.016	0.008	0.202
29000	0.054	0.015	0.024	0.024	0.057	0.002	0.034	0.008	0.007	0.193
30000	0.062	0.017	0.016	0.031	0.057	0.002	0.037	0.008	0.008	0.149
31000	0.062	0.010	0.014	0.017	0.034	0.001	0.003	0.024	0.003	0.086
32000	0.035	0.009	0.011	0.015	0.040	0.001	0.004	0.011	0.003	0.096
33000	0.059	0.005	0.008	0.004	0.020	0.001	0.014	0.010	0.003	0.024
34000	0.027	0.005	0.009	0.004	0.022	0.000	0.017	0.009	0.010	0.091
35000	0.035	0.004	0.004	0.000	0.016	0.000	0.007	0.001	0.010	0.053
36000	0.039	0.004	0.009	0.017	0.016	0.000	0.001	0.001	0.001	0.051
37000	0.011	0.003	0.005	0.000	0.012	0.000	0.003	0.001	0.001	0.042
38000	0.010	0.002	0.003	0.000	0.006	0.000	0.002	0.001	0.000	0.025
39000	0.035	0.002	0.004	0.013	0.011	0.000	0.008	0.001	0.001	0.009
40000	0.004	0.002	0.002	0.000	0.005	0.000	0.000	0.000	0.000	0.037
41000	0.001	0.001	0.001	0.002	0.003	0.000	0.001	0.000	0.000	0.004

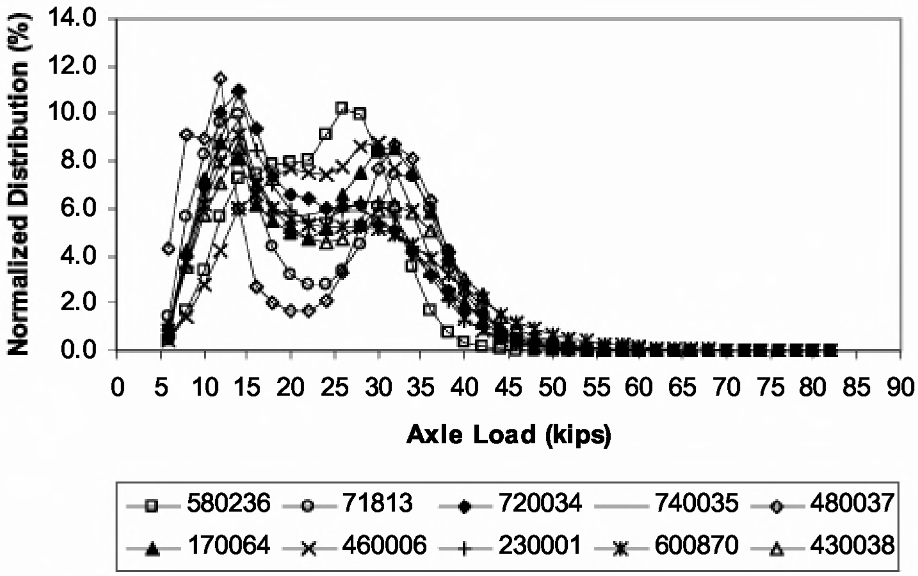

FIGURE 56. VC 9 Tandem Axle Load Spectra for All Stations

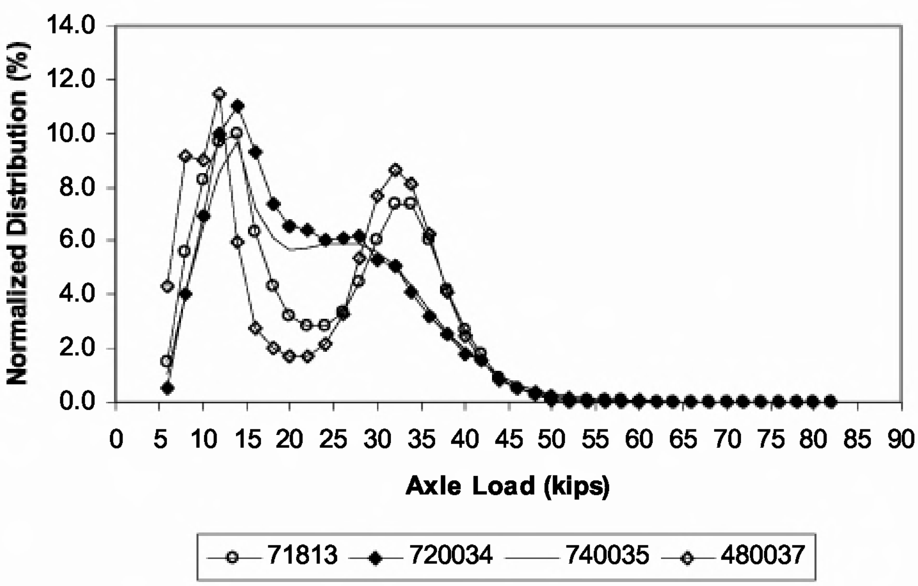

FIGURE 57. VC 9 Tandem Axle Load Spectra for TTC 6

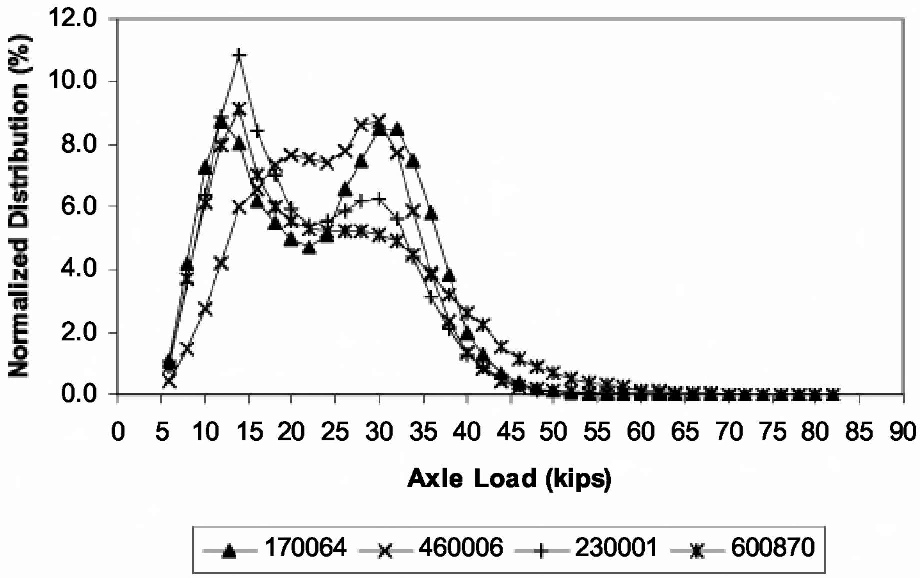

FIGURE 58. VC 9 Tandem Axle Load Spectra for TTC 7

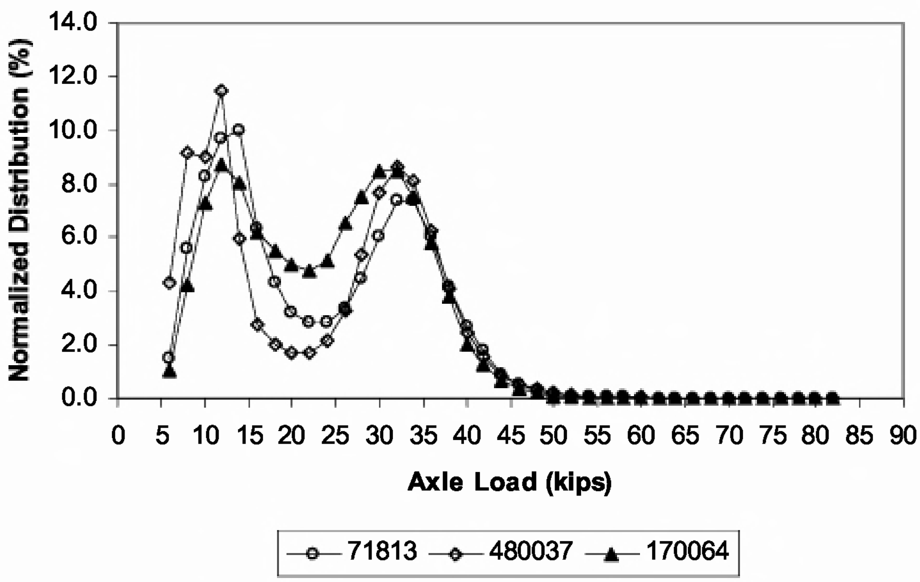

FIGURE 59. Two-Peak Tandem Axle Load Spectra

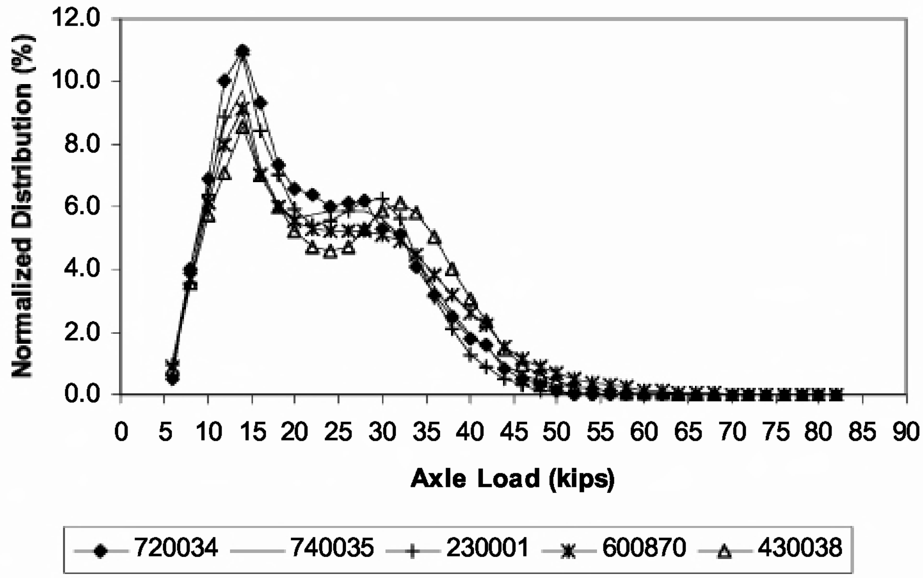

FIGURE 60. Unloaded-Peak Tandem Axle Load Spectra

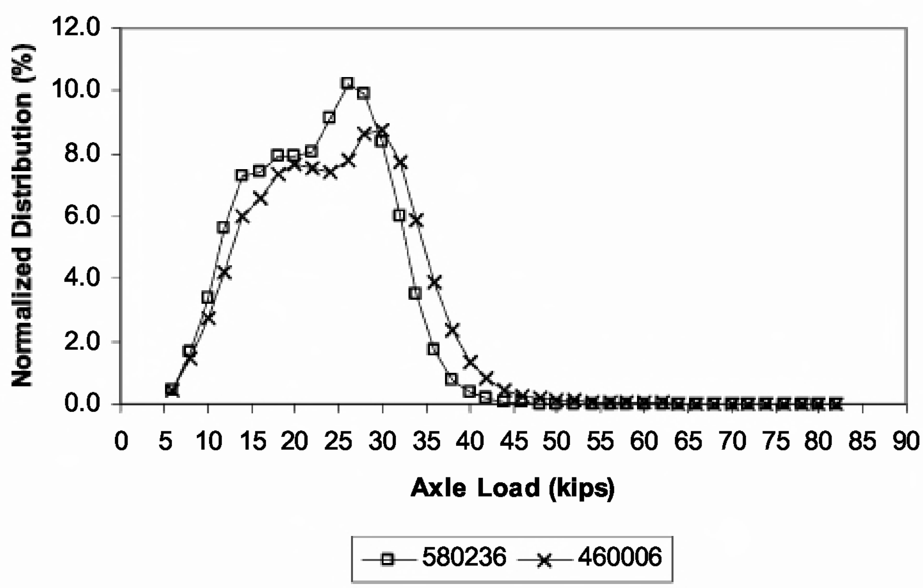

FIGURE 61. Loaded-Peak Tandem Axle Load Spectra

Lu and Harvey found that the variation of tandem axle load spectra was correlated to geographic location (i.e., urban versus rural, coastal versus inland). However, further analyses of the tandem axle load distribution groups in Arkansas showed that the axle load spectra in each group were not correlated to geographic location, functional classification, or truck traffic classification. This grouping method is just useful when the designers know the truck flow characteristics on the roadway of interest: (1) the numbers of unloaded and loaded VC 9 trucks are almost the same; (2) the majority of VC 9 trucks are unloaded; or (3) the majority of VC 9 trucks are loaded. However, the information is often unknown during the design stage. Therefore, it was decided that the average tandem axle load spectra be used as the statewide tandem axle load spectra until more data are available for further analyses.

Figures 62 through 64 compare the statewide and default tandem axle load spectra for vehicle classes 9, 6 and 8, respectively. The statewide tandem axle load spectra were close to the default values. Table 31 presents the statewide tandem axle load spectra for all vehicle classes. It was noted that some vehicle classes, such as vehicle classes 5, 7, and 11, did not have tandem axles, so axle load spectra for these vehicle classes were not available (shown as 0.000).

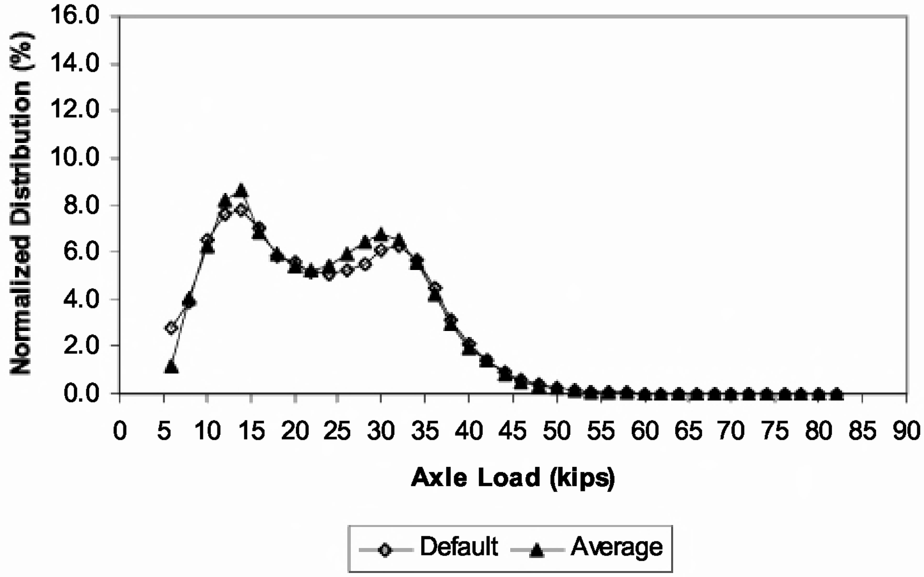

FIGURE 62. Statewide and Default Tandem Load Spectra for VC 9

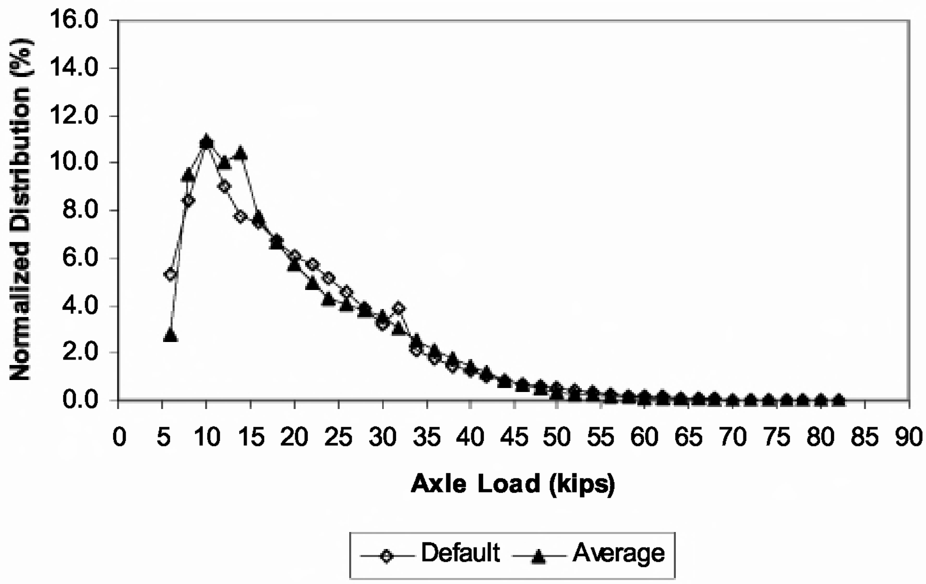

FIGURE 63. Statewide and Default Tandem Load Spectra for VC 6

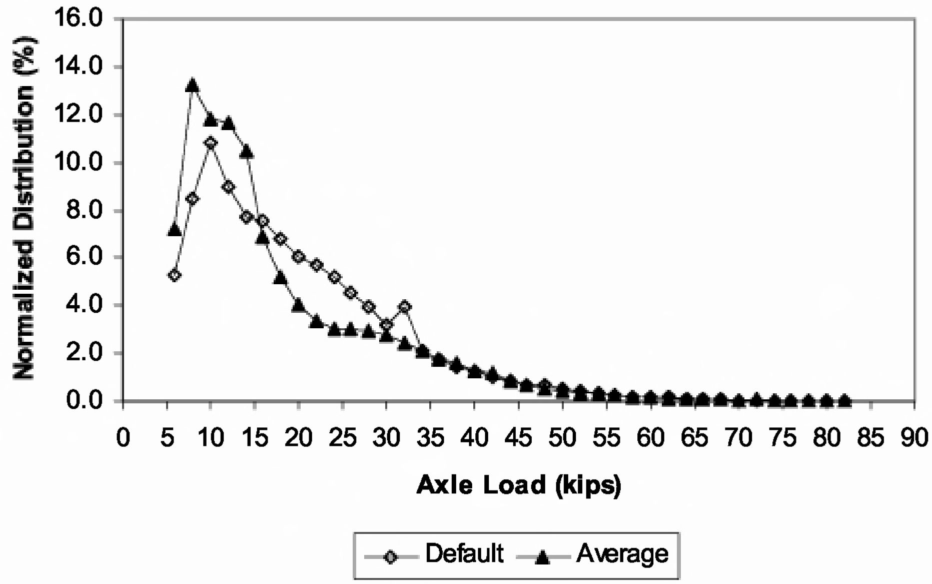

FIGURE 64. Statewide and Default Tandem Load Spectra for VC 8

TABLE 31. Statewide Tandem Axle Load Spectra

Ax. Load	Vehicle Class									
(lb)	4	5	6	7	8	9	10	11	12	13
6000	1.048	0.000	2.788	0.000	7.168	1.186	1.267	0.000	0.416	4.488
8000	2.336	0.000	9.477	0.000	13.251	3.940	2.549	0.000	1.800	8.243
10000	1.836	0.000	10.963	0.000	11.831	6.237	2.716	0.000	4.297	6.281
12000	2.538	0.000	10.010	0.000	11.627	8.563	3.814	0.000	10.014	6.847
14000	3.965	0.000	10.456	0.000	10.441	8.924	6.530	0.000	10.447	7.326
16000	3.542	0.000	7.766	0.000	6.841	6.826	7.607	0.000	9.835	6.278
18000	3.973	0.000	6.678	0.000	5.173	5.962	8.315	0.000	10.847	7.332
20000	5.528	0.000	5.739	0.000	4.010	5.439	8.499	0.000	13.733	6.117
22000	7.661	0.000	4.943	0.000	3.314	5.334	7.700	0.000	12.420	5.012
24000	9.697	0.000	4.266	0.000	3.055	5.625	7.933	0.000	9.828	5.152
26000	11.085	0.000	4.004	0.000	3.004	6.098	7.479	0.000	6.669	4.730
28000	11.073	0.000	3.804	0.000	2.908	6.578	6.661	0.000	3.854	5.120
30000	9.557	0.000	3.530	0.000	2.798	6.783	5.882	0.000	2.644	4.538
32000	7.768	0.000	3.042	0.000	2.451	6.253	4.803	0.000	1.366	4.305
34000	6.433	0.000	2.520	0.000	2.095	5.073	4.166	0.000	0.626	3.216
36000	4.286	0.000	2.096	0.000	1.786	3.684	3.360	0.000	0.375	2.648
38000	2.434	0.000	1.756	0.000	1.553	2.489	2.655	0.000	0.228	2.182
40000	1.456	0.000	1.436	0.000	1.281	1.643	2.031	0.000	0.196	2.090
42000	1.043	0.000	1.215	0.000	1.158	1.174	1.684	0.000	0.119	1.819
44000	0.756	0.000	0.815	0.000	0.860	0.680	1.217	0.000	0.073	1.511
46000	0.499	0.000	0.664	0.000	0.705	0.452	0.747	0.000	0.044	1.511
48000	0.282	0.000	0.480	0.000	0.540	0.308	0.562	0.000	0.062	0.729
50000	0.184	0.000	0.365	0.000	0.442	0.213	0.456	0.000	0.045	0.497
52000	0.240	0.000	0.280	0.000	0.361	0.149	0.287	0.000	0.013	0.395
54000	0.081	0.000	0.213	0.000	0.300	0.105	0.217	0.000	0.011	0.513
56000	0.102	0.000	0.150	0.000	0.226	0.078	0.235	0.000	0.008	0.368
58000	0.156	0.000	0.127	0.000	0.174	0.057	0.159	0.000	0.009	0.135
60000	0.074	0.000	0.092	0.000	0.132	0.041	0.143	0.000	0.004	0.120
62000	0.076	0.000	0.073	0.000	0.112	0.030	0.105	0.000	0.002	0.068
64000	0.090	0.000	0.057	0.000	0.092	0.021	0.045	0.000	0.003	0.066
66000	0.130	0.000	0.045	0.000	0.055	0.016	0.045	0.000	0.005	0.066
68000	0.007	0.000	0.033	0.000	0.050	0.012	0.023	0.000	0.005	0.023
70000	0.028	0.000	0.030	0.000	0.041	0.009	0.028	0.000	0.001	0.039
72000	0.002	0.000	0.024	0.000	0.047	0.008	0.017	0.000	0.001	0.017
74000	0.030	0.000	0.023	0.000	0.033	0.005	0.016	0.000	0.000	0.048
76000	0.000	0.000	0.017	0.000	0.035	0.004	0.022	0.000	0.000	0.027
78000	0.007	0.000	0.014	0.000	0.024	0.003	0.020	0.000	0.003	0.016
80000	0.000	0.000	0.008	0.000	0.020	0.002	0.005	0.000	0.000	0.019
82000	0.001	0.000	0.004	0.000	0.009	0.001	0.001	0.000	0.000	0.111

Tridem and Quad Axle Load Spectra

The statewide tridem axle load spectra were developed in the same manner as for the tandem axle load spectra presented in the previous section. The tridem axle load spectra from the ten stations were averaged to determine the statewide tridem axle load spectra, as shown in Table 32. As for the tandem axle load spectra, some vehicle classes did not have tridem axles, so axle load spectra for these vehicle classes were not available (shown as 0.000).

Since very few quad axles were shown in the WIM data, the quad axle load spectra were not developed. The default quad axle load spectra should be used, if required.

4. SUMMARY

This chapter provided important traffic inputs for initial implementation of MEPDG. First, the requirements for traffic inputs in MEPDG were reviewed. Based on the review, the following strategic plan for developing the traffic inputs was proposed, as follows:

- Traffic inputs using the site specific values
    - Annual average daily truck traffic
- Traffic inputs using the regional/statewide values
    - Monthly distribution factors
    - Vehicle class distribution factors
    - Hourly truck distribution factors
    - Axle load distribution factors (Axle load spectra)

TABLE 32. Statewide Tridem Axle Load Spectra

Ax. Load	Vehicle Class									
(lb)	4	5	6	7	8	9	10	11	12	13
12000	0.000	0.000	0.000	0.157	0.000	0.000	4.717	0.000	0.000	0.000
15000	0.000	0.000	0.000	0.449	0.000	0.000	9.914	0.000	0.000	0.000
18000	0.000	0.000	0.000	0.530	0.000	0.000	9.689	0.000	0.000	0.000
21000	0.000	0.000	0.000	0.655	0.000	0.000	7.746	0.000	0.000	0.000
24000	0.000	0.000	0.000	0.711	0.000	0.000	6.792	0.000	0.000	0.000
27000	0.000	0.000	0.000	1.264	0.000	0.000	7.187	0.000	0.000	0.000
30000	0.000	0.000	0.000	2.015	0.000	0.000	7.184	0.000	0.000	0.000
33000	0.000	0.000	0.000	3.326	0.000	0.000	7.792	0.000	0.000	0.000
36000	0.000	0.000	0.000	6.119	0.000	0.000	7.762	0.000	0.000	0.000
39000	0.000	0.000	0.000	8.980	0.000	0.000	6.188	0.000	0.000	0.000
42000	0.000	0.000	0.000	14.087	0.000	0.000	5.948	0.000	0.000	0.000
45000	0.000	0.000	0.000	14.483	0.000	0.000	4.454	0.000	0.000	0.000
48000	0.000	0.000	0.000	13.647	0.000	0.000	3.698	0.000	0.000	0.000
51000	0.000	0.000	0.000	11.127	0.000	0.000	3.038	0.000	0.000	0.000
54000	0.000	0.000	0.000	7.597	0.000	0.000	1.972	0.000	0.000	0.000
57000	0.000	0.000	0.000	5.083	0.000	0.000	1.733	0.000	0.000	0.000
60000	0.000	0.000	0.000	3.101	0.000	0.000	1.020	0.000	0.000	0.000
63000	0.000	0.000	0.000	2.138	0.000	0.000	0.728	0.000	0.000	0.000
66000	0.000	0.000	0.000	1.491	0.000	0.000	0.619	0.000	0.000	0.000
69000	0.000	0.000	0.000	0.793	0.000	0.000	0.483	0.000	0.000	0.000
72000	0.000	0.000	0.000	0.687	0.000	0.000	0.353	0.000	0.000	0.000
75000	0.000	0.000	0.000	0.436	0.000	0.000	0.242	0.000	0.000	0.000
78000	0.000	0.000	0.000	0.345	0.000	0.000	0.161	0.000	0.000	0.000
81000	0.000	0.000	0.000	0.228	0.000	0.000	0.153	0.000	0.000	0.000
84000	0.000	0.000	0.000	0.194	0.000	0.000	0.100	0.000	0.000	0.000
87000	0.000	0.000	0.000	0.134	0.000	0.000	0.101	0.000	0.000	0.000
90000	0.000	0.000	0.000	0.101	0.000	0.000	0.075	0.000	0.000	0.000
93000	0.000	0.000	0.000	0.075	0.000	0.000	0.063	0.000	0.000	0.000
96000	0.000	0.000	0.000	0.028	0.000	0.000	0.046	0.000	0.000	0.000
99000	0.000	0.000	0.000	0.017	0.000	0.000	0.028	0.000	0.000	0.000
102000	0.000	0.000	0.000	0.005	0.000	0.000	0.016	0.000	0.000	0.000

- Traffic inputs using the default or user-defined values
    - Traffic growth factors
    - Directional distribution factors
    - Lane distribution factors
    - Other general traffic inputs

Second, since the traffic data, including classification and weight data from 2003 through 2005, provided by the Technical Services for use in this study were not checked, the evaluation of the traffic data was performed using the procedures presented in the LTPP and FHWA publications (*4,11*). The evaluation showed that the traffic data were missing several months at many WIM stations. Among 55 WIM stations active from 2003 through 2005, only 25 stations provided enough data for developing the statewide traffic inputs. Then, 24 stations provided "good" classification data for developing the volume adjustment factors, and only 10 stations provided "good" weight data for developing the axle load spectra. It is recommended that AHTD not only keep installing new WIM stations but also frequently check the quality of the collected data, especially the weight data.

Finally, even though complete documentation on development of traffic inputs can be found in MEPDG, the step-by-step procedures used to for developing the statewide traffic inputs can be useful for updating these inputs in the future. Significance of the developed traffic inputs to the corresponding default values is evaluated in the next chapter.

CHAPTER 4 SENSITIVITY ANALYSES

The WIM data provided by the Technical Services for this study were evaluated in Chapter 3. Based on the evaluation procedures recommended by LTPP and FHWA (*4,11*), the data from several WIM stations were not included in development of the statewide traffic inputs because the WIM scales were suspected to be under- or over-calibrate. One objective of the sensitivity analyses is to illustrate the effect of under-calibrated and over-calibrated WIM data on the design.

"Good" WIM data were used to develop the traffic inputs for MEPDG. Some of the developed traffic inputs are different from the default values. Thus, another objective of the sensitivity analyses is to investigate if the developed and the corresponding default traffic inputs are significantly different. If not, the default traffic inputs should be used for the design.

1. EFFECT OF WEIGH-IN-MOTION DATA VARIATION

Variation of WIM data can be caused by several problems, as presented in Chapter 3. One popular problem is because the scale calibration is off. As a result, trucks are not properly weighed. This may significantly influence the traffic inputs and the pavement design.

Since only Class 9 data were used in the evaluation process, this analysis was performed based on the VC 9 truck data. The data collected at Station 480037 was selected for this analysis because the peaks of gross weight distribution curves for VC 9 were about the middle of the expected ranges of 32,000±4,000 lb. and 76,000±4,000 lb, as shown in Figure 65. Most trucks were expected to be fully loaded or empty. This was assumed to be an ideal situation. For this analysis, 4,000 lb. was considered one deviation.

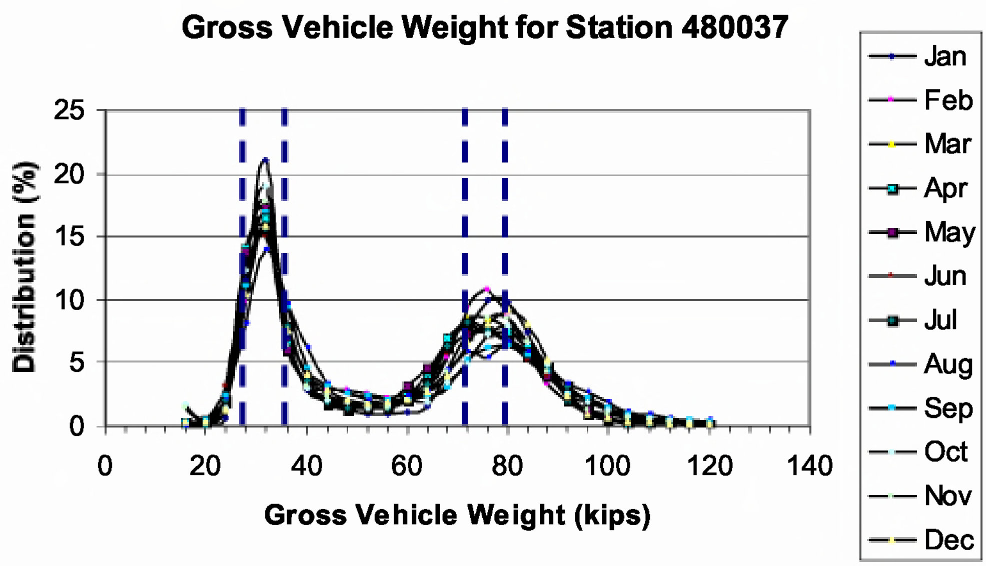

FIGURE 65. Gross Vehicle Weight Distributions of Station 480037

To evaluate the effects of the scale calibration, the "ideal" gross weight distribution curve in Figure 66 was varied as if the WIM scale was under-calibrated or over-calibrated by 4 or 8 kips, which was one or two deviations. Figures 67 and 68 show the single and tandem axle distribution curves of VC 9 trucks at Station 480037 when the scale was under-calibrated or over-calibrated. The following sensitivity analysis is performed based on the *1993 Guide* and the MEPDG software.

1.1 Sensitivity Analysis Using 1993 AASHTO Guide

The single and tandem axle load spectra for each case in Figures 67 and 68 were used to determine the number of equivalent single axle loads (ESAL) based on the *1993 Guide* (*1*). Other data for a low volume roadway used for determination of the number of ESALs are presented in Table 33.

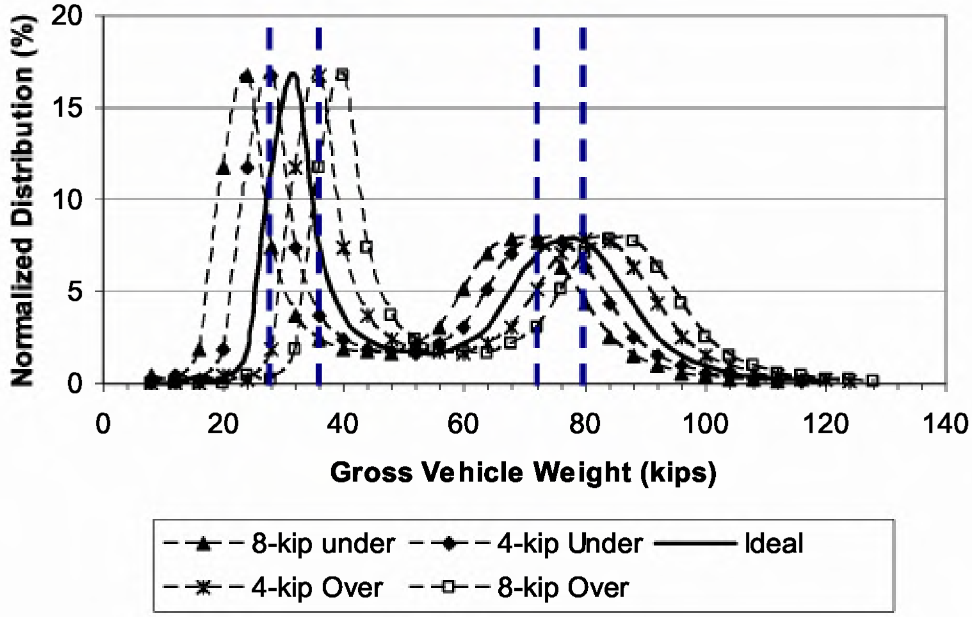

FIGURE 66. Various Gross Vehicle Weight Distribution Curves

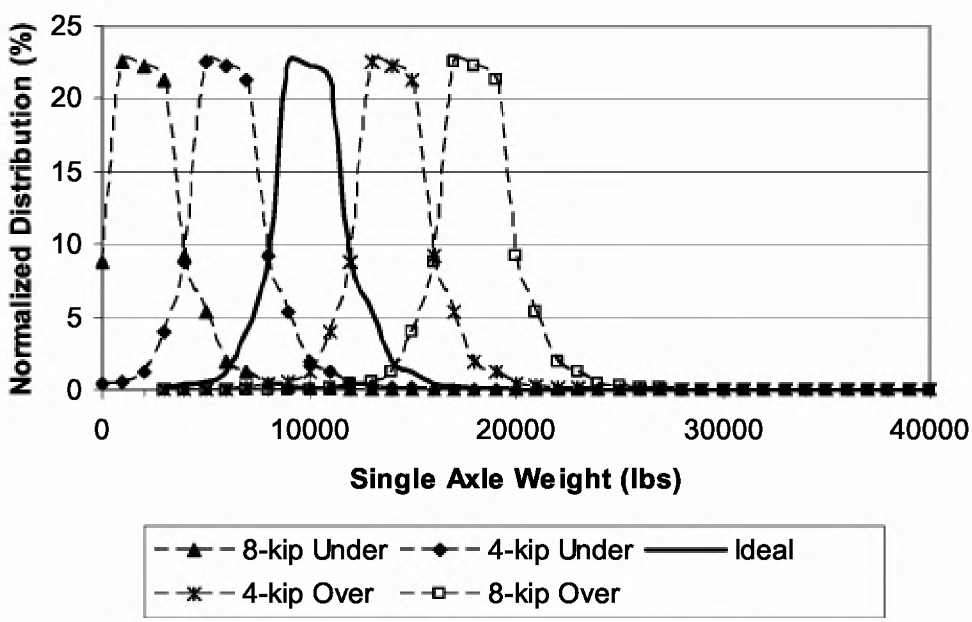

FIGURE 67. Single Axle Load Spectra

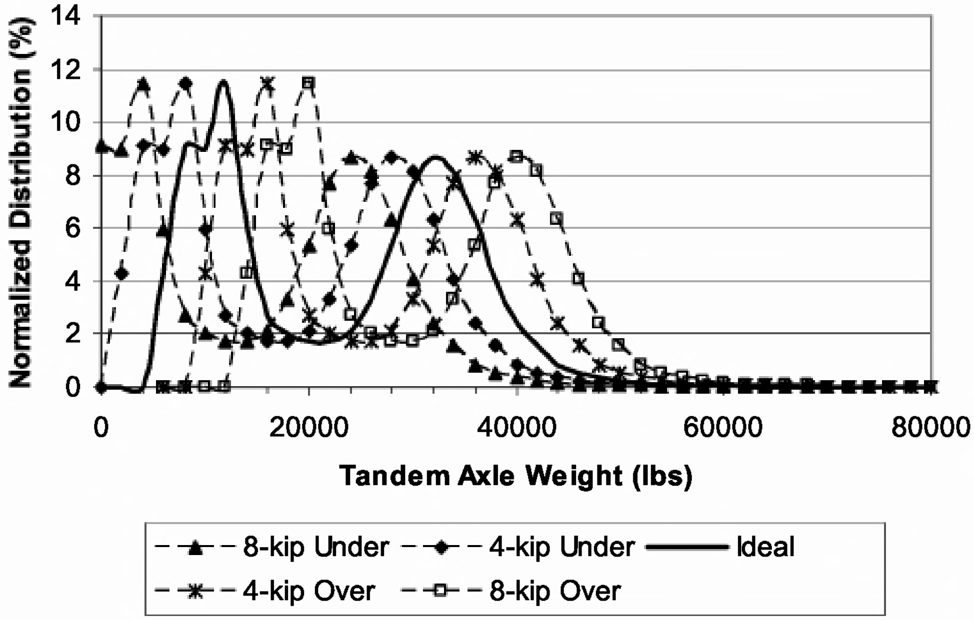

FIGURE 68. Tandem Axle Load Spectra

TABLE 33. General Inputs for Determination of ESALs

Description	Input
Vehicle Class	9
Percent of Trucks	100 Percent
AADT of VC 9	350
Truck Factor	Variable
Growth Factor	4 Percent (Compound)
Directional Distribution	0.5
Lane Distribution	100 Percent

The number of ESALs was then used to calculate the structural number and thickness of asphalt layer for each case. General inputs used for this analysis are presented in Table 34.

TABLE 34. General Inputs for Calculating Structural Number and Asphalt Thickness

Description	Input
Design Traffic, w_{18} (ESAL)	Variable
Reliability, R	90 Percent
Standard Deviation, S_o	0.45
Subgrade Modulus, M_R	5,000 psi
Performance, ΔPSI	2.0
Structural Coefficient (Asphalt)	0.44
Structural Coefficient (Base Course – Class 7)	0.14
Thickness of Base Course	9 in.

In order to generalize the analysis, the variation is normalized using Equation 4.1.

$$NV = \frac{x_i - x_{ideal}}{x_{ideal}} \times 100 \quad (4.1)$$

where:

NV = normalized variation

x_i = parameter of interest in case i

x_{ideal} = parameter of interest in "ideal" case

Figure 69 presents normalized variation of equivalent single axle loads (ESAL) based on the scale calibration situation. The ESAL variation seems to be moderate when the scale under-calibrated. It is more severe when the scale is over-calibrated. The number of ESALs can increase up to 200 percent when the scale is over-calibrated by 8,000 lb.

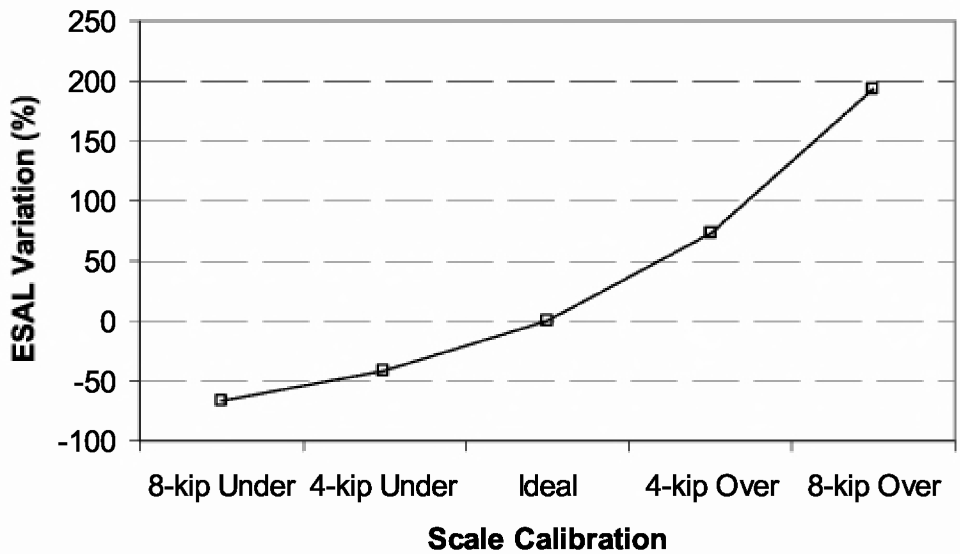

FIGURE 69. Variation of Equivalent Single Axle Loads

Figure 70 presents normalized variation of thickness of asphalt layer for each scale calibration situation for the low volume roadway. Thickness of asphalt layer varies 10 percent if the WIM scale is over-calibrated or under-calibrated by an increment of 4,000 lb. To investigate the effect on high volume roadways, daily traffic of 10,000 Class 9 trucks is used. A daily truck traffic volume of more than 10,000 is often observed on interstate highways in Arkansas, as shown in Table 23. Thickness of Class 7 granular base layer for a high volume roadway is increased from 9 inches to 14 inches. Figure 71 illustrates normalized variation of thickness of asphalt layer for a high volume roadway. The variation is similar to that of a low volume roadway.

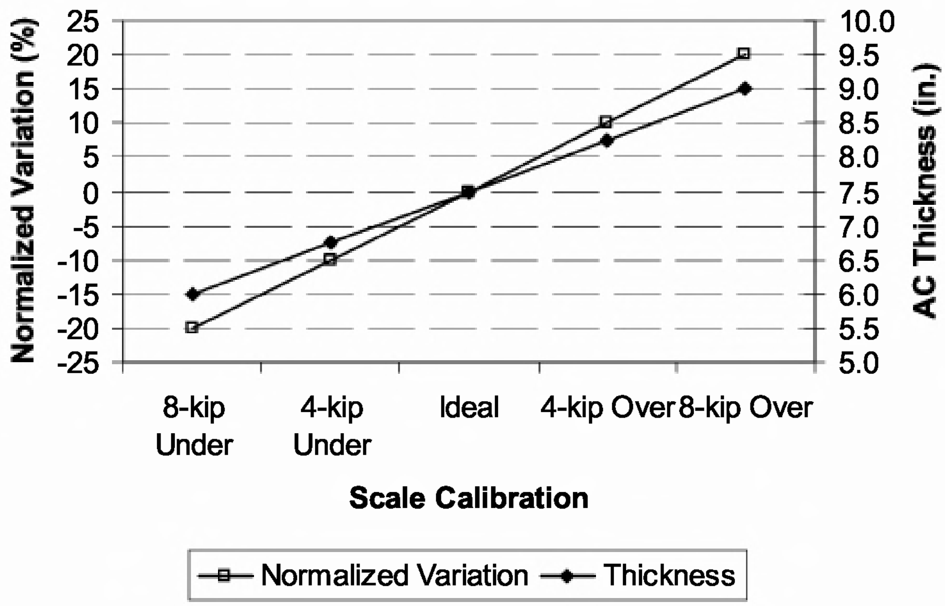

FIGURE 70. Variation of Thickness of Asphalt Layer for Low Volume Roadway

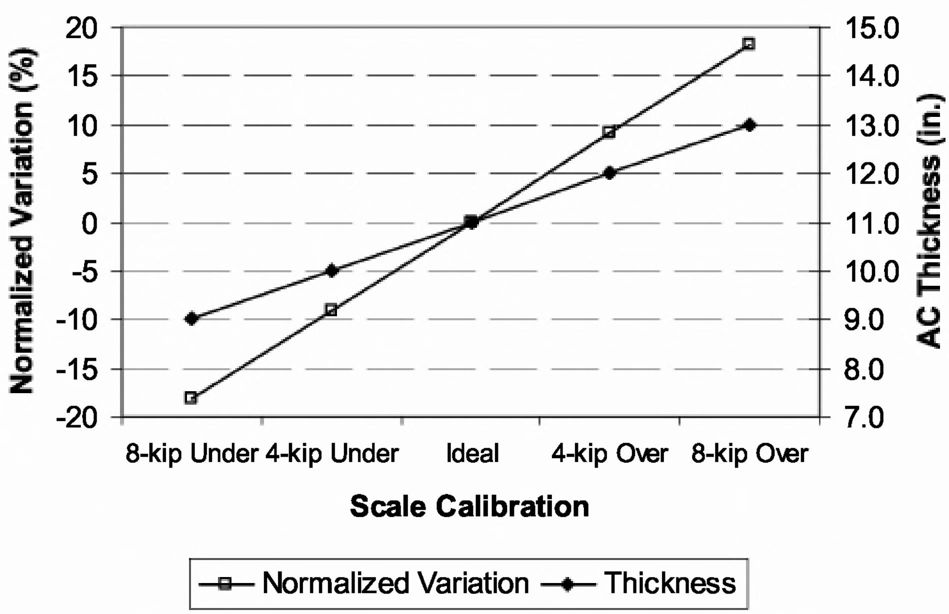

FIGURE 71. Variation of Thickness of Asphalt Layer for High Volume Roadway

This analysis shows that if traffic data pass the quality control checks recommended by LTPP and FHWA, the effect of data variation on the pavement design based on the *1993 Guide* is minimized. Thickness of asphalt layer varies about one inch if the WIM data are under- or over-estimated by an increment of 4,000 lb.

1.2 Sensitivity Analysis Using MEPDG Software

Since axle load spectra are an important input in MEPDG, significance of the weight data variation in the MEPDG procedures needs to be evaluated. The high volume roadway designed for the "ideal" calibration situation using the *1993 Guide* in the previous section is used for this analysis. For this roadway, daily traffic of Class 9 vehicles is 10,000. The pavement structure consists of 11 inches of asphalt concrete and 14 inches of Class 7 granular base. Table 35 summarizes the inputs used for the analysis. Other parameters in the MEPDG software are the default values.

Two predicted distresses of interest in this analysis are rutting and fatigue cracking. Design limits for these distresses in the MEPDG software are 0.75 inches of rutting and 25 percent of fatigue cracking. Figures 72 and 73 present predicted rutting and cracking for five calibration situations, respectively. The pavement is predicted to fail due to excessive rutting. The two figures show that the sensitivity of the predicted distresses to the weight data variation is significant. Based on the rutting design limit, the predicted pavement life for each calibration case is shown in Figure 74. The predicted pavement lives are about one year different if the scale calibration is within 4,000 lb. from the "ideal". When the scale is under- or over-calibrated by 8,000 lb., the predicted pavement lives are about three years different from that of the "ideal" situation. Compared to the predicted life of 141 months for the pavement under "ideal" situation, the normalized differences are about 9 and 25 percent.

TABLE 35. Inputs for Sensitivity Analysis Using MEPDG

Description	Input
General Information	
Type of Design	Flexible
Traffic Volume	
Two-way AADTT	10,000
Lanes in Design Direction	2
Vehicle Class Distribution	
Class 4	0%
Class 5	0%
Class 6	0%
Class 7	0%
Class 8	0%
Class 9	100%
Class 10	0%
Class 11	0%
Class 12	0%
Class 13	0%
Axle Load Distribution Factors	Variable
Climate	Fayetteville
Asphalt Layer	
Thickness	11 in.
Mix	12.5mm and PG 70-22
Granular Base	
Thickness	14 in.
Modulus	40,000 psi
Subgrade	
Classification	A-7-6
Modulus	5,000 psi

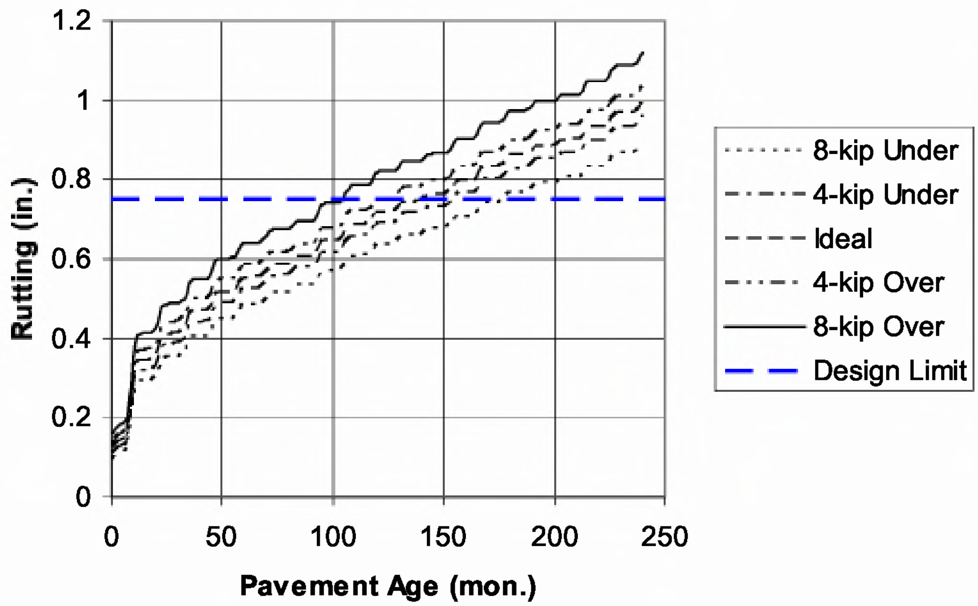

FIGURE 72. Predicted Rutting for Five Calibration Situations

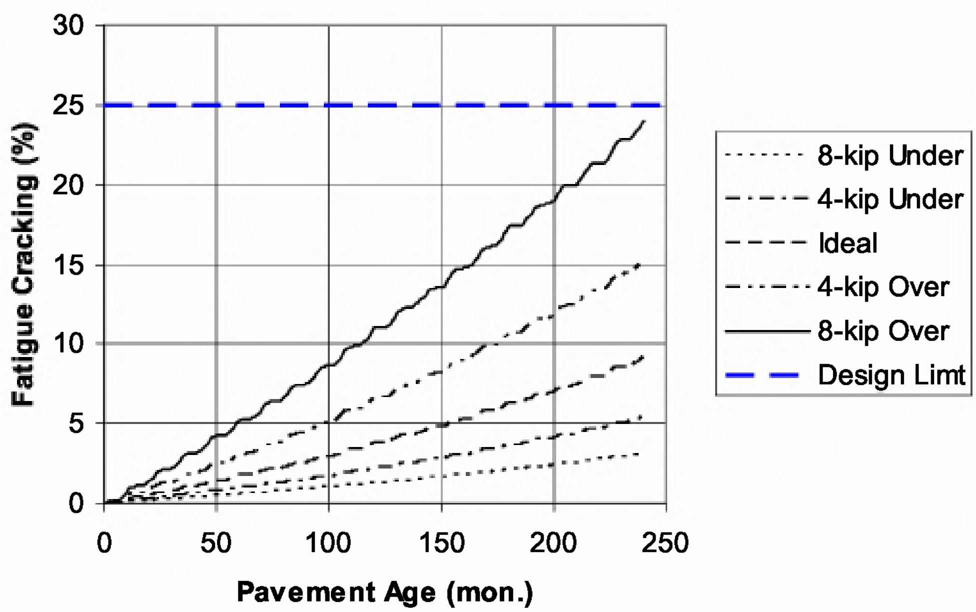

FIGURE 73. Predicted Cracking for Five Calibration Situations

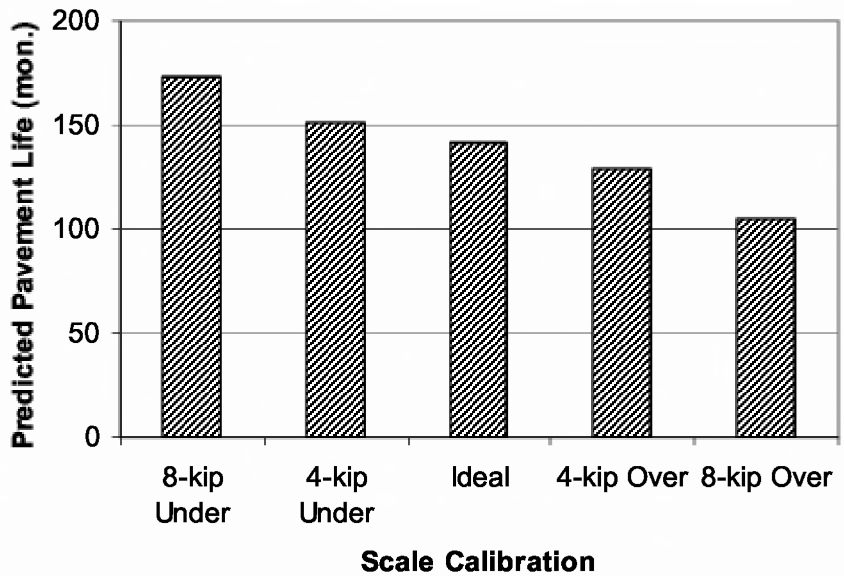

FIGURE 74. Predicted Pavement Life Based on Rutting Design Limit

Figure 75 compares the predicted cracking after 141 months, which are the predicted pavement life of the "ideal" situation. Even though the amount of cracking is less than the design limit, it is felt that the predicted cracking is sensitive to the WIM scale calibration.

In summary, the analyses show that the scale calibration influences the pavement design. If the scale is calibrated within the limits recommended in the LTPP and FHWA publications (*4*,*11*), the effect can be minimized. If the scale calibration is off 8,000 lb. from the limits, the design thickness of asphalt layer can be different by two inches from that of the "ideal" calibration using the *1993 Guide*, or the difference in the predicted pavement life can be three years or 25 percent using the MEPDG software if the rutting criterion governs the design. However, since predicted cracking is very sensitive to the weight data variation, the differences in the predicted pavement lives may be more significant if the design is governed by the cracking criterion.

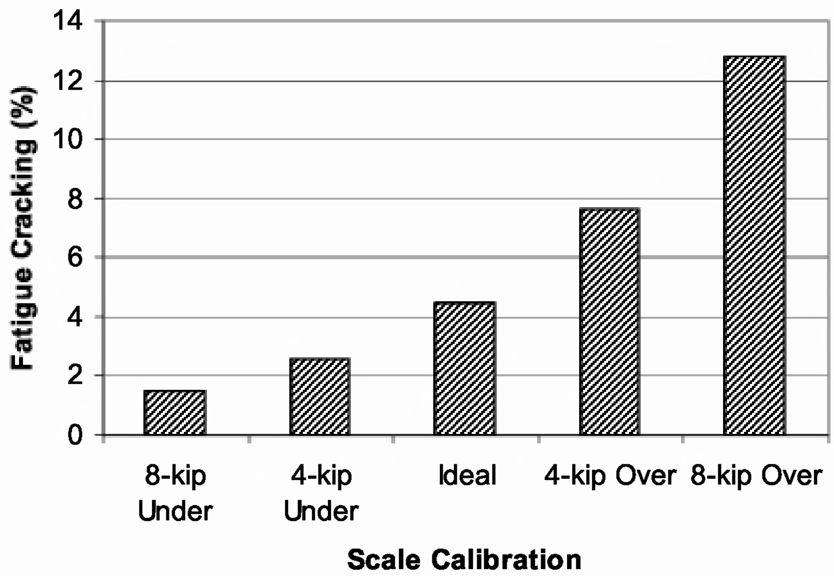

FIGURE 75. Predicted Cracking After 141 months

2. SIGNIFICANCE OF STATEWIDE TRAFFIC INPUTS FOR ARKANSAS

The statewide traffic inputs for Arkansas were developed in Chapter 3. These inputs are developed independently from the default traffic inputs, which is also called the nationwide traffic inputs developed based on the LTPP database, used in the MEPDG software. Thus, sensitivity of the pavement design to the developed statewide traffic inputs needs to be evaluated using the MEPDG software. Based on the analysis, only significant traffic inputs will be recommended for periodical updates, and the default values will be recommended for insignificant inputs. Table 36 summarizes the inputs used in the analysis. The following developed statewide traffic inputs are compared to the corresponding default values:

- Monthly distribution factors
- Hourly distribution factors
- Vehicle classification distribution factors

- Axle load distribution factors

TABLE 36. Inputs for Sensitivity Analysis of Developed Traffic Inputs

Description	Input
General Information	
Type of Design	Flexible
Traffic Volume	
Two-way AADTT	10,000
Lanes in Design Direction	2
Monthly Distribution Factors	Variable
Vehicle Class Distribution Factors	Variable
Hourly Distribution Factors	Variable
Axle Load Distribution Factors	Variable
Climate	Fayetteville
Asphalt Layer	
Thickness	11 in.
Mix	12.5mm and PG 70-22
Granular Base	
Thickness	14 in.
Modulus	40,000 psi
Subgrade	
Classification	A-7-6
Modulus	5,000 psi

2.1 Significance of Monthly Distribution Factors

The statewide monthly distribution factors developed in Chapter 3 are shown in Table 27. Figure 76 compares the developed statewide monthly distribution factors and the default values recommended in the MEPDG software. The statewide monthly distribution factors are slightly different from the default values. In general, the monthly distribution percentage is higher in couple months before the summer and Christmas.

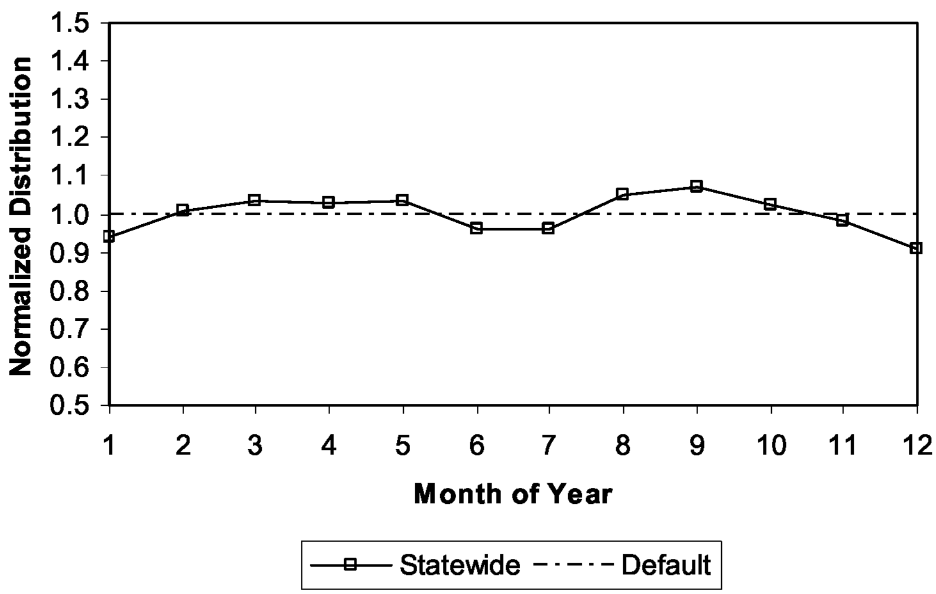

FIGURE 76. Statewide versus Default Monthly Distribution Factors

Figures 77 and 78 compare the predicted rutting and fatigue cracking based on the statewide and default monthly distribution factors. The predicted pavement distresses based on the two sets of monthly distribution factors are not significantly different. Thus, it is reasonable to use the default monthly distribution factors in the MEPDG software for the pavement design in the future.

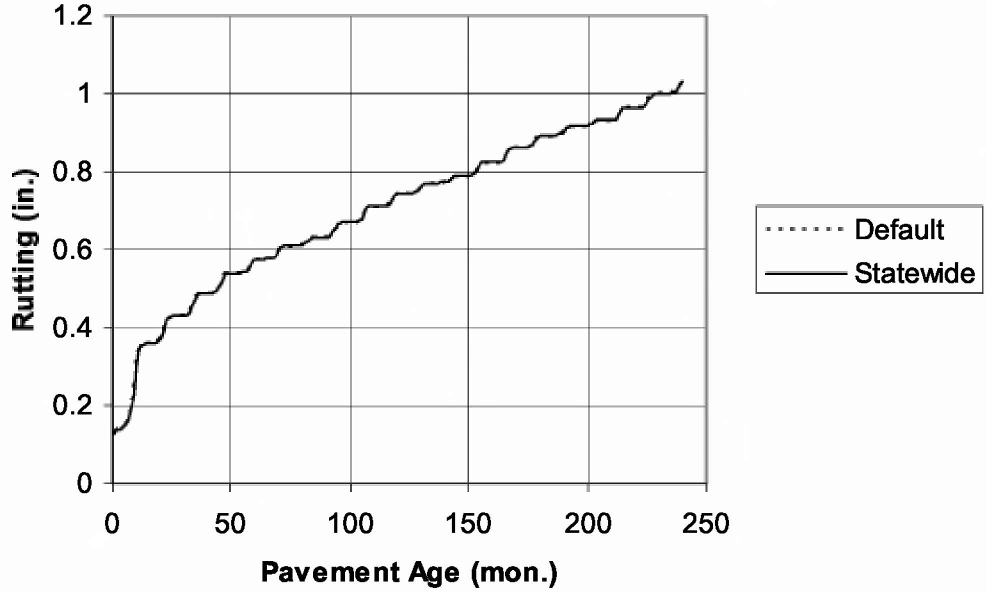

FIGURE 77. Rutting - Statewide and Default Monthly Distribution Factors

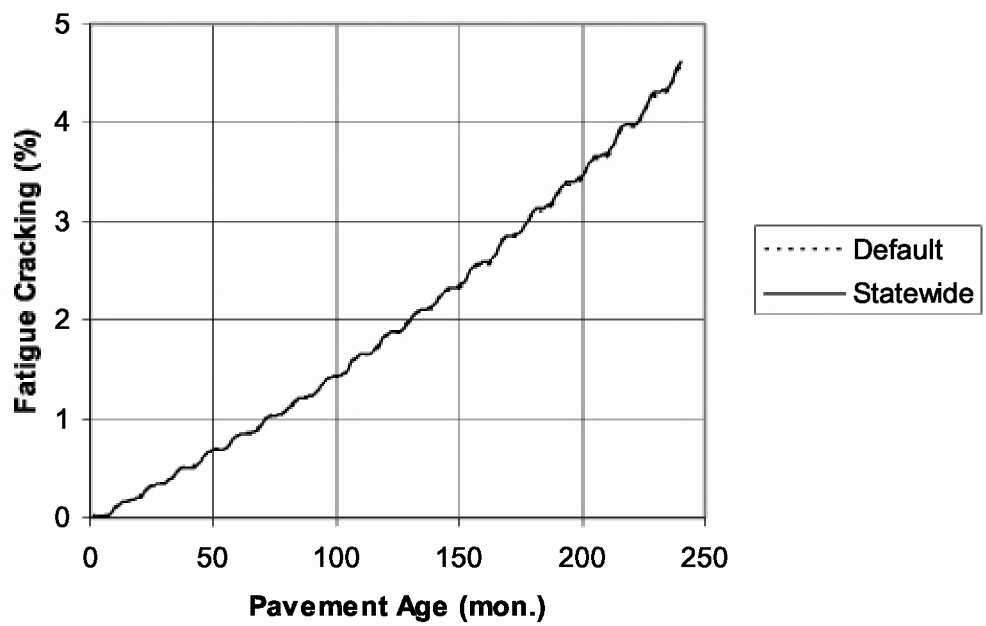

FIGURE 78. Fatigue Cracking - Statewide and Default Monthly Distribution Factors

2.2 Significance of Hourly Distribution Factors

Figure 79 compares the developed statewide hourly distribution factors with the default values. The statewide distribution percentage is higher than that of the default values during the day and lower than the default at night. Variation of hourly distribution factors may cause more rutting in flexible pavements due to higher temperatures at noon. In addition, it may affect the thermal expansion/contraction activities in rigid pavements throughout the day.

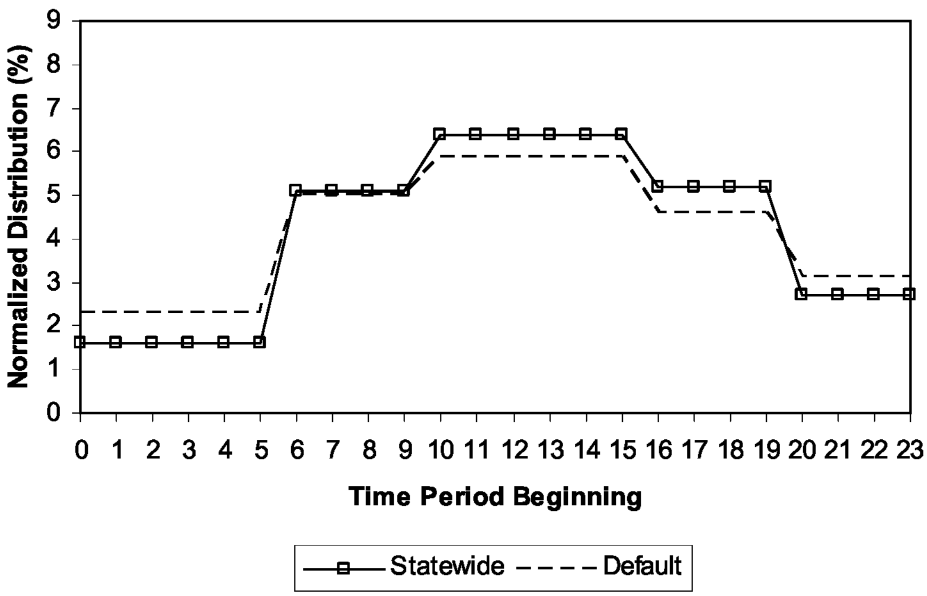

FIGURE 79. Statewide versus Default Hourly Distribution Factors

Figures 80 and 81 present the predicted rutting and fatigue cracking for the statewide and default hourly distribution factors. The predicted distresses are not significantly different. Thus, the default hourly distribution factors are recommended for the design of flexible pavements in the future.

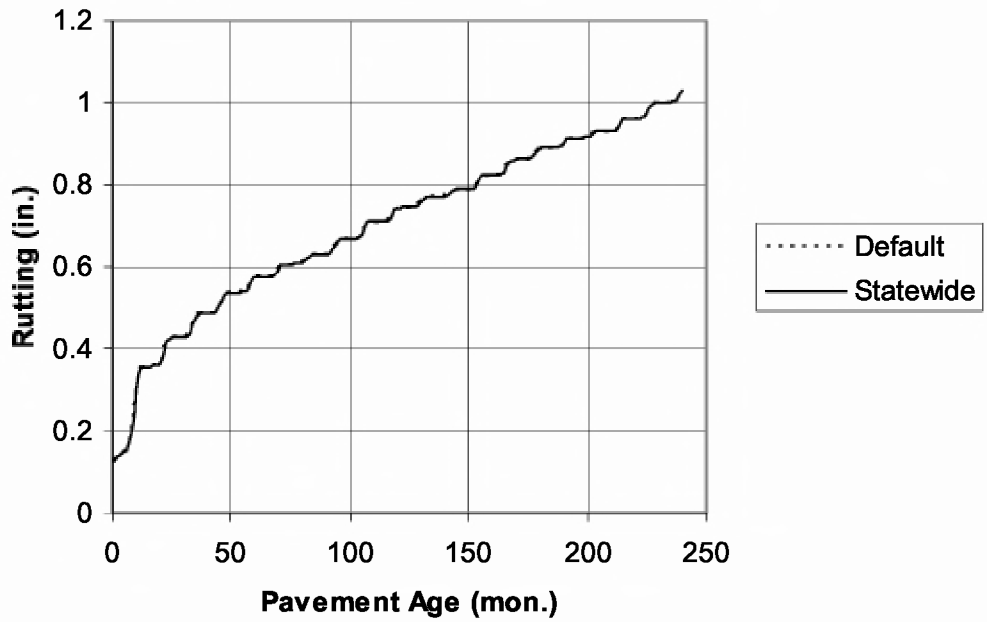

FIGURE 80. Rutting - Statewide and Default Monthly Distribution Factors

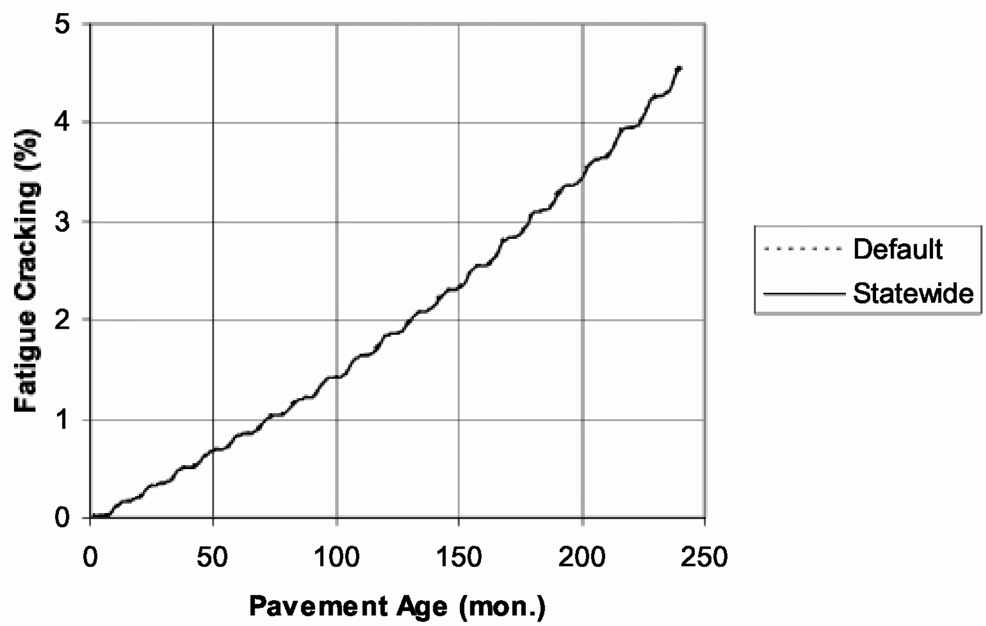

FIGURE 81. Fatigue Cracking - Statewide and Default Monthly Distribution Factors

Since concrete is sensitive to the temperature variation throughout the day, it is suspected that the differences in the statewide and default hourly distribution factors may influence the rigid pavement design. A similar sensitivity analysis is performed using a 15-in jointed plain concrete pavement (JPCP). The traffic inputs used in this analysis are the same for those of the flexible pavement, as presented in Table 36. Figure 82 presents the predicted faulting for the rigid pavement using the statewide and default hourly distribution factors. The predicted faulting is not significantly different.

FIGURE 82. Faulting - Statewide and Default Monthly Distribution Factors

Even though the statewide hourly distribution factors are different from the corresponding default values, as shown in Figure 79, it is still reasonable to use the default hourly distribution factors for the design in the future because the sensitivity of the design to the differences in the hourly distribution factors is not significant.

2.3 Significance of Vehicle Class Distribution Factors

The default class distribution factors are grouped based on the truck traffic classification (TTC) system. The default class distribution factors were developed for 17 different TTC groups using the LTPP database. All default class distribution factors are included in the MEPDG software.

This study used the traffic data provided by the Technical Services of AHTD. The statewide class distribution factors were developed for seven TTC groups, including TTC groups 3, 6, 7, 9, 10, 12, and 13, based on the available traffic data. This section presents an analysis on the sensitivity of the pavement design to the statewide and default vehicle class distribution factors.

Figures 83 through 89 compare the statewide class distribution factors with the corresponding default values for the seven TTC groups. The statewide and default class distribution factors for the first six TTC groups are slightly different. The class distribution factors for TTC 13 are more different than the first six groups. For most of the groups, the statewide class distribution factors show more VC 6 and 8 trucks and less VC 13 vehicles than the default distributions.

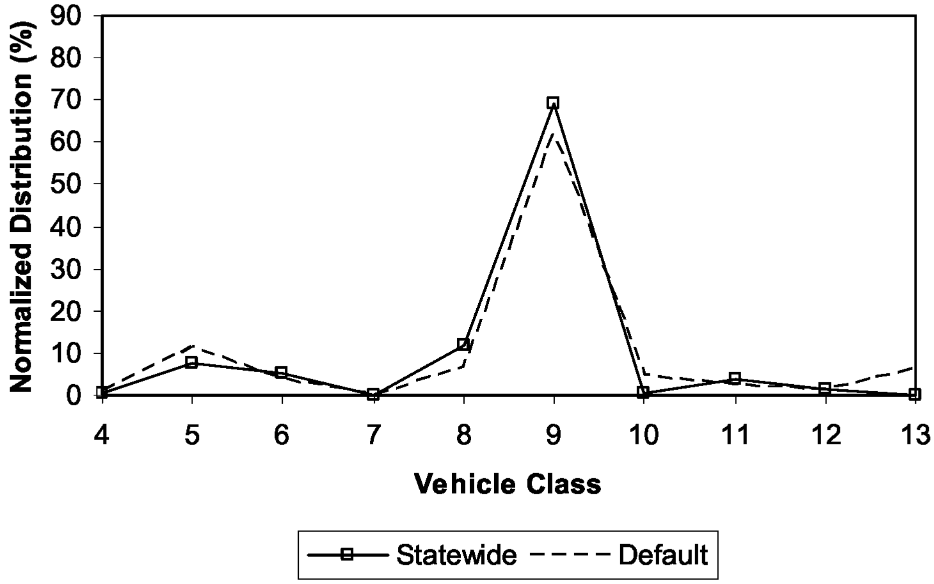

FIGURE 83. Statewide and Default Class Distribution Factors for TTC 3

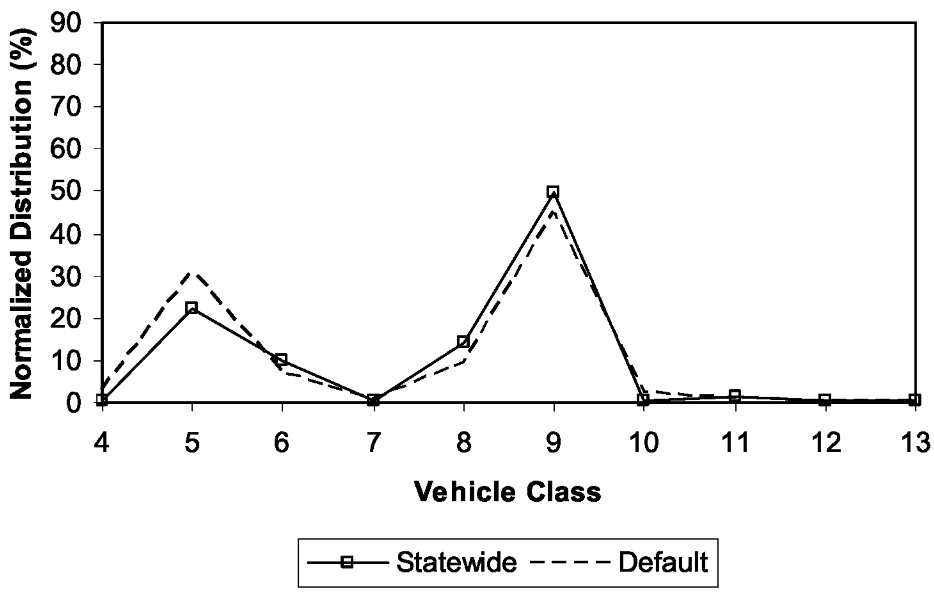

FIGURE 84. Statewide and Default Class Distribution Factors for TTC 6

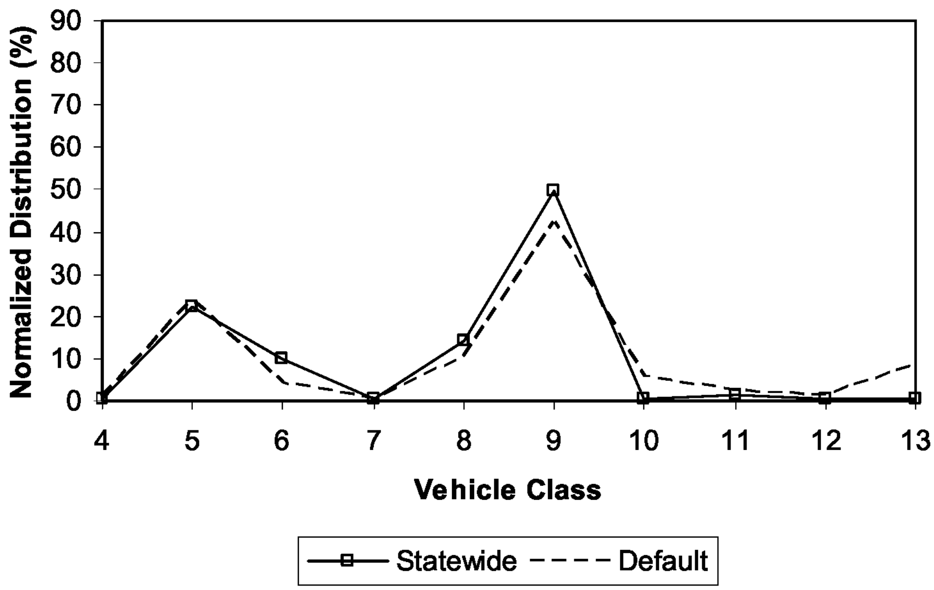

FIGURE 85. Statewide and Default Class Distribution Factors for TTC 7

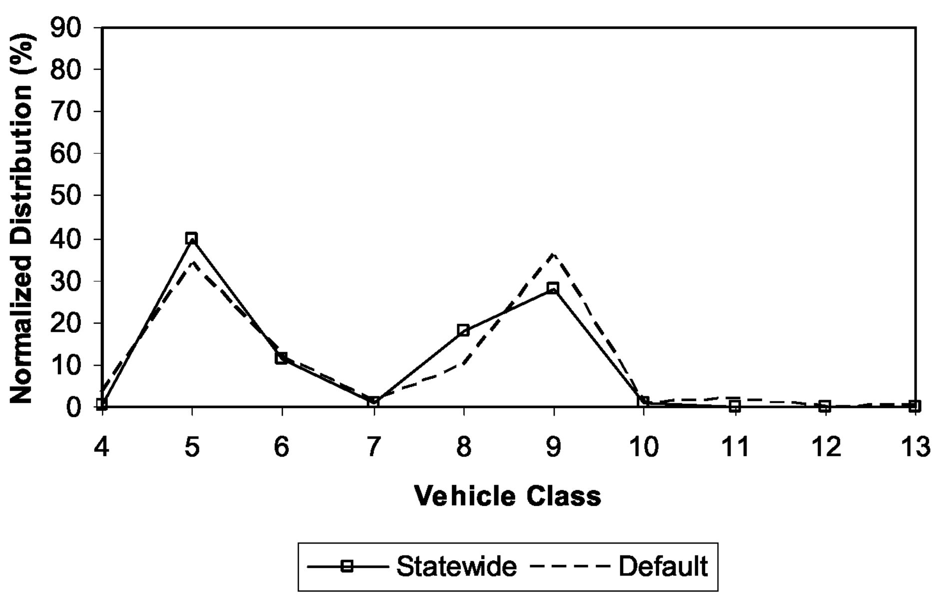

FIGURE 86. Statewide and Default Class Distribution Factors for TTC 9

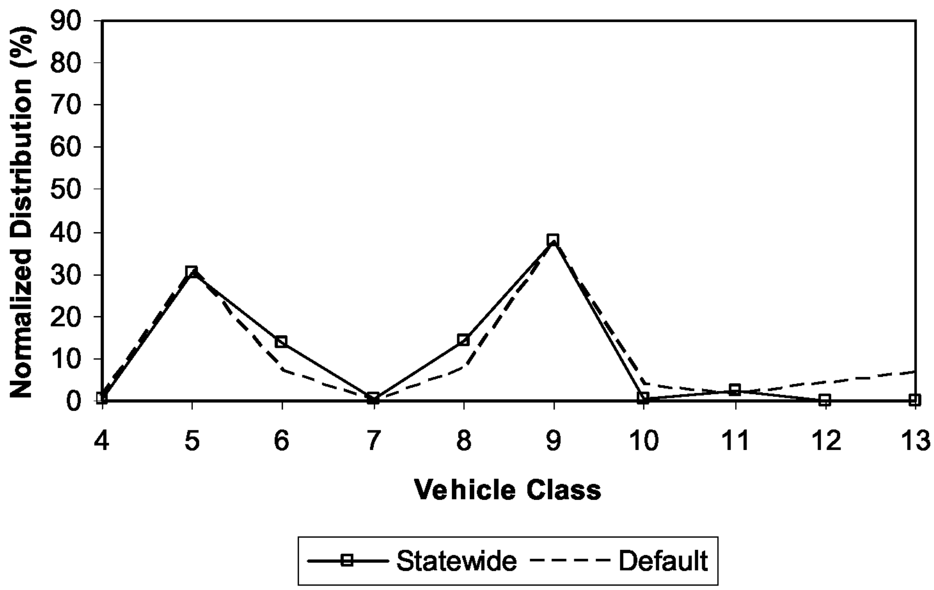

FIGURE 87. Statewide and Default Class Distribution Factors for TTC 10

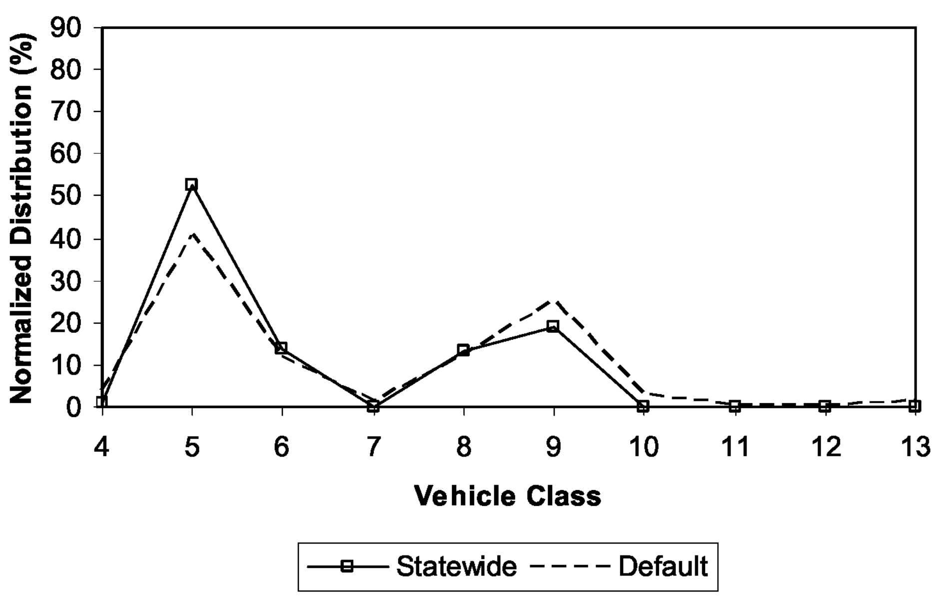

FIGURE 88. Statewide and Default Class Distribution Factors for TTC 12

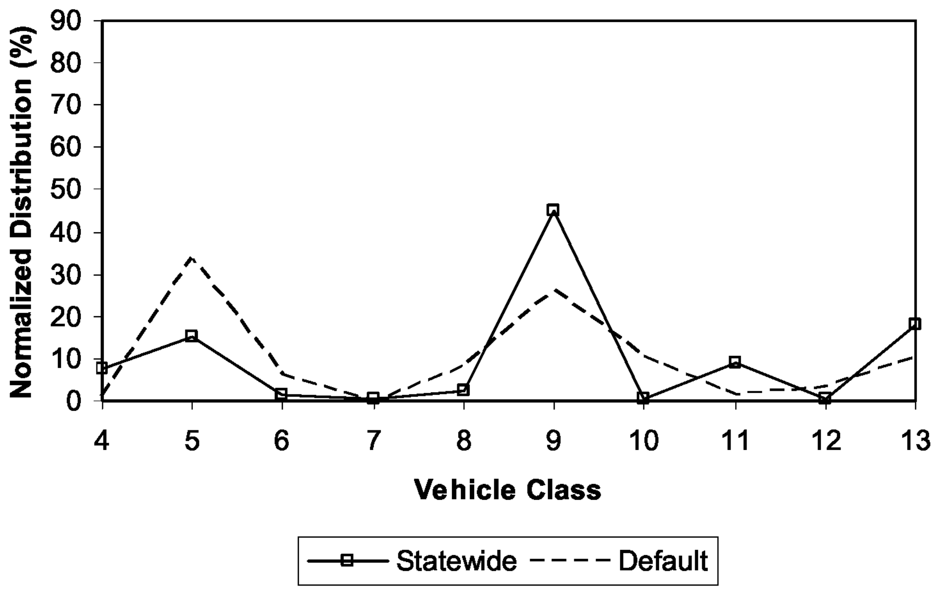

FIGURE 89. Statewide and Default Class Distribution Factors for TTC 13

Figures 90 through 103 compare the rutting and fatigue cracking predicted by the MEPDG software using the statewide and default class distribution factors. The rutting and fatigue cracking based on the statewide class distribution factors are different from those based on the default values. For all cases, predicted pavement lives are governed by the predicted rutting. Figure 104 compares the predicted pavement lives based on the statewide and default class distribution factors. The differences in the predicted pavement lives based on the statewide and default class distribution factors are ranging from one to three years. The differences are normalized in Figure 105. The normalized differences are ranging from 10 to 20 percent. Figure 106 shows the normalized differences in the predicted pavement life based on the default class distribution factors for the seven TTC groups. The differences are ranging from 1 to 20 percent. This shows that the sensitivity of predicted rutting to the differences between the statewide and default class distribution factors is as much as to the differences between the default values for the seven TTC groups.

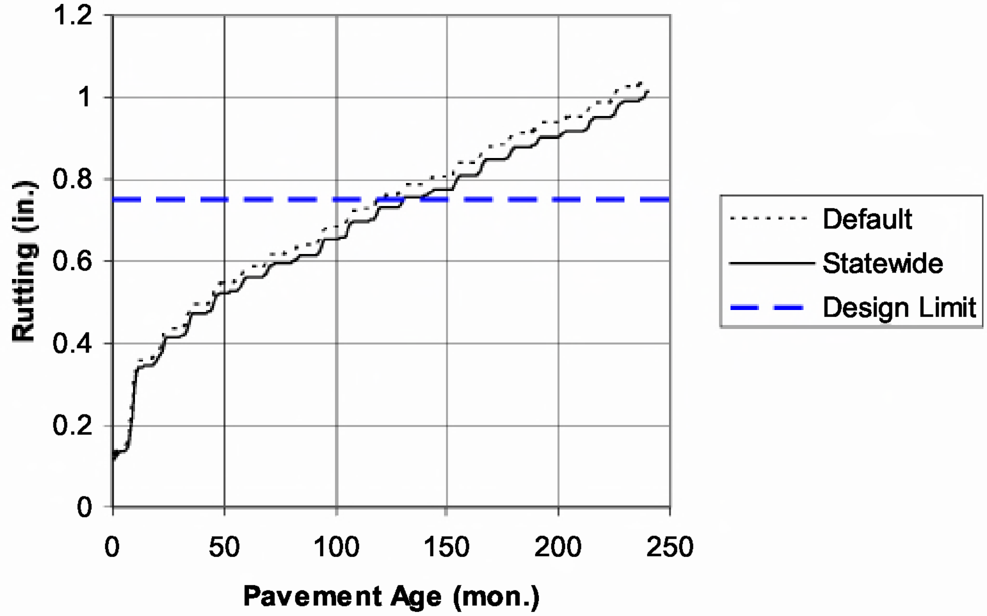

FIGURE 90. Rutting – Statewide and Default Class Distribution Factors for TTC 3

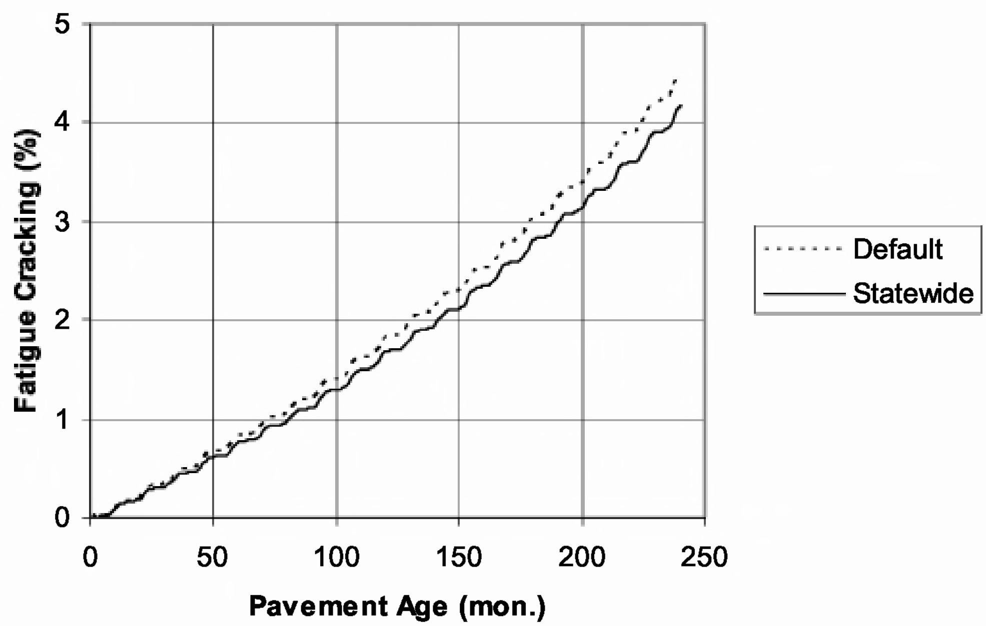

FIGURE 91. Cracking – Statewide and Default Class Distribution Factors for TTC 3

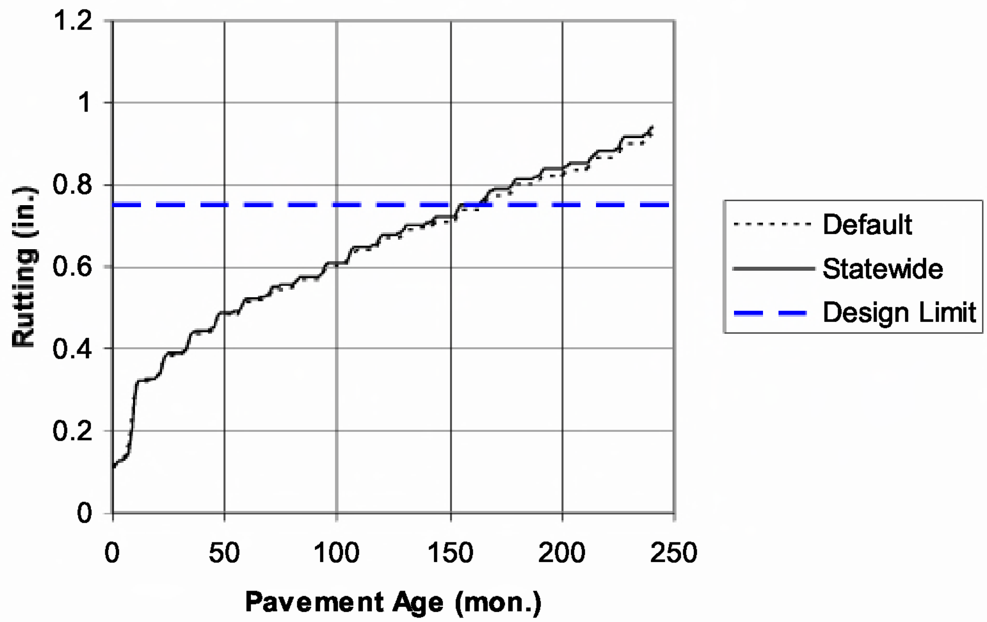

FIGURE 92. Rutting – Statewide and Default Class Distribution Factors for TTC 6

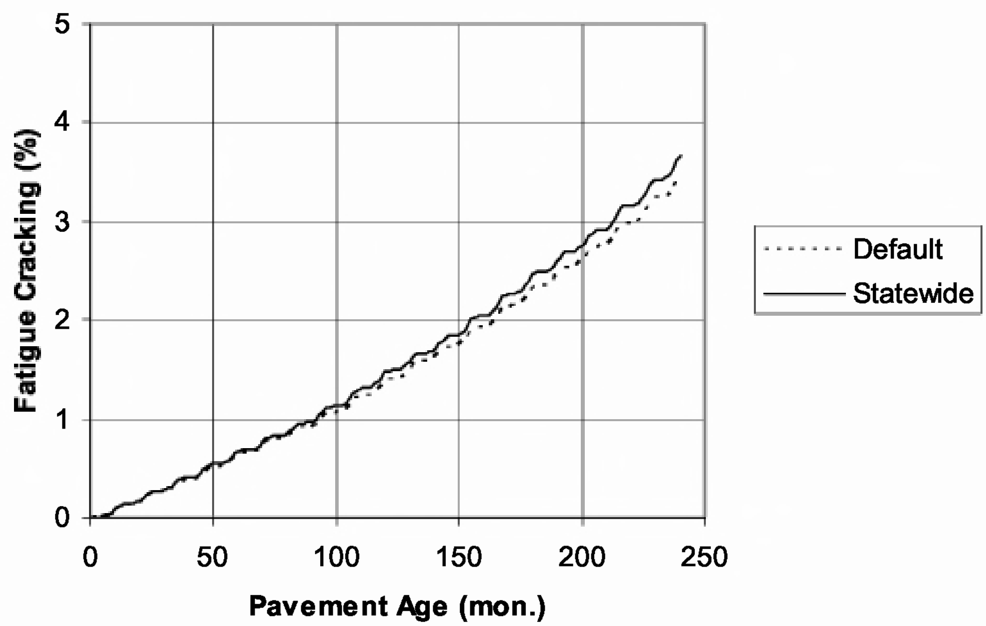

FIGURE 93. Cracking – Statewide and Default Class Distribution Factors for TTC 6

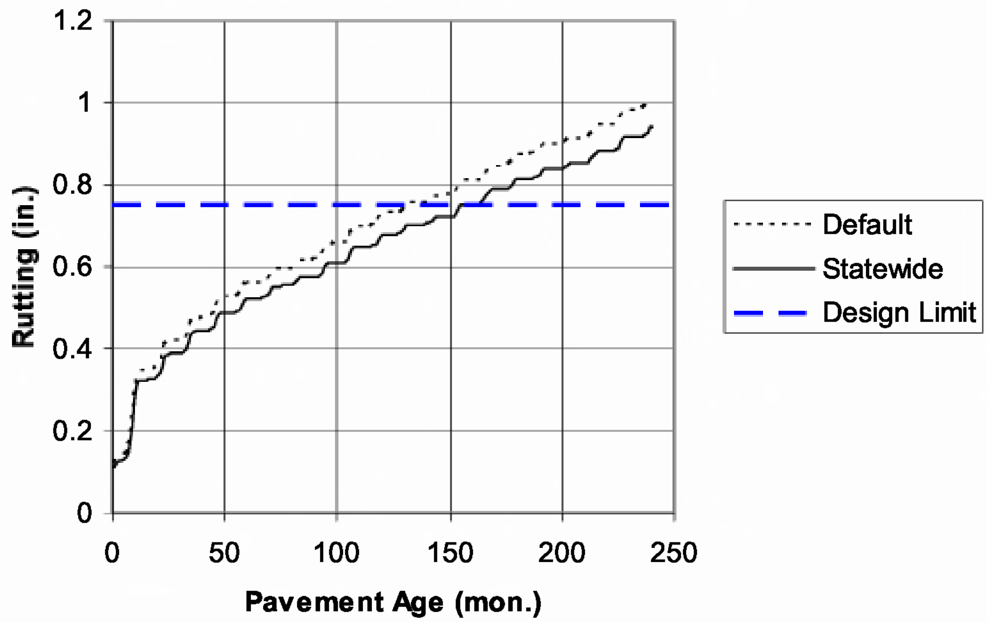

FIGURE 94. Rutting – Statewide and Default Class Distribution Factors for TTC 7

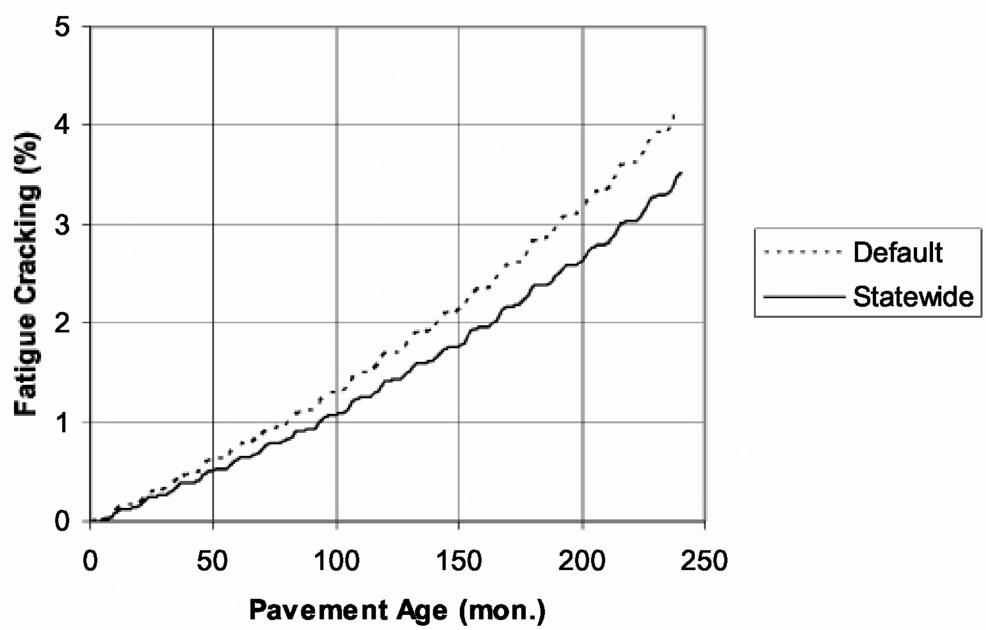

FIGURE 95. Cracking – Statewide and Default Class Distribution Factors for TTC 7

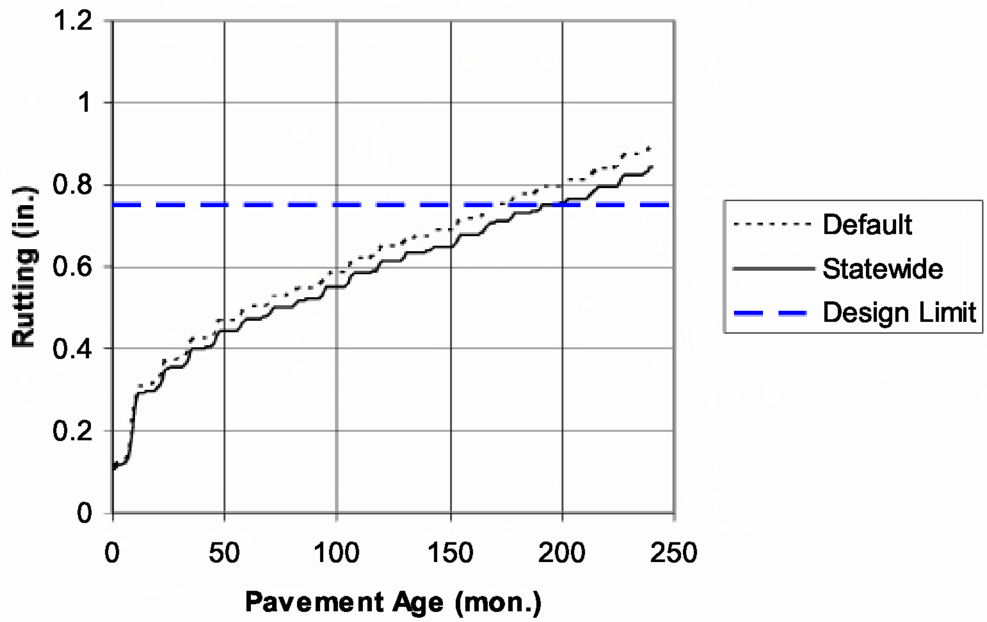

FIGURE 96. Rutting – Statewide and Default Class Distribution Factors for TTC 9

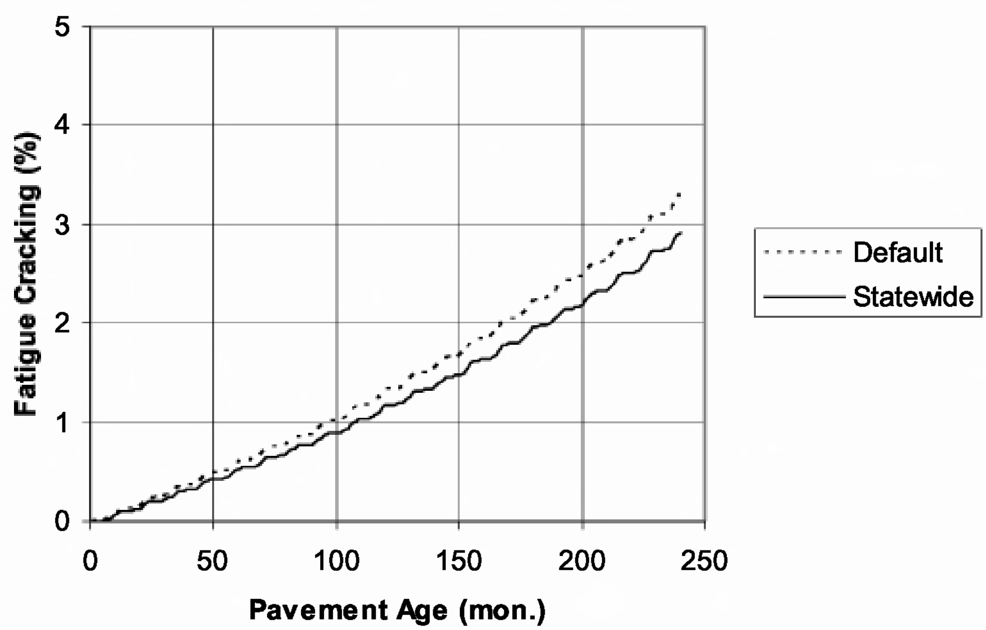

FIGURE 97. Cracking – Statewide and Default Class Distribution Factors for TTC 9

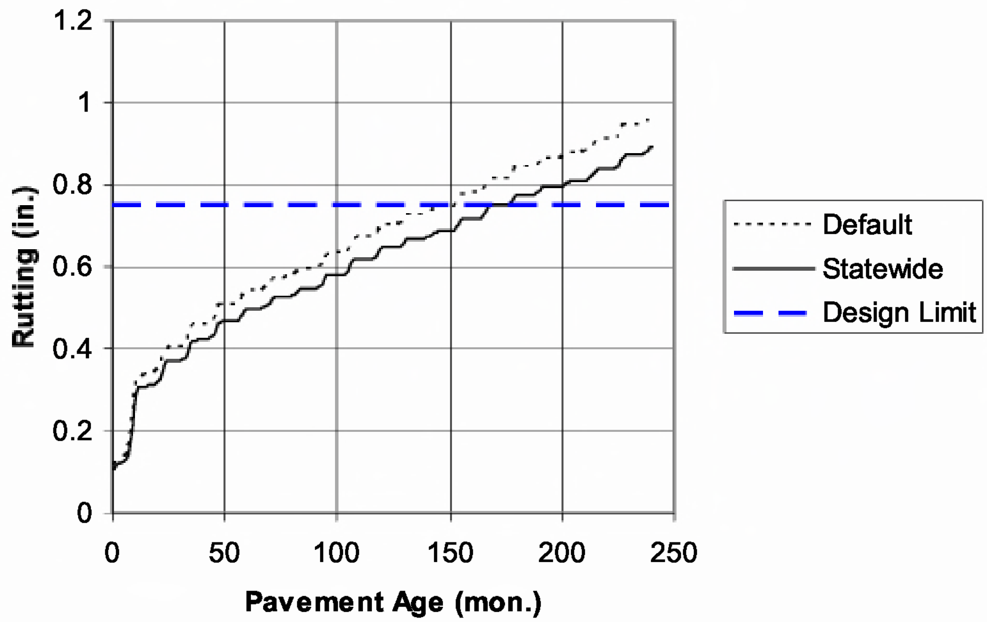

FIGURE 98. Rutting – Statewide and Default Class Distribution Factors for TTC 10

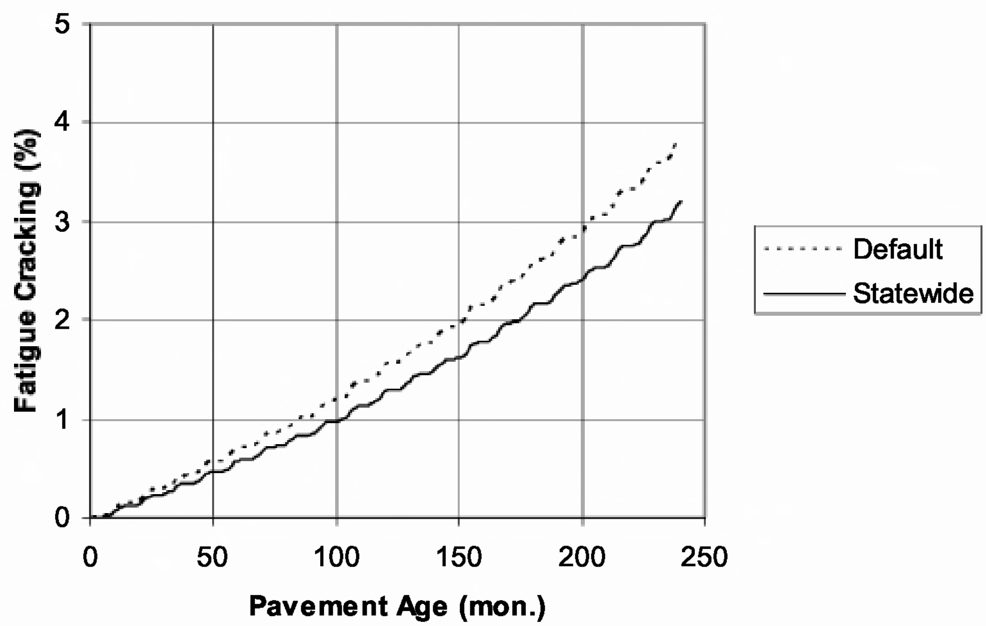

FIGURE 99. Cracking – Statewide and Default Class Distribution Factors for TTC 10

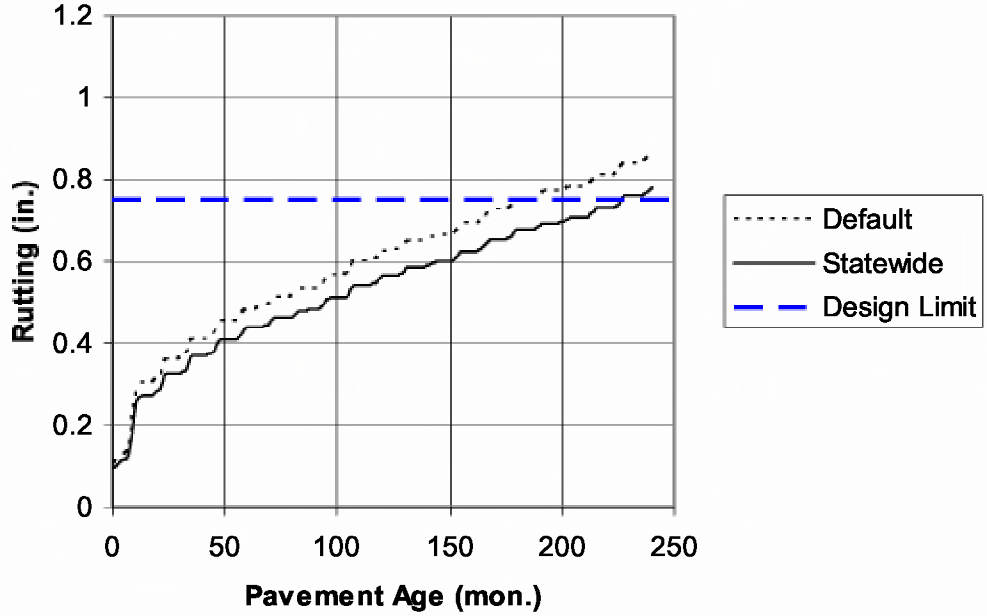

FIGURE 100. Rutting – Statewide and Default Class Distribution Factors for TTC 12

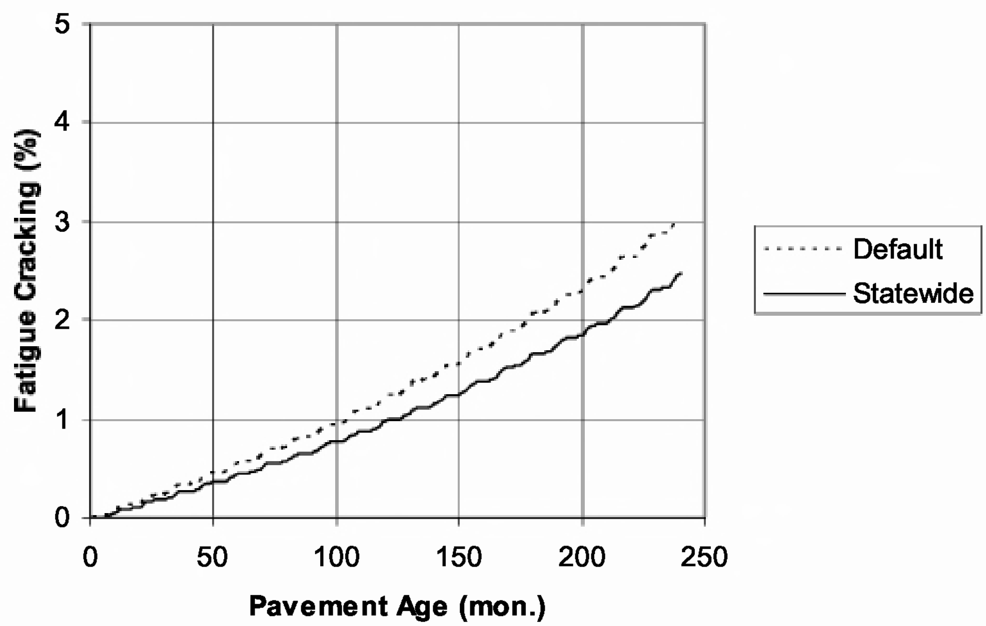

FIGURE 101. Cracking – Statewide and Default Class Distribution Factors for TTC 12

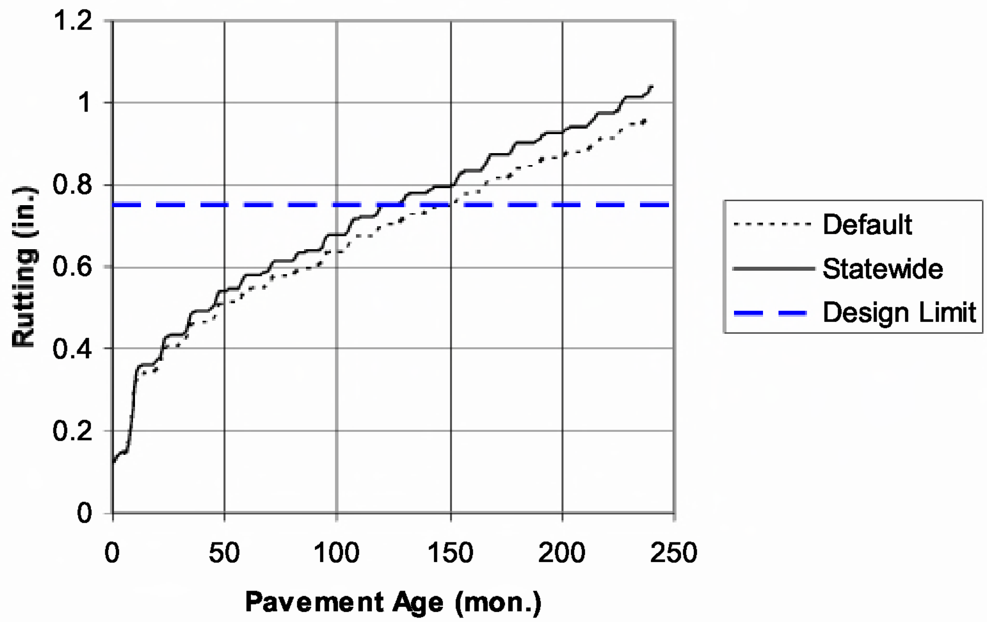

FIGURE 102. Rutting – Statewide and Default Class Distribution Factors for TTC 13

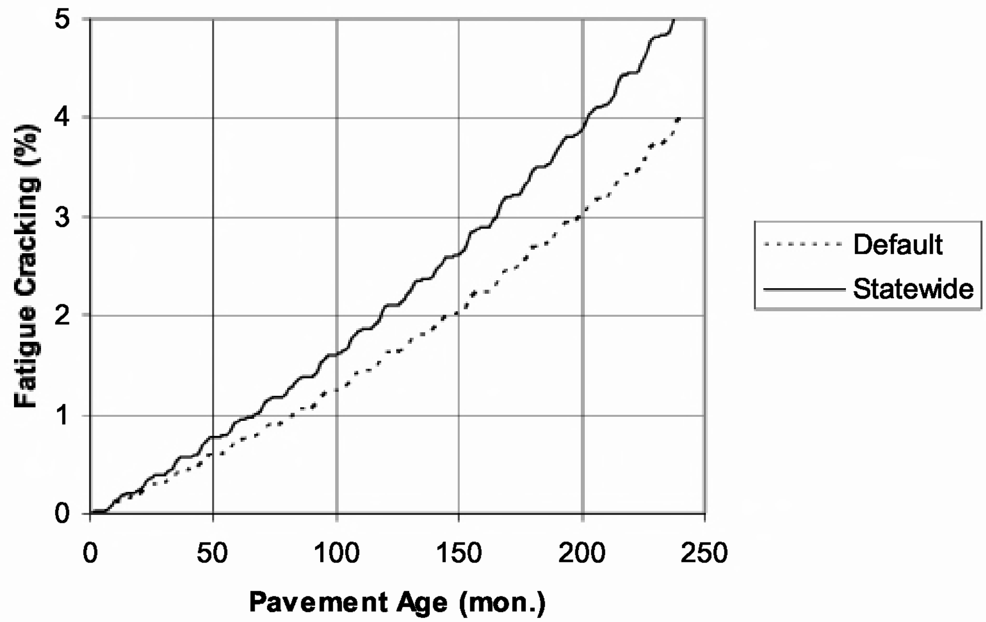

FIGURE 103. Cracking – Statewide and Default Class Distribution Factors for TTC 13

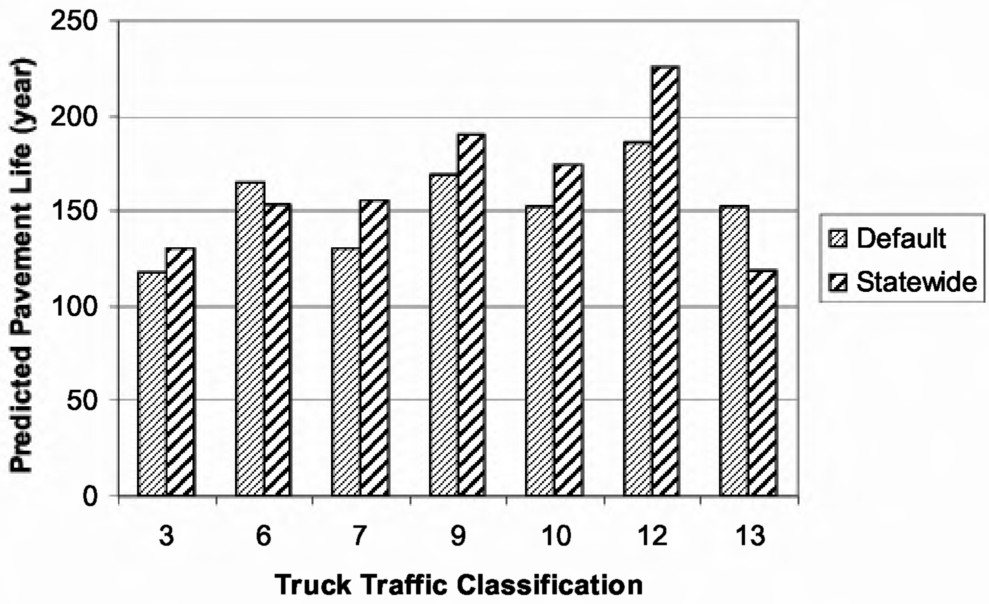

FIGURE 104. Predicted Pavement Lives based on Rutting

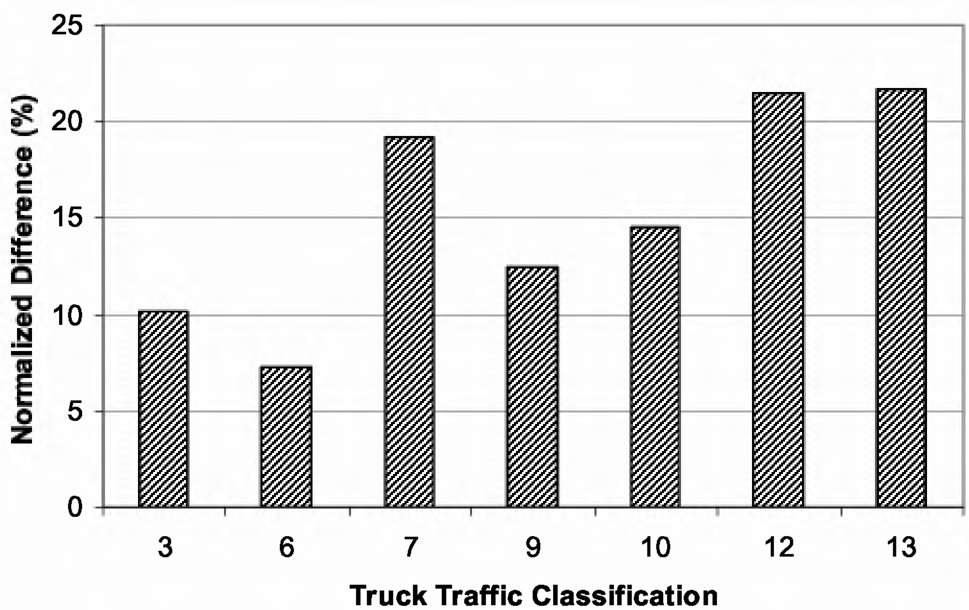

FIGURE 105. Normalized Differences in Predicted Pavement Life Based on Default and Statewide Class Distribution Factors

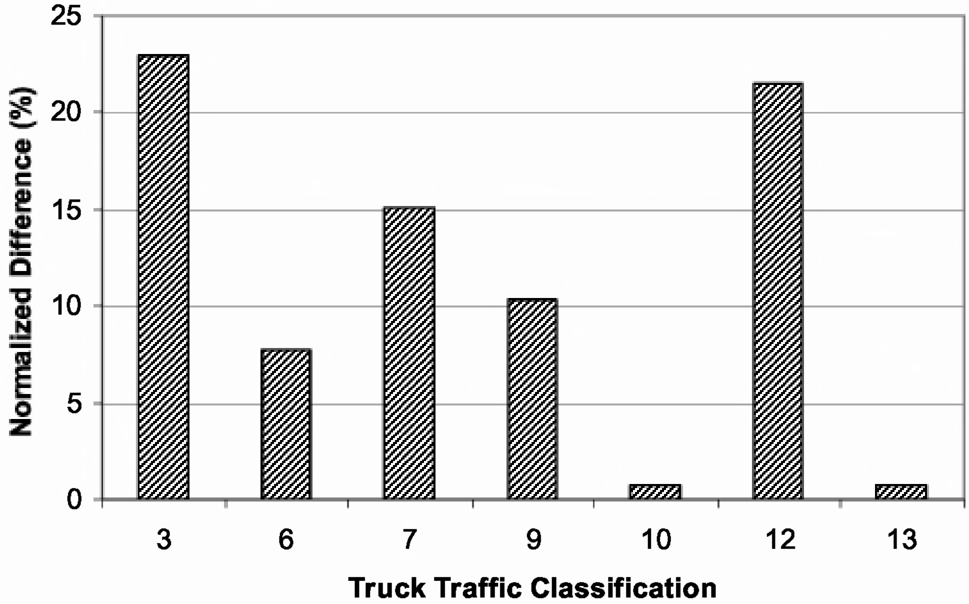

FIGURE 106. Normalized Differences in Predicted Pavement Life Based on Default Class Distribution Factors

Figure 104 shows that the average predicted pavement life is 13 years. The predicted cracking after 13 years is determined for the seven TTC groups. Figure 107 shows the normalized differences in the predicted cracking after 13 years based on the statewide and default class distribution factors. The differences are ranging from 6 to 30 percent. Figure 108 illustrates the normalized differences in the predicted cracking after 13 years based on the default class distribution factors. The differences are ranging from 2 to 20 percent. This shows that the sensitivity of predicted fatigue cracking to the differences between the statewide and default class distribution factors is greater than to the differences between the default factors for the seven TTC groups. In summary, the statewide class distribution factors for the seven TTC groups should be used in the design. For the other TTC groups, the default class distribution factors provided in the MEPDG software should be used, if required.

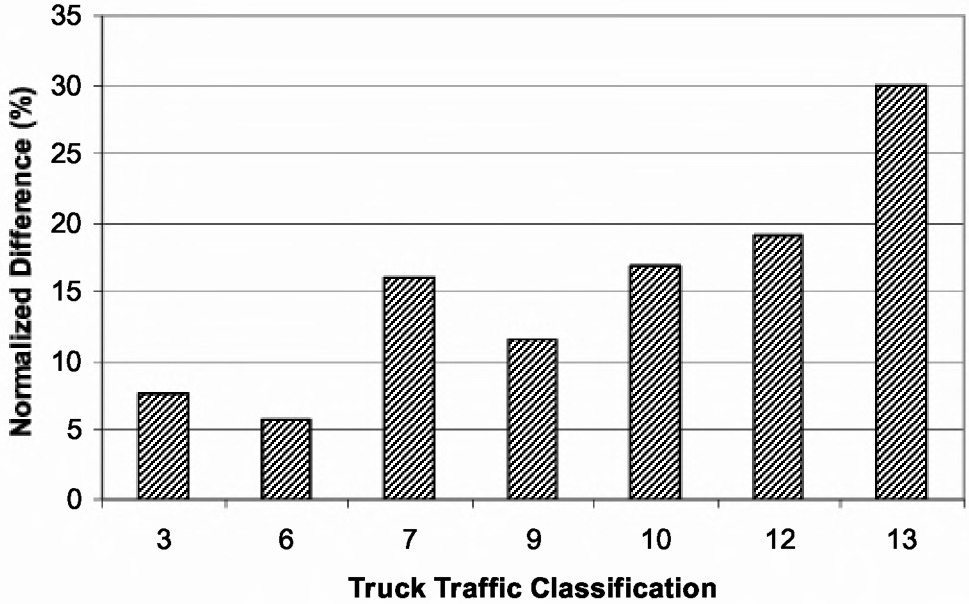

FIGURE 107. Normalized Differences in Predicted Cracking after 13 Years Based on Default and Statewide Class Distribution Factors

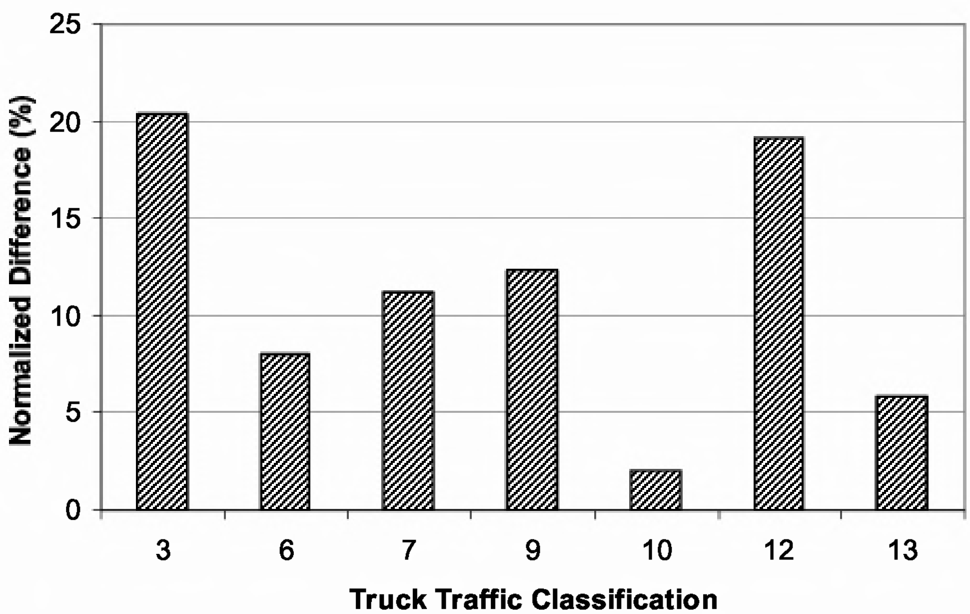

FIGURE 108. Normalized Differences in Predicted Cracking after 13 Years Based on Default Class Distribution Factors

2.4 Significance of Axle Load Distribution Factors

The statewide axle load spectra for single, tandem and tridem axles were developed in Chapter 3. Since very few quad axles were found in the available traffic data, the axle load spectra for quad axles were not developed, and it is recommended that the default axle load spectra for quad axles be used, if required.

Figures 109 and 110 compare the statewide single and tandem axle load spectra for Class 9 trucks with the default values, respectively. The axle load spectra are similar for both single and tandem axles of Class 9 vehicles.

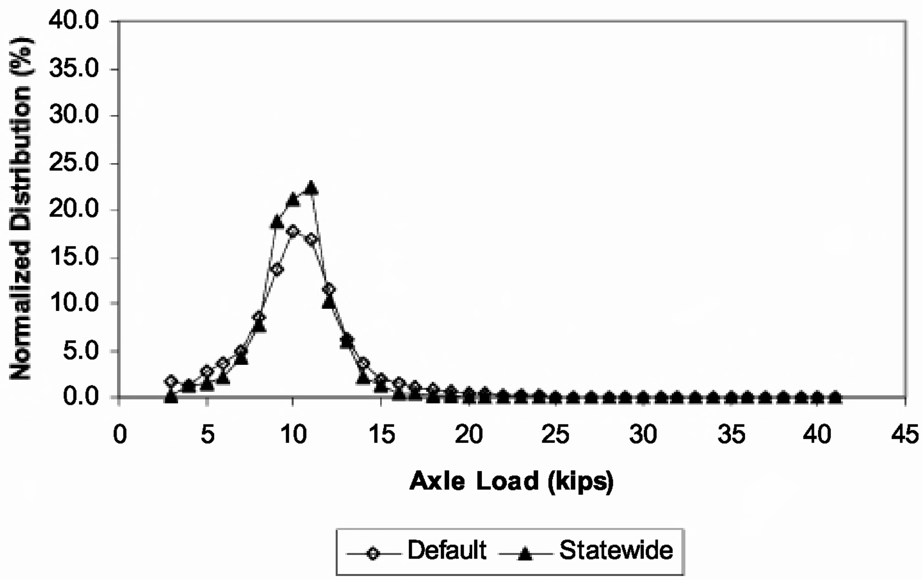

FIGURE 109. Default versus Statewide Single Axle Load Spectra for VC 9

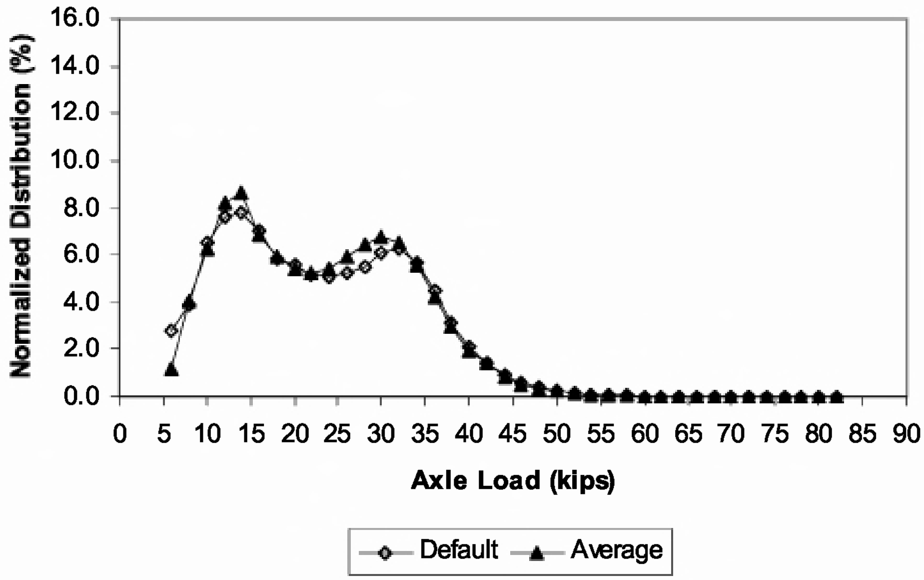

FIGURE 110. Default versus Statewide Tandem Axle Load Spectra for VC 9

Figures 111 and 112 compare the rutting and fatigue cracking predicted by the MEPDG software based on the statewide and default axle load spectra. The predicted distresses based on the statewide axle load spectra are different from those based on the default values. The normalized differences in pavement life, rutting and cracking are presented in Figure 113. The normalized differences show that the predicted design parameters are sensitive to the axle load spectra. The sensitivity of the pavement design to the axle load spectra is also reported by Zaghloul (*19*).

It is recommended that the statewide axle load spectra be used for initial implementation of MEPDG instead of the default axle load spectra provided in the design software. Since the predicted distresses are sensitive to the axle load spectra, site specific (Level 1) axle load spectra should be developed and used in the design if traffic data are available.

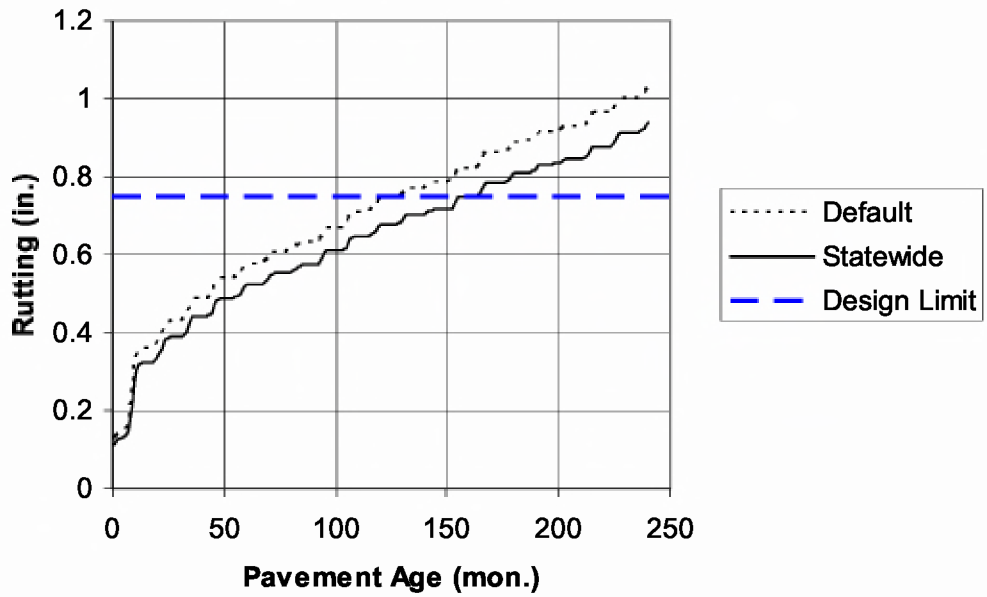

FIGURE 111. Rutting – Default and Statewide Axle Load Spectra

FIGURE 112. Fatigue Cracking - Default and Statewide Axle Load Spectra

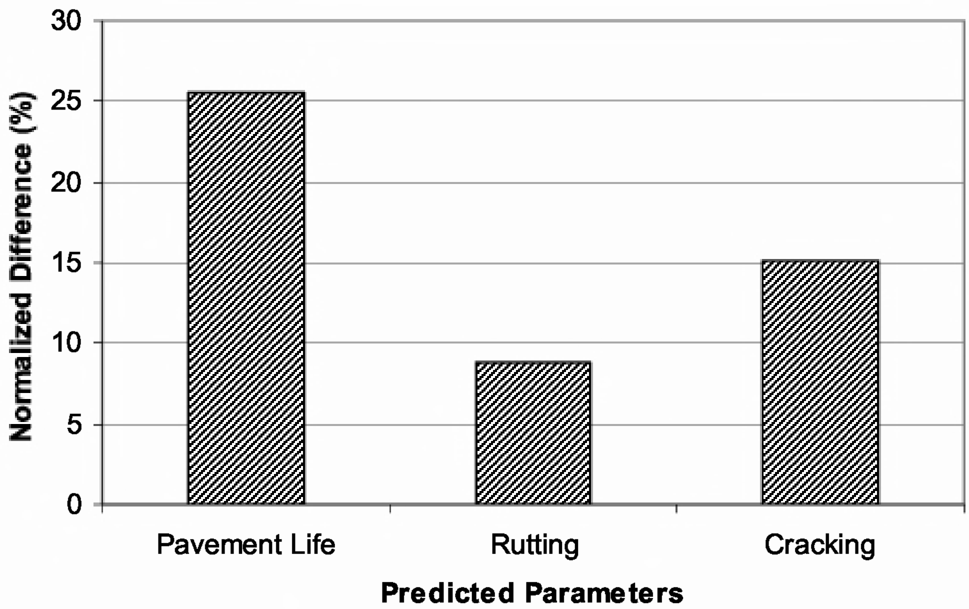

FIGURE 113. Normalized Differences in Predicted Parameters Based on Default and Statewide Axle Load Spectra

3. SUMMARY

Two sensitivity analyses were performed in this chapter. One was to investigate the effect of variation of WIM data on the pavement design when the scale calibration was off. This analysis was performed based on the *1993 Guide* and the MEPDG software. Based on the *1993 Guide*, the number of ESAL can increase up to 200 percent if the scale is over-calibrated by 8,000 lb. Thickness of asphalt layer may vary about one and two inches if the WIM data are misestimated by 4,000 and 8,000 lb., respectively.

Based on the MEPDG software, if the WIM data are misestimated by 4,000 and 8,000 lb., the differences in the predicted pavement life can be one year (9 percent) or three years (25 percent), respectively, using the MEPDG software when the rutting criterion governs the design. However, since predicted cracking is sensitive to the weight data variation, the differences in the predicted pavement lives may be more significant if the design is governed by the cracking criterion.

Based on the analysis, it is recommended that the WIM scales be calibrated regularly. In addition, the WIM data, especially the weight data, should be evaluated before they are used for design purposes. The evaluation process can be done using the procedure recommended in the FHWA and LTPP publications (*4,11*).

Another sensitivity analysis performed in this chapter was to investigate the significance of the developed statewide traffic inputs for Arkansas. Based on the analysis, the differences in the design results based on the statewide and default monthly distribution factors are not significant. Likewise, the differences in the predicted distresses based on the statewide and default hourly distribution factors are not significant. However, the differences in the predicted distresses based on the statewide and default vehicle class distribution factors for the seven TTC groups are significant. In addition, the predicted distressed based on the statewide and default axle load spectra are significantly different.

Based on the analysis, it is recommended that the default monthly and hourly distribution factors be used for the design. However, the statewide vehicle classes developed in this project for seven TTC groups, including TTC groups 3, 6, 7, 9, 10, 12, and 13, should be used for initial implementation of MEPDG. The default vehicle class distribution factors for the other TTC groups can be used for design purposes, if required. The statewide axle load spectra developed in this study are also recommended for the design instead of the default axle load spectra. It is also recommended that vehicle class distribution factors and axle load spectra be updated every three years unless no changes in these inputs are observed in the future.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

The following conclusions are made based on analyses of Arkansas traffic data for developing statewide traffic inputs used in MEPDG:

- Traffic data collected at 55 stations in Arkansas were used in this study. The data were not available from many stations in several months for analyses. Among the 55 WIM stations, only 25 sites provided enough data for evaluation of monthly variation of traffic.
- Two FHWA's file formats for classification and weight data are useful for storing massive WIM data. They can be easily transferred and imported into Microsoft Excel® for post-processing. However, some files were not readable and repairable in this project. They may be corrupted during the writing process.
- During quality control checks of the classification data collected at the 25 WIM sites, no errors were found in the data collected at 17 stations, and all of the data collected at these sites were accepted. For other 7 stations, errors were detected in the data in several months, and the erroneous data were rejected. The data collected at the 7 stations were partially accepted. All of data collected at one station were not accepted because the remaining data did not allow the evaluation of monthly variation after several months of data were rejected.
- Quality control checks of the weight data collected at the 25 WIM sites were performed based on the procedure recommended in the FHWA and LTPP publications (*4,11*). The procedure evaluates the weight data collected at a WIM station based on load distributions of the front axle, drive tandem and gross vehicle

weight of Class 9 trucks. Only 10 of the 25 WIM sites which provided “good” weight data based on the evaluation procedure were selected for developing statewide axle load spectra. The weight data collected at other stations were not accepted because the scales were failed or the calibration was off.

- A sensitivity analysis performed in this study shows that the quality control checks are very important, especially for weight data. If the WIM data are maximally misestimated by 4,000 lb. as allowed in the FHWA and LTPP procedure, the design thickness of asphalt layer can be different by one inch from the value based on the “true” data using the *1993 Guide*, or the normalized difference in the predicted pavement life can be nine percent using the MEPDG software. If the WIM data are misestimated by 8,000 lb., the difference in the design thickness of asphalt layer can be two inches from the values based on the true data using the *1993 Guide*, or the normalized difference in the predicted pavement life can be 25 percent using the MEPDG.
- For development of statewide traffic inputs for Arkansas, the *Trafload* program was first used. The software could read the classification data in C_Card files, but it was not able to import the weight data in W-Card files. No mistakes in the weight data files were found. The error is still unknown. Thus, it was decided that the *Trafload* program not be used in this study. It is not sure if the software can be used to generate the traffic inputs for MEPDG in Arkansas in the future.
- Instead of using the *Trafload* software, two computer programs, named “CLASS.xls” and “WEIGHT.xls”, were developed. These programs help perform quality control checks for the classification and weight data, and they are used to develop Level 1

traffic inputs for MEPDG. The traffic data used for these programs are based on the FHWA file formats. Each file contains all classification or weight data collected at the active WIM sites in Arkansas in a specific month. The program can generate site specific monthly distribution factors, hourly distribution factors, vehicle class distribution factors, and axle load spectra for the MEPDG software. In order to use the programs, users are required to know the FHWA and LTPP quality control procedure and the procedure for developing traffic inputs in MEPDG (*2*).

- The primary truck class observed on most interstates and four-lane highways in Arkansas is Class 9. This class compromises up to 70 percent of truck traffic. Therefore, most analyses are based on Class 9 trucks. The next major truck class is Class 5.
- Since considerable variability in truck distribution was observed on roadways within the same functional classification, the statewide volume adjustment factors were developed based on the truck traffic classification (TTC) system. The TTC system appeared to better define roadway groups than the functional classification system. Three statewide volume adjustment factors, including monthly distribution factors, hourly distribution factors, and vehicle class distribution factors, were developed for seven TTC groups, including TTC 3, 6, 7, 9, 10, 12, and 13.
- The differences in the predicted distresses based on the statewide and default monthly and hourly distribution factors are not significant. However, the differences in the predicted distresses using the statewide and default vehicle class distribution factors are significant.

- One set of statewide axle load spectra was developed based on the weight data. The single axle load spectra are similar for all stations. Thus, the single axle load spectra for all stations are grouped to develop the statewide single axle load spectra.
- It is more difficult to group tandem axle load spectra into clusters that have similar load distribution characteristics. The TTC system cannot be used to groups tandem axle load spectra. One method used to group tandem axle load spectra in this study is based on the loading condition of the truck: fully loaded, partially loaded, and unloaded. This method should be used to group tandem axle load spectra when more WIM stations are available in the future.
- Since a small sample size of 10 WIM stations which can provide "good" weight data is used in this study, it is decided that tandem axle load spectra for all stations be best grouped to develop the statewide axle load spectra.
- The statewide tridem axle load spectra are developed in the same manner as for the statewide tandem axle load spectra. Since very few quad axles are observed in the WIM data, the statewide quad axle load spectra are not developed in this study.
- The differences in the predicted distresses based on the statewide and default axle load spectra are significant.

2. RECOMMENDATIONS

The following recommendations are presented based on the findings in this study:

- Calibration of WIM scales should be carefully monitored.

- Traffic data should be evaluated before they are used for design purposes, especially weight data. The process can be performed based on the evaluation procedure recommended in the FHWA and LTPP documents (*3*,*11*).
- Two programs developed in this project can be used to facilitate the evaluation process, and users are required to know the evaluation process before using the programs. It is emphasized that the two programs are developed for analyses in this study and should not be considered as a product of this project. It should be recognized that production-graded software should require significant efforts in the future.
- Annual average daily truck traffic (AADTT) should be site specific or Level 1. The information can be provided by the Technical Services of AHTD.
- The statewide vehicle class distribution factors for TTC groups 3, 6, 7, 9, 10, 12, and 13 should be used for the design.
- The statewide axle load spectra should be used instead of the default axle load spectra.
- Default or user-defined values can be used for other inputs, such as monthly distribution factors, hourly distribution factors, and general traffic inputs unless specific information is obtained.
- Statewide vehicle class distribution factors and axle load spectra should be updated every three years unless no significant changes in these inputs are observed in the future.

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APPENDIX A. WIM DATA FOR DEVELOPMENT OF TRAFFIC INPUTS

TABLE A-1. Active WIM Sites in 2003

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10009	10009	10009	10009	10009	10009	10009	10009					10009
20006				20006	20006	20006	20006					
30032	30032	30032	30032	30032	30032	30032	30032			30032	30032	30032
40432												
71813	71813	71813	71813	71813	71813	71813	71813				71813	71813
80004	80004	80004	80004	80004	80004	80004	80004			80004	80004	80004
100019	100019	100019	100019			100019	100019			100019	100019	100019
160058	160058	160058	160058									
160074										160074	160074	160074
170049		170049	170049	170049	170049	170049	170049					
170064		170064	170064	170064	170064	170064				170064	170064	170064
171651	171651	171651	171651	171651	171651	171651	171651			171651	171651	171651
180002	180002		180002	180002	180002	180002	180002	180002		180002	180002	180002
181501					181501	181501	181501	181501		181501	181501	181501
210033	210033	210033	210033	210033	210033	210033						
220024							220024				220024	
230001	230001	230001	230001	230001						230001	230001	230001
230021												
260059												
270012												
281983		281983	281983	281983	281983	281983	281983	281983		281983	281983	281983
290002										290002	290002	290002
291613	291613	291613										
350019	350019	350019	350019	350019	350019					350019		350019
350215	350215					350215	350215			350215	350215	350215
350314		350314	350314	350314	350314	350314	350314			350314	350314	350314
350512						350512	350512	350512		350512		350512
370001											370001	370001
420010	420010	420010	420010	420010	420010	420010	420010			420010	420010	420010
430037		430037	430037	430037	430037	430037	430037	430037		430037	430037	430037
430038	430038	430038	430038	430038	430038	430038				430038	430038	430038
460006	460006					460006	460006			460006	460006	460006
460011												
460286	460286	460286	460286	460286	460286	460286	460286	460286		460286	460286	460286
480037	480037	480037	480037	480037	480037	480037	480037					480037
481524												
580236						580236	580236	580236		580236	580236	580236
600573												
600705												
600870		600870	600870	600870	600870	600870	600870	600870		600870		600870
620012										620012	620012	
630008												
641932	641932	641932	641932	641932	641932	641932				641932	641932	
650284												
651653												
670027	670027	670027	670027	670027	670027	670027	670027	670027			670027	670027
680025	680025	680025								680025	680025	680025
680032	680032	680032	680032	680032	680032	680032	680032			680032	680032	
700058		700058										700058
720034					720034	720034	720034	720034		720034	720034	720034
721683												
730068						730068				730068	730068	730068
740035	740035	740035	740035			740035				740035	740035	740035
750006										750006	750006	750006
750010												750010

TABLE A-2. Active WIM Sites in 2004

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10009	10009	10009	10009				10009	10009	10009			
20006					20006	20006	20006	20006	20006	20006	20006	
30032	30032	30032	30032	30032	30032	30032	30032	30032	30032	30032		
40432										40432	40432	40432
71813	71813	71813	71813	71813	71813	71813	71813	71813	71813	71813	71813	
80004	80004	80004	80004	80004		80004						
100019	100019	100019	100019	100019	100019					100019	100019	100019
160058		160058		160058	160058	160058		160058	160058	160058	160058	
160074	160074	160074	160074	160074	160074	160074	160074			160074	160074	160074
170049			170049	170049	170049	170049	170049		170049	170049	170049	170049
170064	170064	170064	170064	170064	170064	170064	170064	170064	170064	170064	170064	
171651	171651	171651	171651	171651	171651	171651	171651	171651	171651	171651	171651	171651
180002	180002	180002	180002	180002	180002	180002	180002	180002	180002	180002	180002	180002
181501	181501	181501	181501	181501	181501	181501	181501		181501	181501	181501	181501
210033												
220024	220024	220024	220024			220024	220024	220024	220024			
230001	230001	230001	230001	230001	230001	230001	230001	230001	230001	230001	230001	230001
230021										230021	230021	230021
260059												
270012												
281983	281983	281983	281983	281983	281983	281983	281983		281983	281983	281983	281983
290002	290002	290002	290002	290002	290002	290002	290002	290002	290002	290002	290002	290002
291613												
350019	350019	350019					350019		350019	350019		
350215	350215	350215	350215	350215	350215	350215	350215	350215	350215	350215	350215	350215
350314	350314	350314	350314	350314	350314	350314	350314	350314	350314	350314	350314	350314
350512	350512	350512	350512	350512	350512	350512	350512	350512	350512	350512	350512	350512
370001	370001	370001	370001	370001	370001	370001			370001	370001	370001	370001
420010	420010	420010	420010	420010		420010	420010	420010	420010		420010	420010
430037	430037	430037	430037	430037	430037	430037	430037	430037	430037	430037	430037	430037
430038	430038	430038	430038	430038	430038	430038	430038	430038	430038	430038	430038	430038
460006	460006	460006	460006	460006	460006	460006	460006	460006	460006	460006	460006	
460011												
460286	460286	460286	460286	460286	460286	460286	460286	460286	460286	460286	460286	460286
480037	480037	480037	480037	480037	480037	480037	480037	480037	480037	480037	480037	480037
481524						481524	481524		481524	481524	481524	481524
580236	580236	580236	580236	580236	580236	580236	580236	580236	580236	580236	580236	580236
600573								600573	600573	600573		
600705								600705				
600870	600870	600870	600870	600870	600870	600870	600870	600870	600870	600870	600870	600870
620012		620012	620012	620012	620012	620012	620012	620012	620012	620012		
630008						630008			630008	630008	630008	630008
641932	641932	641932	641932	641932	641932	641932	641932		641932	641932	641932	641932
650284							650284	650284	650284	650284	650284	650284
651653										651653		651653
670027	670027	670027	670027	670027	670027	670027	670027	670027	670027	670027	670027	670027
680025		680025			680025	680025	680025	680025	680025	680025	680025	680025
680032	680032	680032		680032	680032	680032	680032	680032	680032		680032	680032
700058												
720034				720034	720034	720034	720034	720034	720034	720034	720034	720034
721683				721683	721683	721683	721683	721683	721683	721683	721683	
730068	730068	730068	730068	730068	730068	730068	730068	730068	730068	730068	730068	
740035	740035	740035	740035	740035	740035	740035	740035	740035	740035	740035	740035	740035
750006	750006	750006	750006	750006	750006			750006	750006	750006		
750010	750010	750010		750010		750010	750010	750010	750010	750010	750010	750010

TABLE A-3. Active WIM Sites in 2005

ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10009												
20006	20006	20006				20006			20006		20006	20006
30032												
40432	40432	40432	40432	40432	40432	40432			40432	40432	40432	40432
71813	71813		71813	71813	71813	71813	71813	71813	71813	71813	71813	
80004				80004	80004	80004			80004	80004	80004	80004
100019	100019	100019	100019									
160058						160058	160058	160058			160058	160058
160074	160074	160074	160074	160074	160074			160074				
170049		170049	170049	170049	170049	170049			170049	170049	170049	170049
170064	170064	170064		170064								
171651	171651	171651	171651	171651	171651	171651	171651	171651	171651	171651	171651	171651
180002	180002	180002	180002	180002	180002	180002	180002					
181501	181501	181501	181501	181501	181501	181501		181501	181501	181501	181501	181501
210033												
220024			220024	220024	220024	220024			220024	220024	220024	220024
230001	230001	230001	230001	230001	230001	230001				230001	230001	230001
230021	230021	230021	230021	230021	230021	230021			230021	230021	230021	230021
260059											260059	260059
270012									270012	270012	270012	270012
281983	281983	281983	281983	281983	281983	281983	281983	281983	281983	281983	281983	281983
290002	290002	290002	290002	290002	290002	290002			290002	290002	290002	290002
291613												
350019												
350215	350215	350215	350215			350215						
350314	350314	350314	350314	350314	350314	350314			350314	350314	350314	350314
350512	350512	350512	350512	350512	350512	350512			350512	350512	350512	350512
370001	370001	370001	370001	370001	370001	370001			370001	370001	370001	370001
420010	420010	420010	420010	420010	420010	420010			420010	420010	420010	
430037	430037	430037	430037	430037	430037		430037	430037	430037	430037	430037	
430038	430038	430038	430038	430038	430038	430038		430038	430038	430038	430038	430038
460006				460006	460006	460006		460006	460006	460006	460006	460006
460011								460011	460011	460011	460011	460011
460286	460286	460286	460286	460286	460286	460286			460286	460286	460286	460286
480037	480037	480037	480037	480037	480037	480037	480037	480037	480037	480037	480037	
481524	481524	481524	481524	481524	481524	481524	481524	481524	481524		481524	
580236	580236	580236	580236	580236	580236	580236						
600573												
600705												
600870		600870	600870	600870	600870	600870	600870	600870	600870	600870	600870	600870
620012		620012										
630008	630008	630008		630008	630008	630008			630008	630008	630008	630008
641932	641932	641932	641932	641932	641932	641932			641932	641932	641932	641932
650284	650284	650284	650284	650284	650284				650284	650284	650284	650284
651653	651653	651653										
670027	670027	670027	670027	670027	670027	670027			670027	670027	670027	670027
680025	680025	680025	680025	680025	680025	680025		680025	680025	680025		
680032	680032	680032	680032	680032	680032	680032	680032	680032	680032	680032	680032	680032
700058												
720034	720034	720034	720034	720034	720034				720034		720034	
721683		721683	721683	721683	721683	721683				721683		
730068		730068	730068	730068	730068	730068		730068	730068	730068	730068	730068
740035	740035	740035	740035	740035	740035	740035	740035	740035	740035	740035	740035	740035
750006	750006			750006								750006
750010	750010	750010	750010	750010	750010	750010			750010		750010	750010

APPENDIX B. EVALUATION OF AUTOMATED CLASSIFICATION DATA

Figure B.1 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 170064 on Interstate I-540. An unusual change in distribution between truck Classes 8 and 9 occurred in September 2004. Thus, the data collected in September 2004 are discarded. The final plots for this station are shown in Figure B.2.

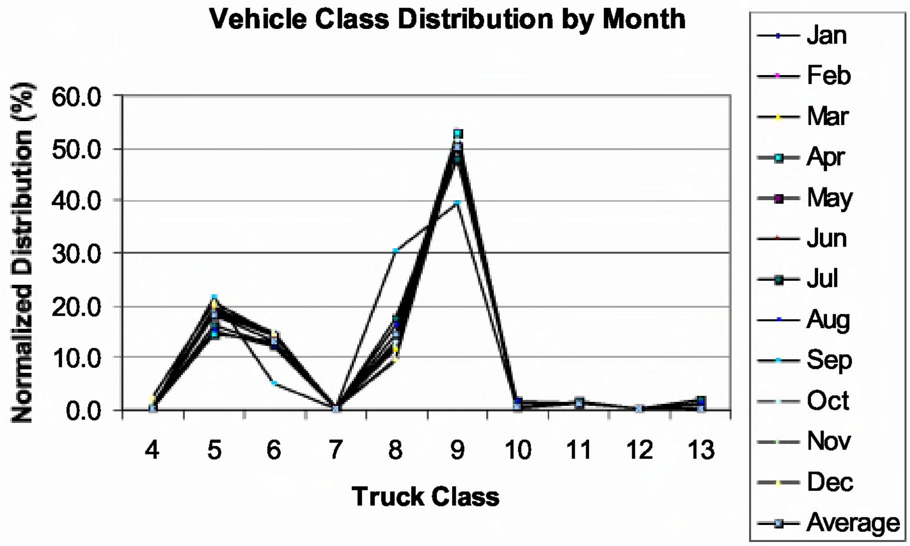

FIGURE B.1. Monthly Class Distribution for Station 170064 (I-540, Alma)

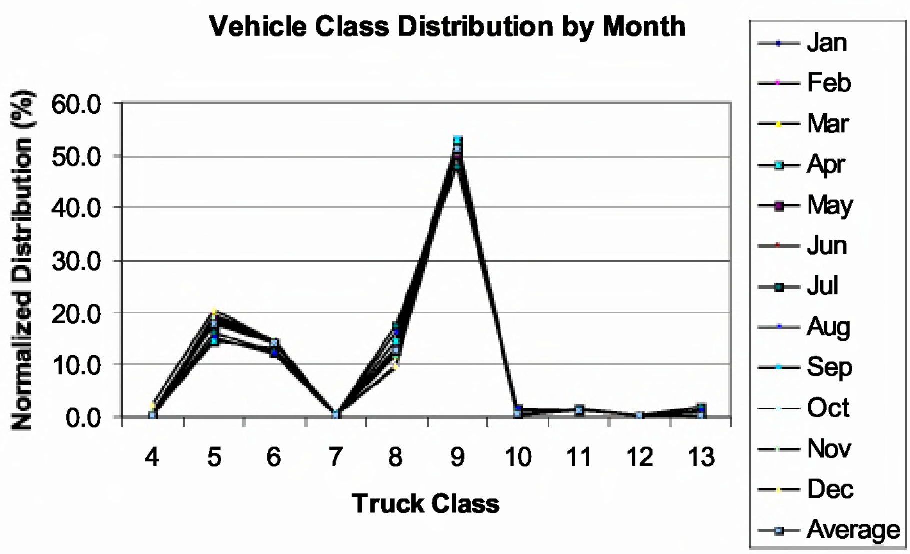

FIGURE B.2. Adjusted Monthly Class Distribution for Station 170064

Figure B.3 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 430037 on Interstate I-40. Unusual changes in distribution between truck Classes 8 and 9 and between Classes 5 and 6 occurred in December 2004, and January and February 2005. Thus, the data collected in these months are discarded. The final plots for this station are shown in Figure B.4.

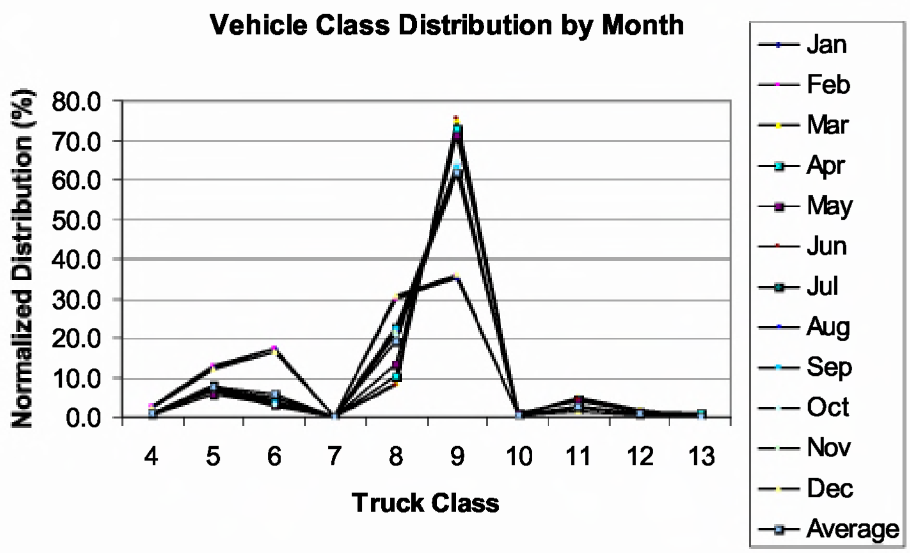

FIGURE B.3. Monthly Class Distribution for Station 430037 (I-40, Lonoke)

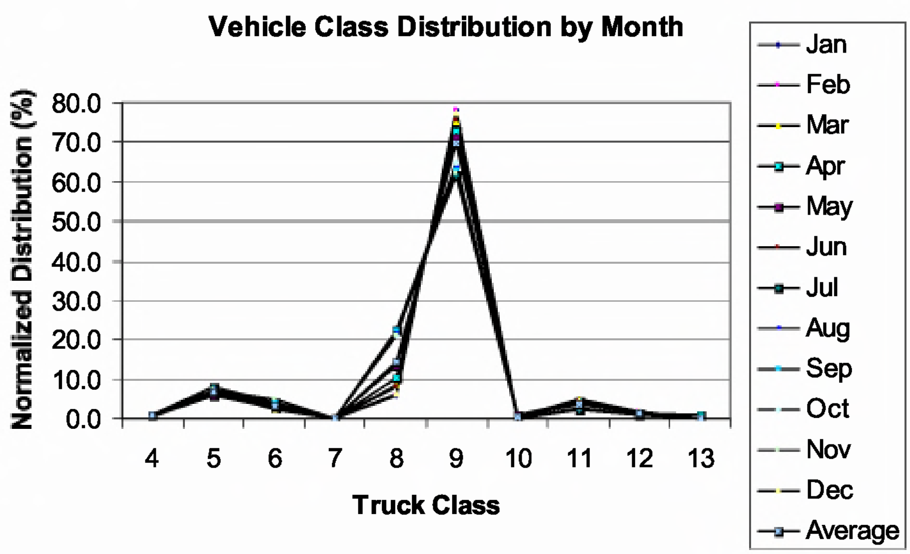

FIGURE B.4. Adjusted Monthly Class Distribution for Station 430037

Figure B.5 presents the average monthly class distribution plots for 12 months for station 460006 on Interstate I-30. A slight change in distribution of truck Classes 6 and 9 occurred in the month of April. These changes are consistent with historical data, as shown in Figure B.6. Thus, the data collected in April are included in the analysis.

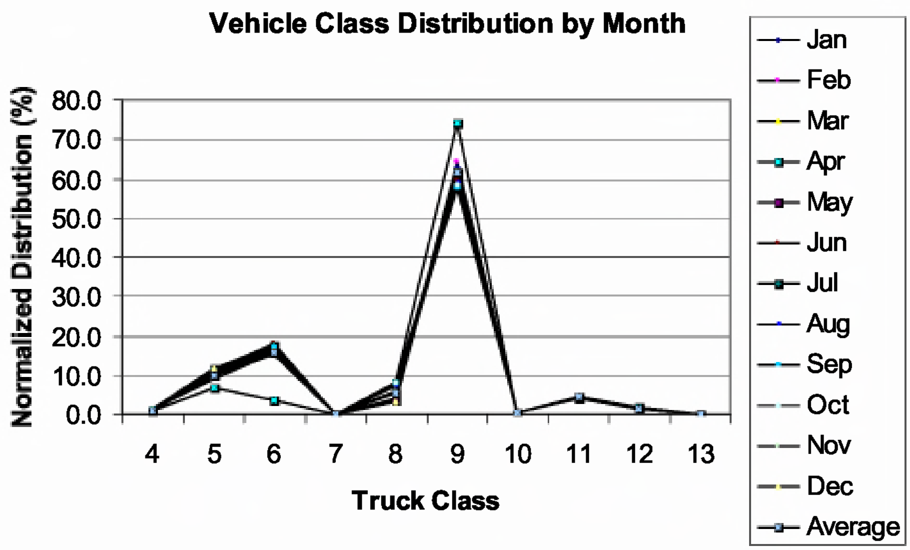

FIGURE B.5. Monthly Class Distribution for Station 460006 (I-30, Texarkana)

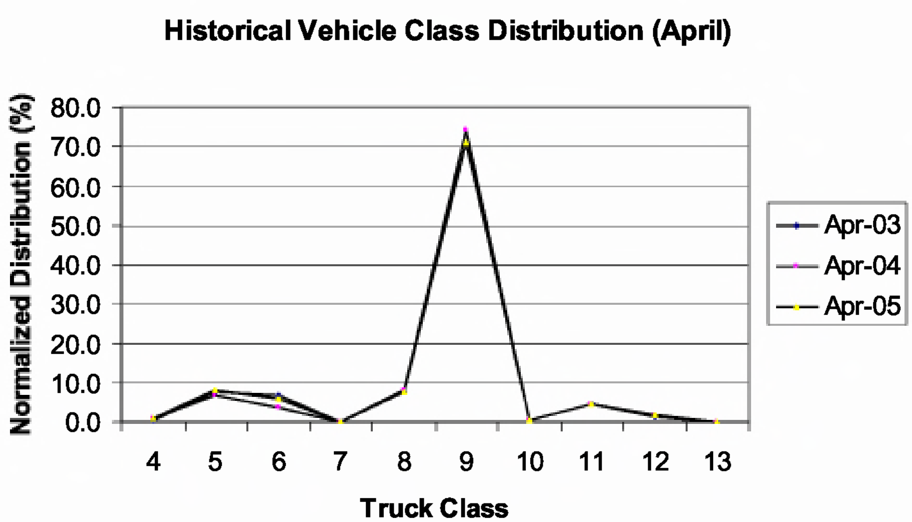

FIGURE B.6. Historical Class Distribution for Station 460006 in April

Figure B.7 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 481524 on Interstate I-40. The plots are consistent with the historical data and throughout the 12 different months.

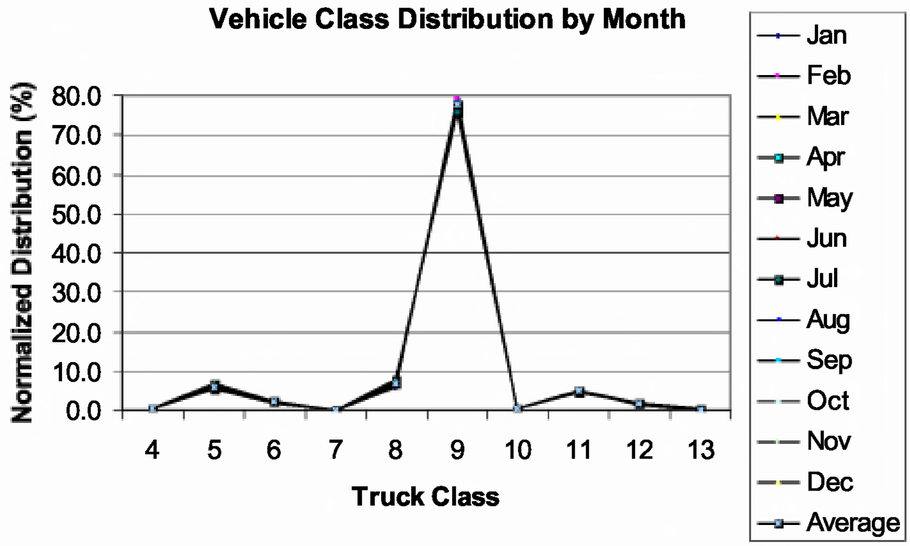

FIGURE B.7. Monthly Class Distribution for Station 481524 (I-40, Brinkley)

Figure B.8 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 580236 on Interstate I-40. Slight changes in distribution between truck Classes 8 and 9 occurred in the months of August through November. These changes are evaluated by comparing the data for those months with the historical data. These changes are consistent with historical data. Thus, those months are included in the analysis.

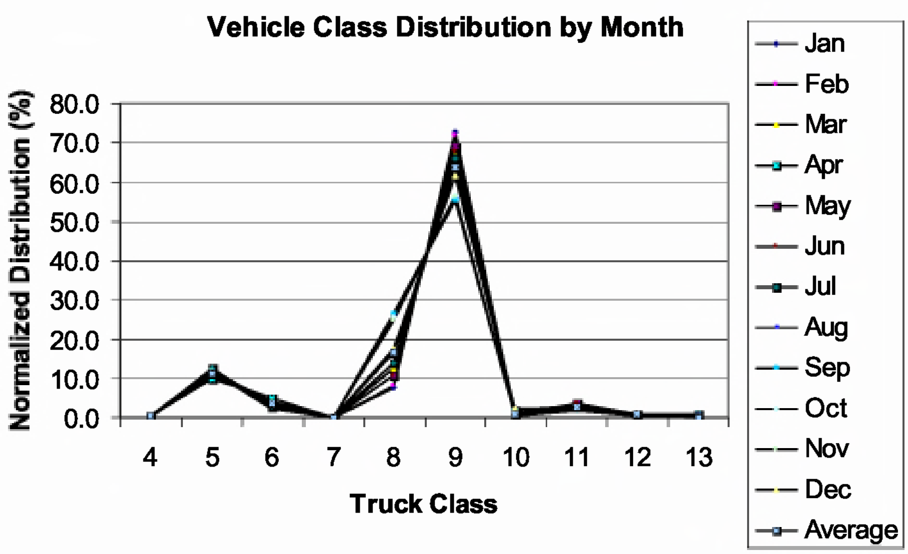

FIGURE B.8. Monthly Class Distribution for Station 580236 (I-40, Russellville)

Figure B.9 presents the average monthly class distribution plots for 12 months for station 680025 on Interstate I-40. Unexpected changes in distribution between truck Classes 8 and 9 occurred in March and April 2005. These changes are not consistent with historical data. Thus, those months are discarded. The final plots for this station are shown in Figure B.10.

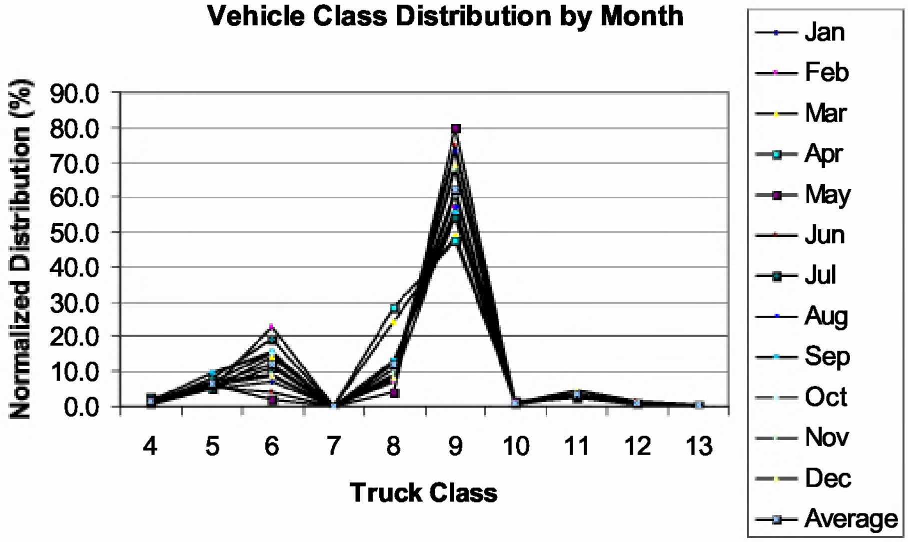

FIGURE B.9. Monthly Class Distribution for Station 680025 (I-40, Russellville)

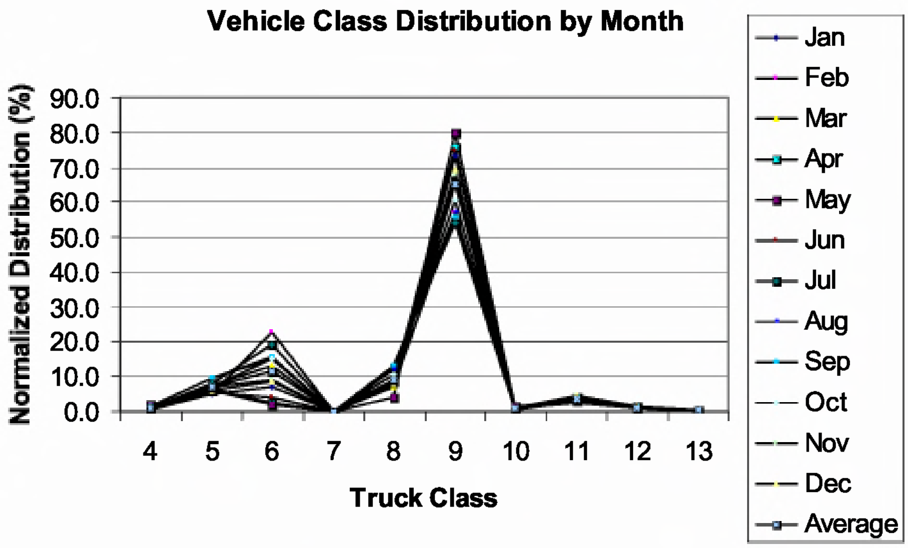

FIGURE B.10. Adjusted Monthly Class Distribution for Station 680025

Figure B.11 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 071813 on U.S. Highway 79. The plots are consistent with the historical data and throughout the 12 different months.

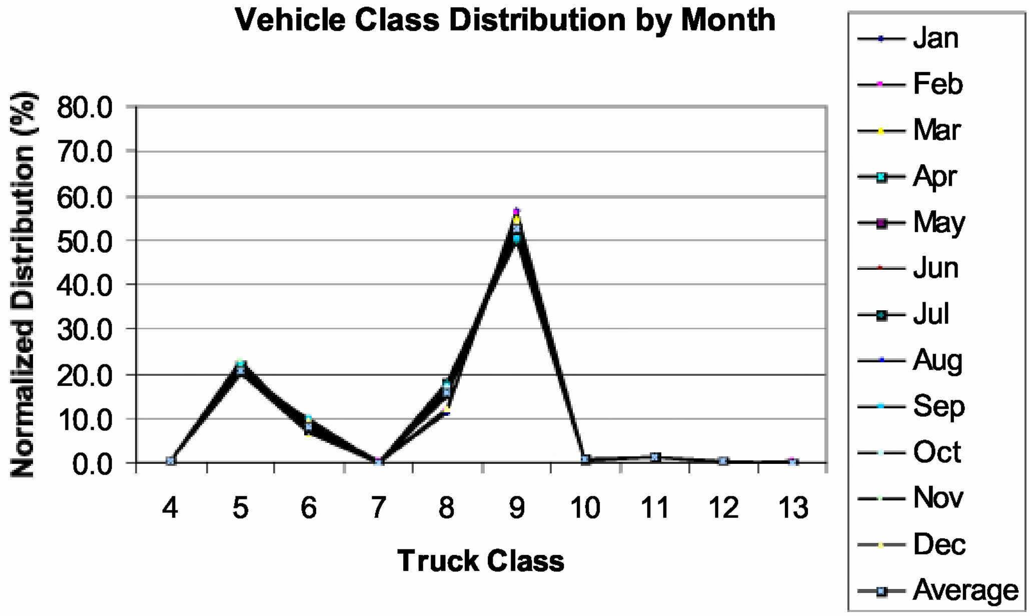

FIGURE B.11. Monthly Class Distribution for Station 071813 (US 79, Thornton)

Figure B.12 presents the average monthly class distribution plots for 12 months for station 230001 on U.S. Highway 65. Significant changes in distribution between truck Classes 8 and 9 occurred from July through October. Figures B.13 through B.15 show the plots of data available for each year from 2003 through 2005. The changes seem to be consistent. However, the detailed data shows that the number of Class 1 vehicles (704 units) is significant in September 2004. The number of Class 1 units in this roadway is zero in several years. Thus, the vehicle class data collected in September 2004 are discarded.

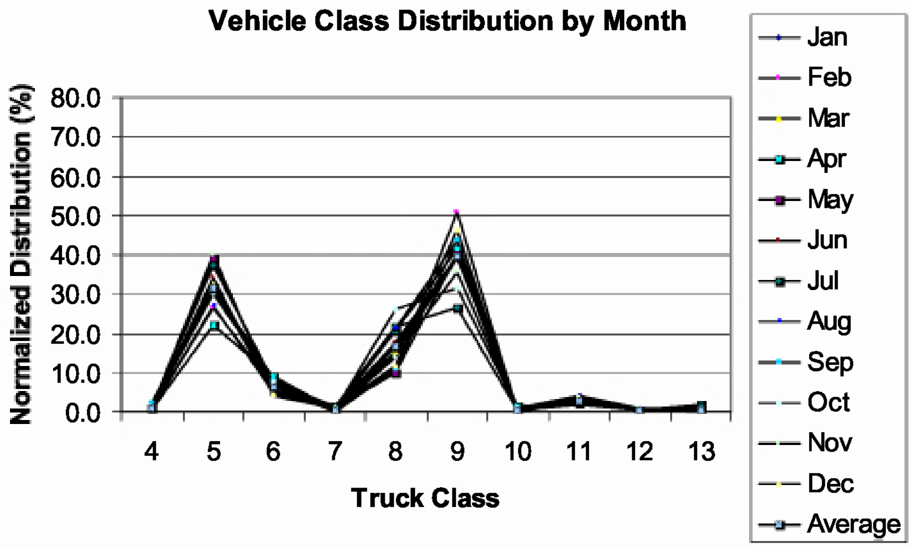

FIGURE B.11. Monthly Class Distribution for Station 230001 (US 65, Damascus)

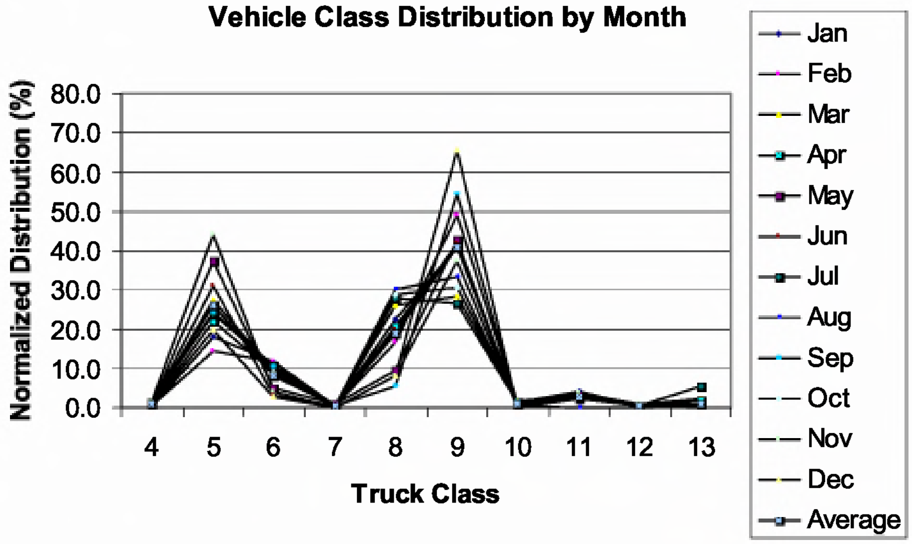

FIGURE B.12. Monthly Class Distribution for Station 230001 (Data Collected in 2003)

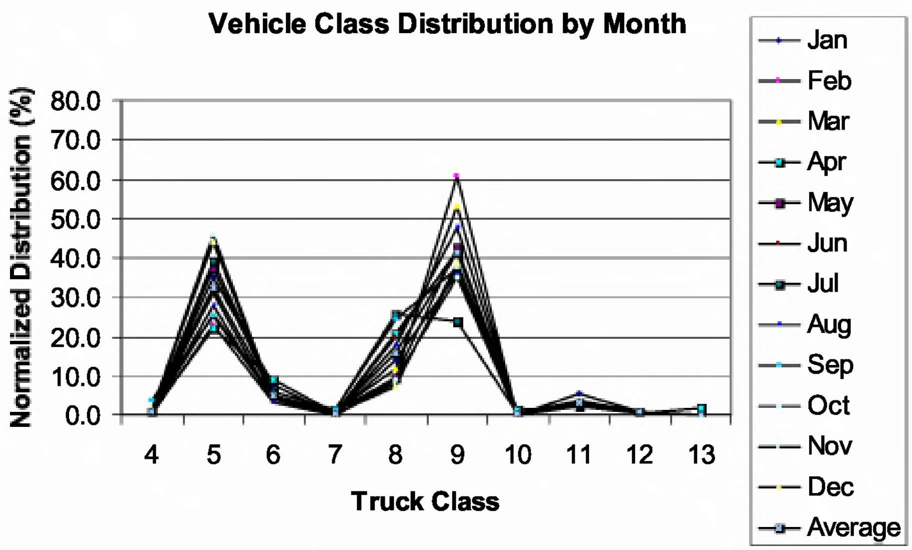

FIGURE B.13. Monthly Class Distribution for Station 230001 (Data Collected in 2004)

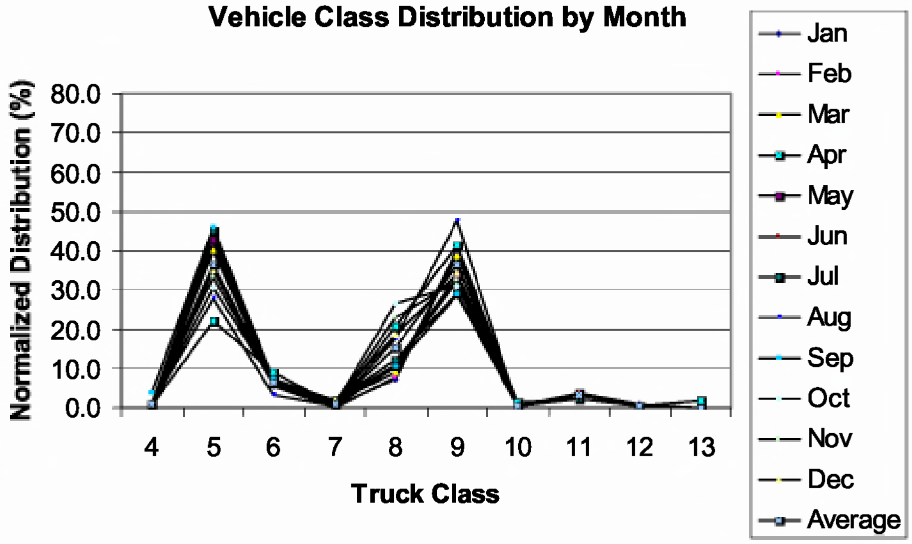

FIGURE B.14. Monthly Class Distribution for Station 230001 (Data Collected in 2005)

Figure B.15 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 281983 on U.S. Highway 412. The plots are consistent with the historical data and throughout the 12 different months.

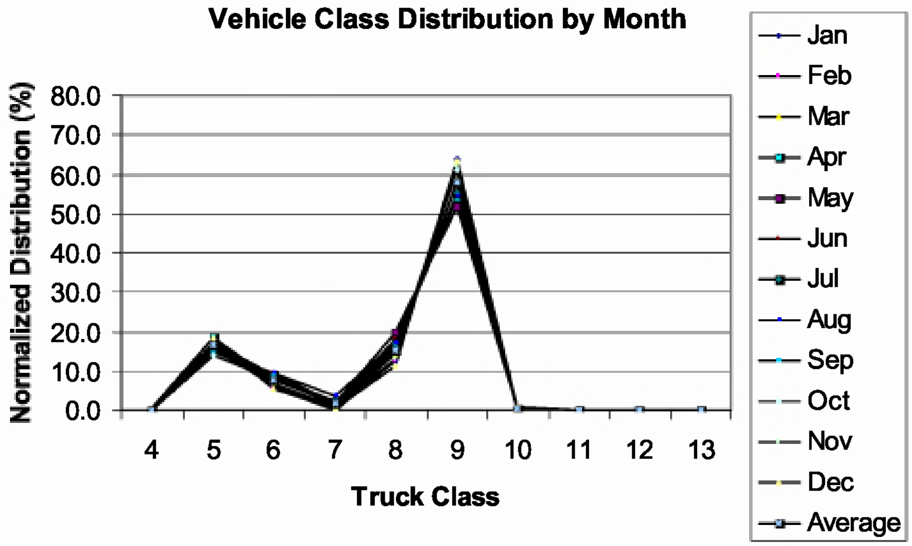

FIGURE B.15. Monthly Class Distribution for Station 281983 (US 412, Light)

Figure B.16 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 720034 on U.S. Highway 412. Unexpected changes in distribution between truck Classes 8 and 9 occurred in August and September. The changes are evaluated by comparing the data collected in August and September from 2003 through 2005. Figure B.17 shows that the changes are not consistent. However, it is difficult to know if the changes are due to the malfunctions of equipment. Thus, the data are included for further analyses using the weight data.

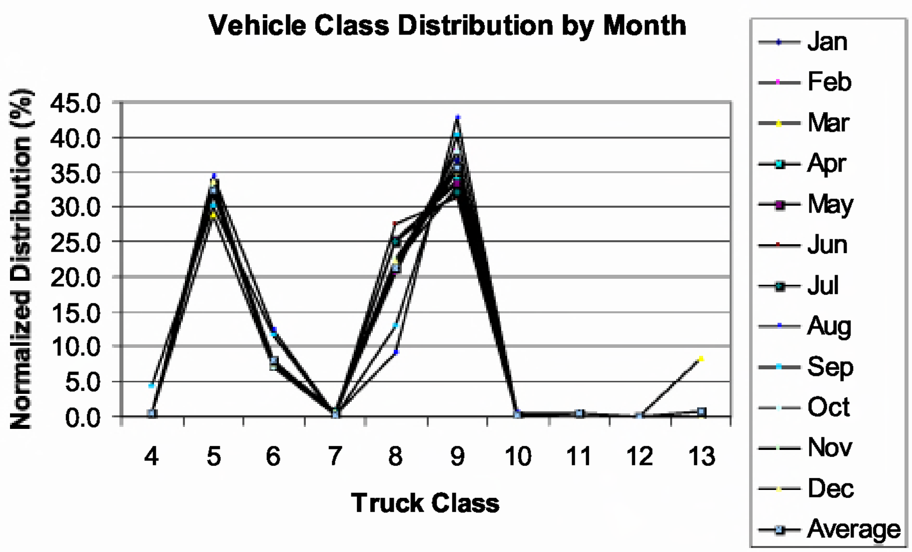

FIGURE B.16. Monthly Class Distribution for Station 720034 (US 412, Tonitown)

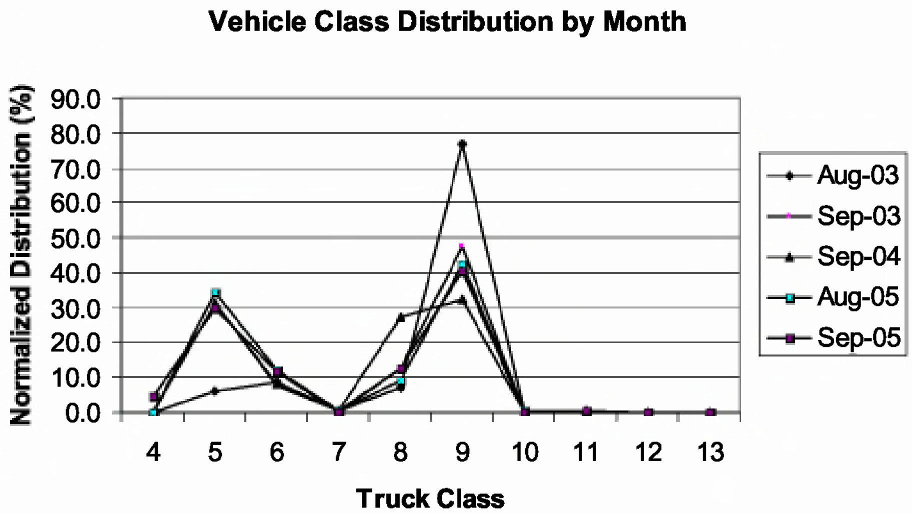

FIGURE B.17. Monthly Class Distribution in August and September

Figure B.18 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 730068 on U.S. Highway 67. The plots are consistent with the historical data and throughout the 12 different months.

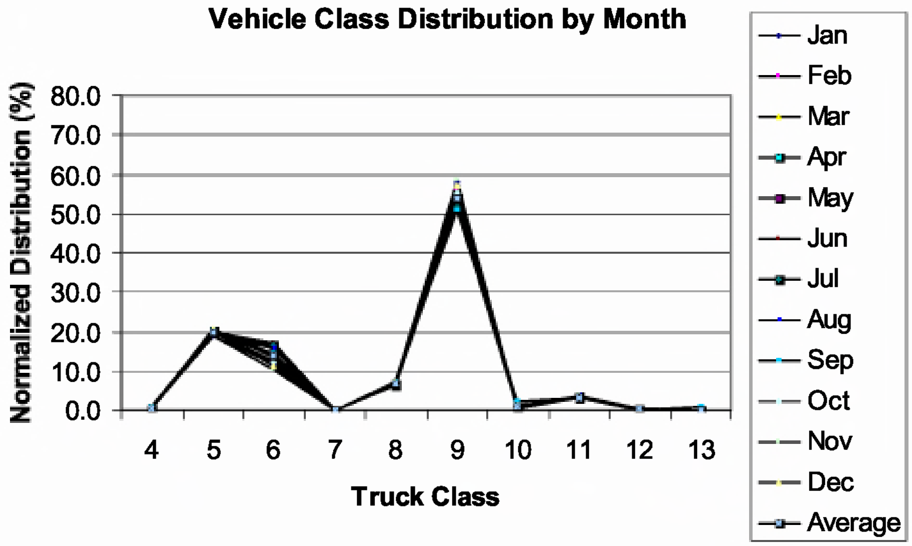

FIGURE B.18. Monthly Class Distribution for Station 730068 (US 67, Bald Knob)

Figure B.19 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 171651 on State Highway 59. The plots are consistent with the historical data and throughout the 12 different months.

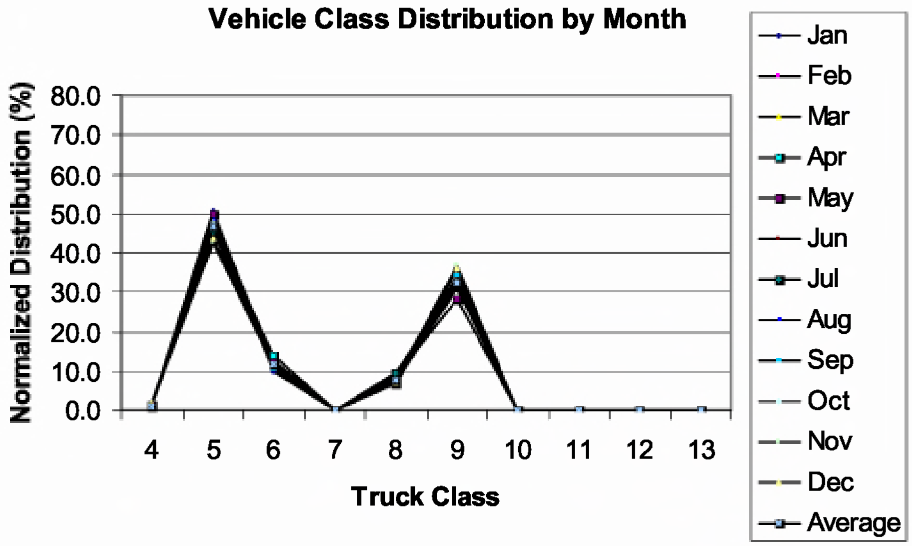

FIGURE B.19. Monthly Class Distribution for Station 171651 (SH 59, Natural Dam)

Figure B.20 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 290002 on US Highway 278. The plots are consistent with the historical data and throughout the 12 different months.

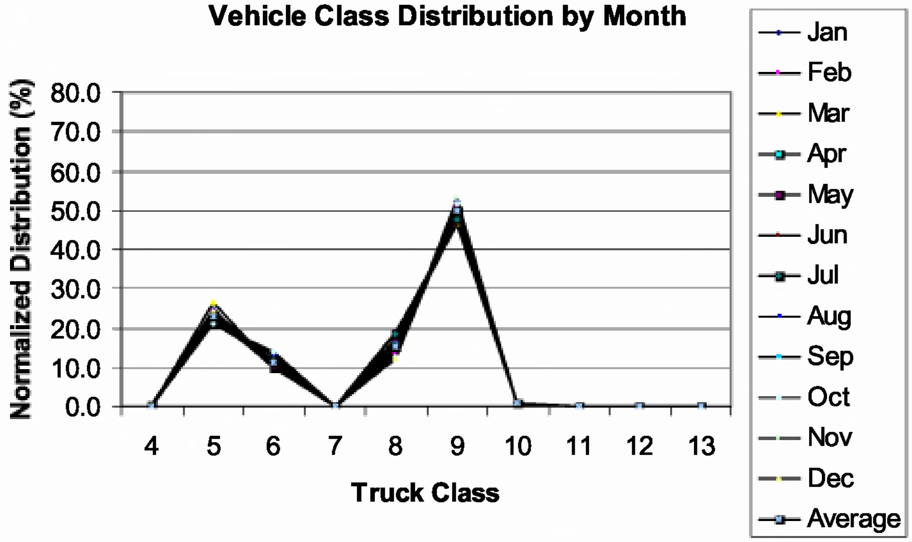

FIGURE B.20. Monthly Class Distribution for Station 290002 (US 278, Ozan)

Figure B.21 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 740035 on US Highway 278. The plots are consistent with the historical data and throughout the 12 different months.

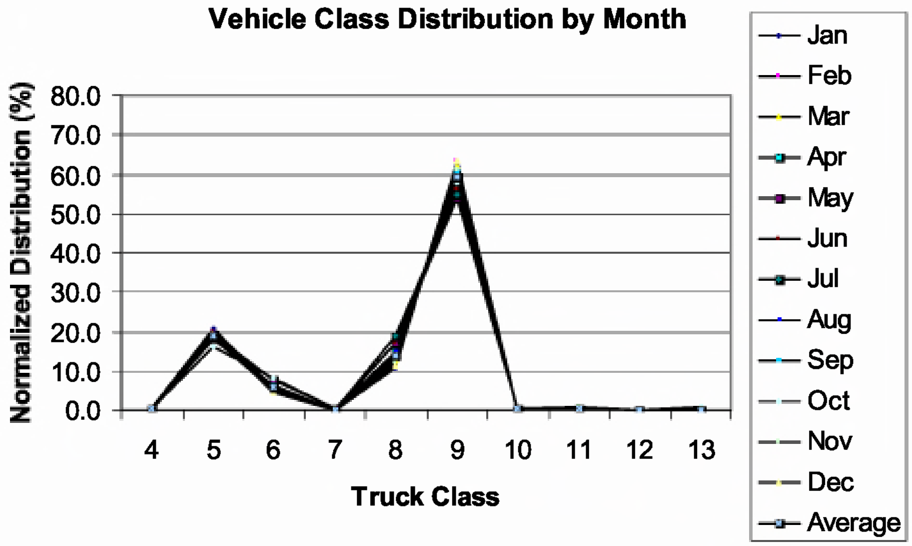

FIGURE B.21. Monthly Class Distribution for Station 740035 (US 278, Ozan)

Figure B.22 presents the average monthly class distribution plots for 12 months for station 750010 on State Highway 10. Unusual changes in distribution between truck Classes 8 and 9 occurred in July and August 2004. Further analyses showed that the data collected in these two months were not consistent with the historical data. Thus, the data collected in these months are discarded. The final plots for this station are shown in Figure B.23.

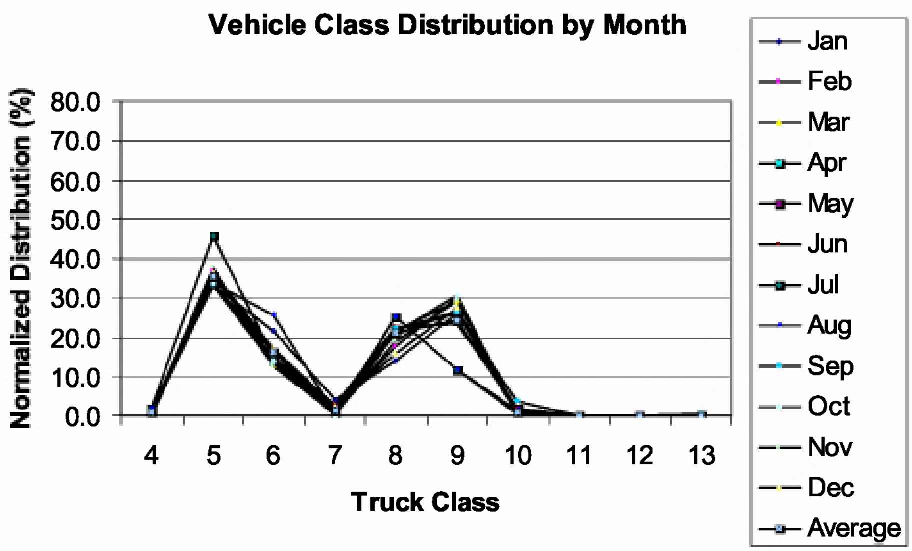

FIGURE B.22. Monthly Class Distribution for Station 750010 (SH 10, Havana)

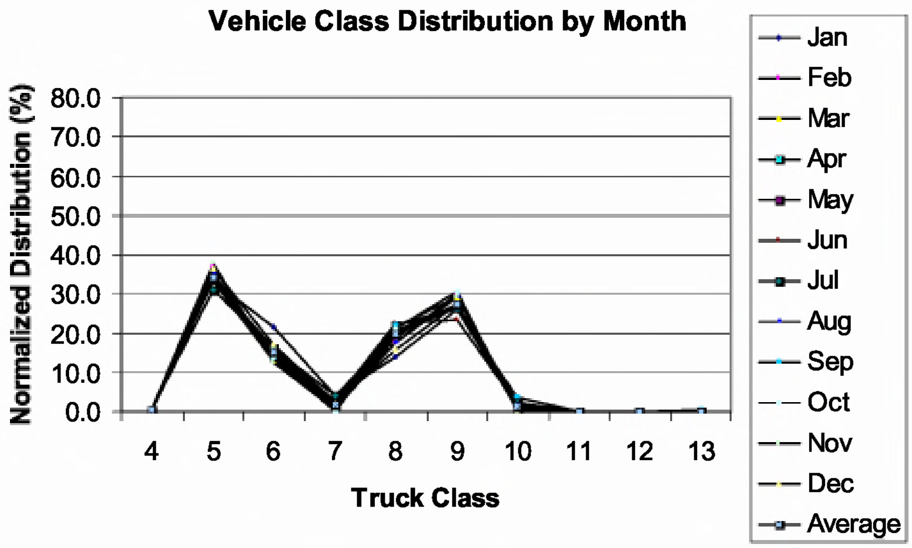

FIGURE B.23. Adjusted Monthly Class Distribution for Station 750010

Figure B.24 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 480037 on US Highway 70. The plots are consistent with the historical data and throughout the 12 different months.

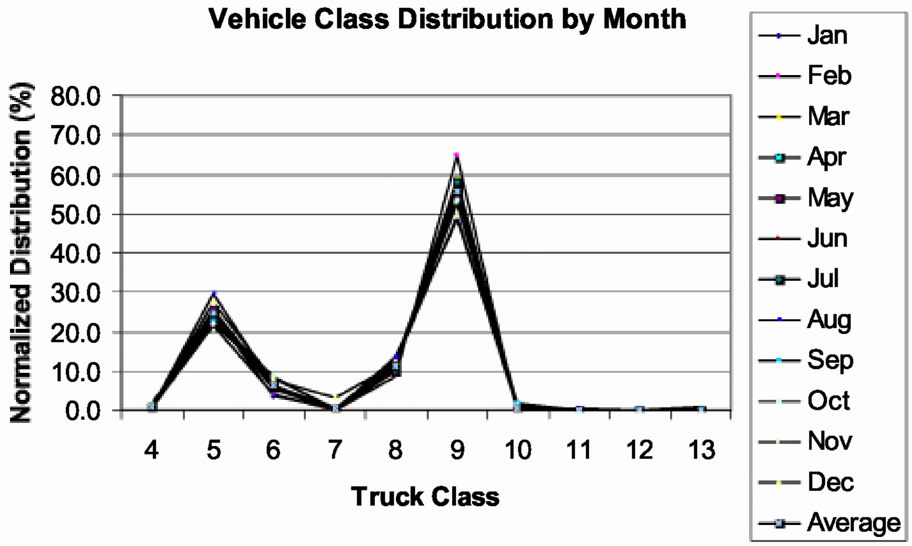

FIGURE B.24. Monthly Class Distribution for Station 480037 (US 70, Brinkley)

Figure B.25 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 670027 on State Highway 115. The plots are consistent with the historical data and throughout the 12 different months.

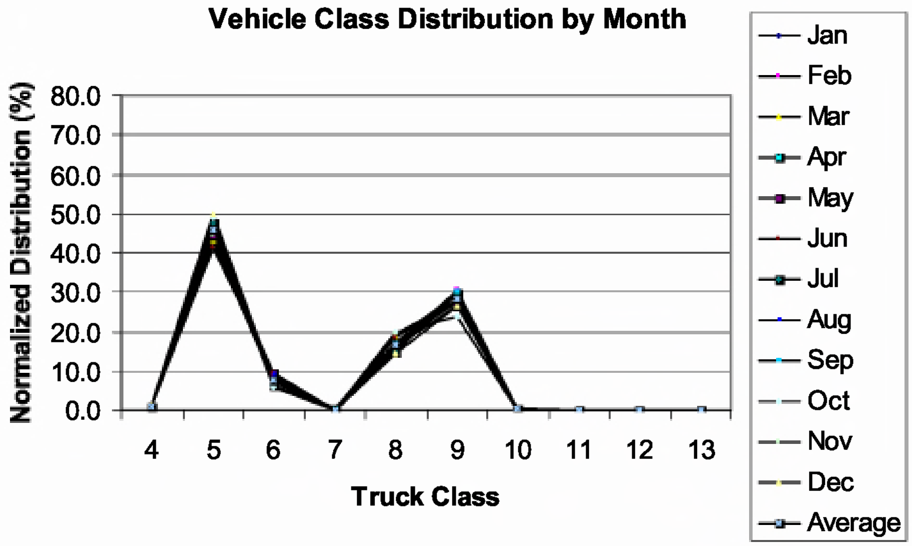

FIGURE B.25. Monthly Class Distribution for Station 670027 (SH 115, Cave City)

Figure B.26 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 680032 on State Highway 50. Even though the class distribution for April 2004 is slightly different, the plots are basically consistent with the historical data and throughout the 12 different months.

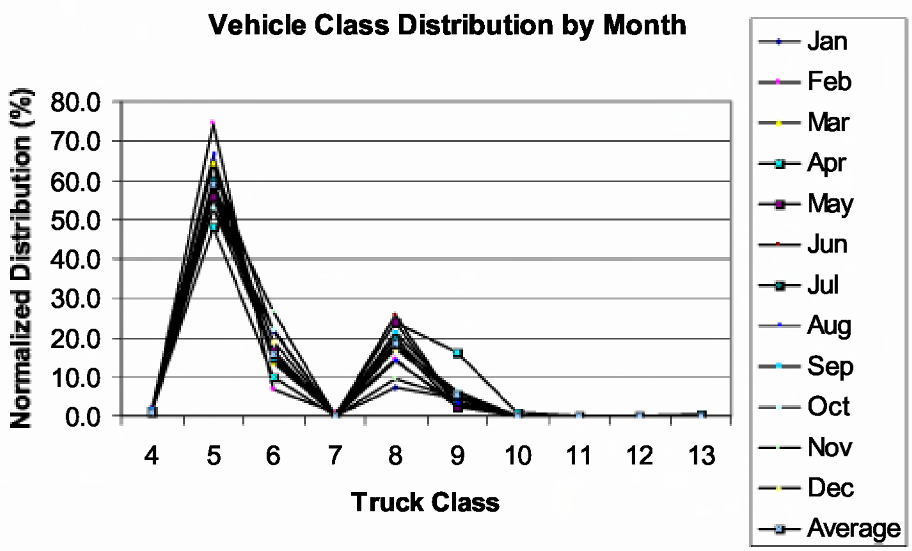

FIGURE B.26. Monthly Class Distribution for Station 680032 (SH 50, Madison)

Figure B.27 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 180002 on Interstate I-55. The trend of the plots is consistent with the historical data and throughout the 12 different months.

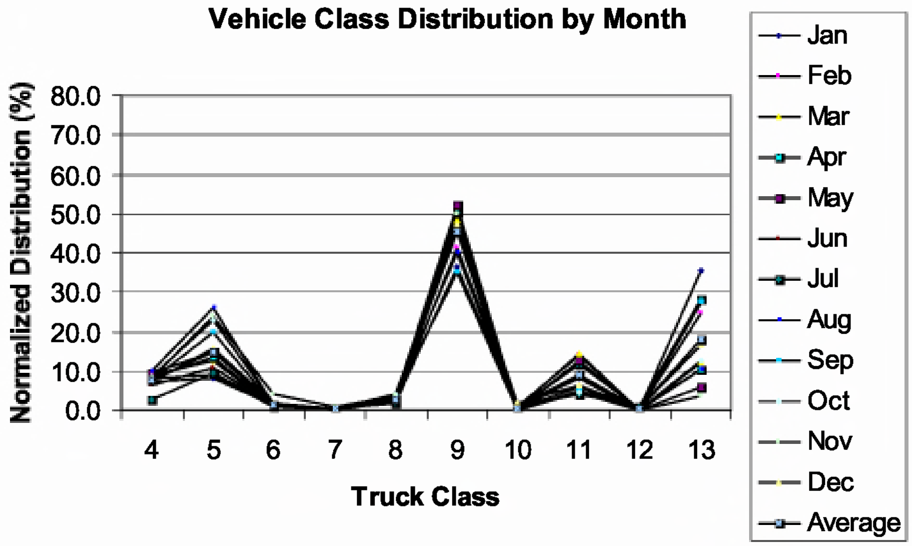

FIGURE B.27. Monthly Class Distribution for Station 180002 (I-55, Marion)

Figure B.28 presents the average monthly class distribution plots for 12 months for station 350314 on Interstate I-530. Unexpected changes in distribution between truck Classes 8 and 9 occurred in the months of January, February, and March. Figures B.29 through B.31 show the plots of data available for each year from 2003 through 2005. The data were consistent in 2003 and then seemed to get fluctuated in 2004 and 2005. One month (September) in 2004 and four months (January through April) in 2005 which have unexpected changes in distribution of truck traffic are discarded. The final plot of the average monthly class distributions for station 350314 is presented in Figure B.32.

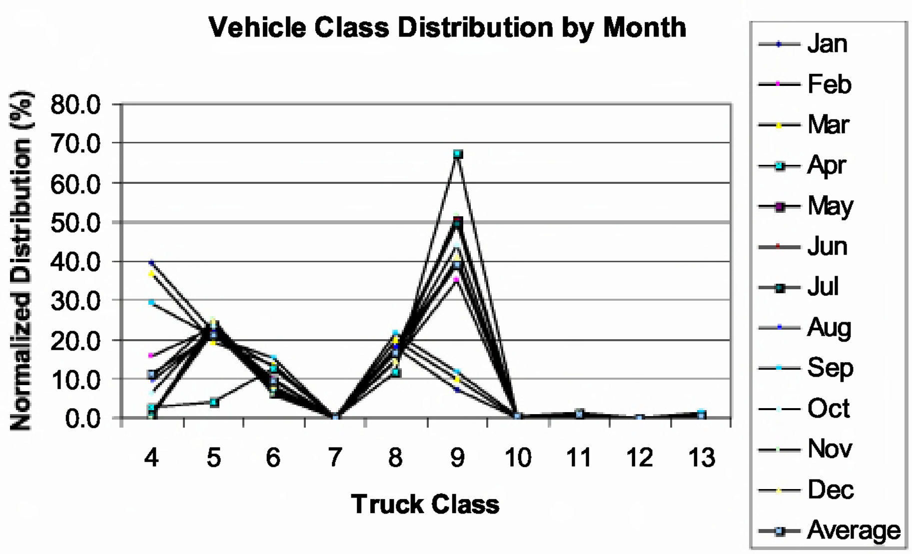

FIGURE B.28. Monthly Class Distribution for Station 350314 (I-530, Pine Bluff)

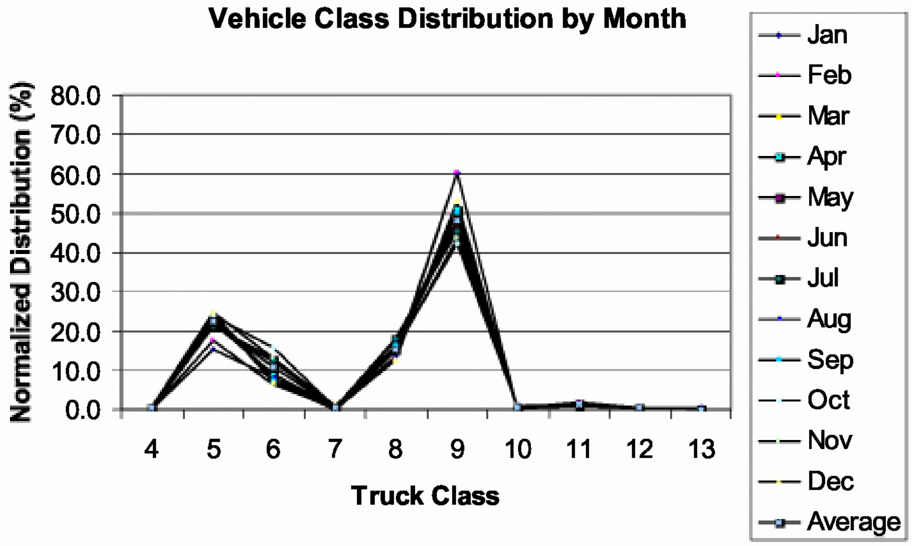

FIGURE B.29. Monthly Class Distribution for Station 350314 (Data Collected in 2003)

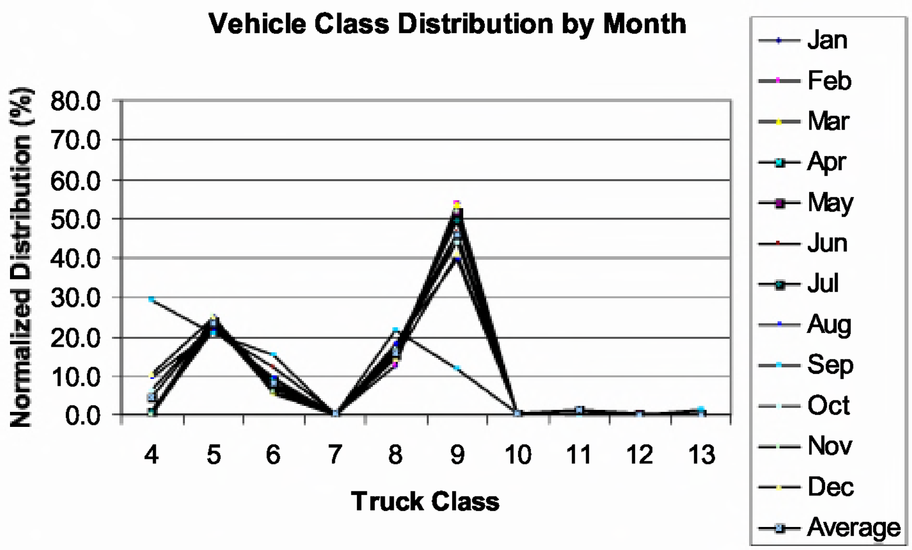

FIGURE B.30. Monthly Class Distribution for Station 350314 (Data Collected in 2004)

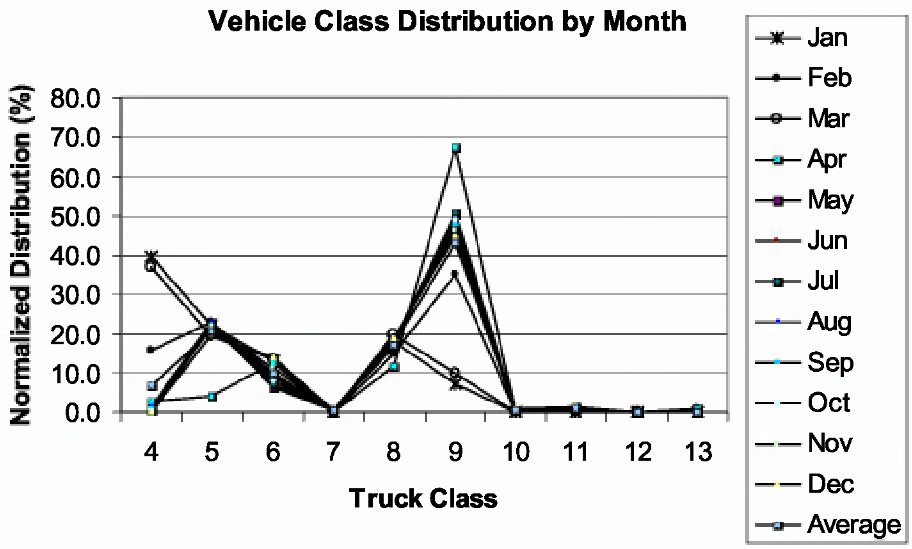

FIGURE B.31. Monthly Class Distribution for Station 350314 (Data Collected in 2005)

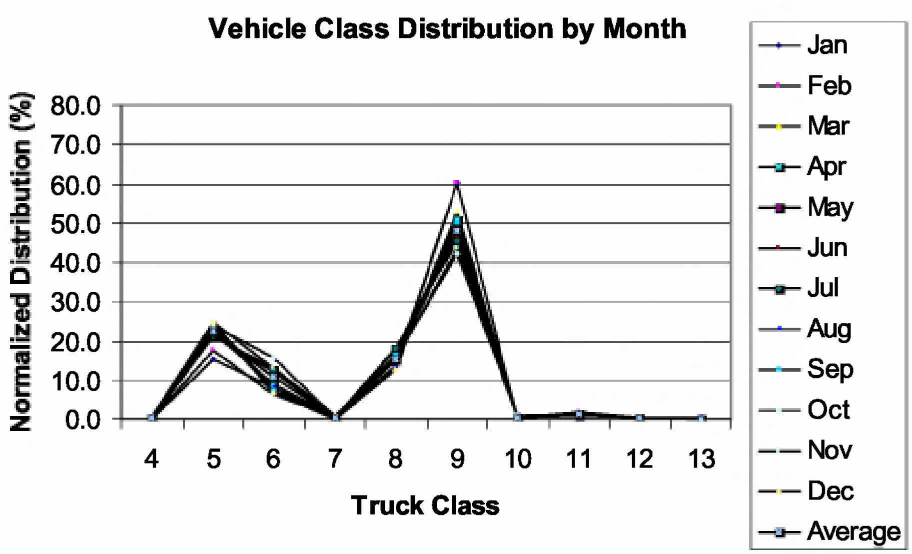

FIGURE B.32. Adjusted Monthly Class Distribution for Station 350314

Figure B.33 presents the average monthly class distribution plots for 12 months for station 350215 on U.S. Highway 65. Unexpected changes in distribution between truck Classes 8 and 9 occurred in the months of April and September 2003. After discarding the suspected data, the remaining data do not represent 12 months (i.e., January through December), so this station is not included for further analysis.

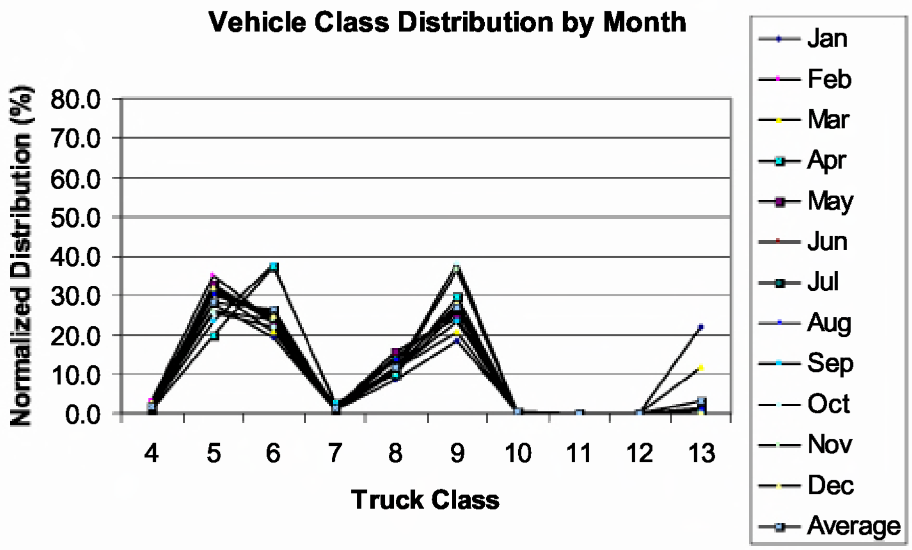

FIGURE B.33. Monthly Class Distribution for Station 350215 (US 65, Pine Bluff)

Figure B.34 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 430038 on U.S. Highway 67. The plots are consistent with the historical data and throughout the 12 different months.

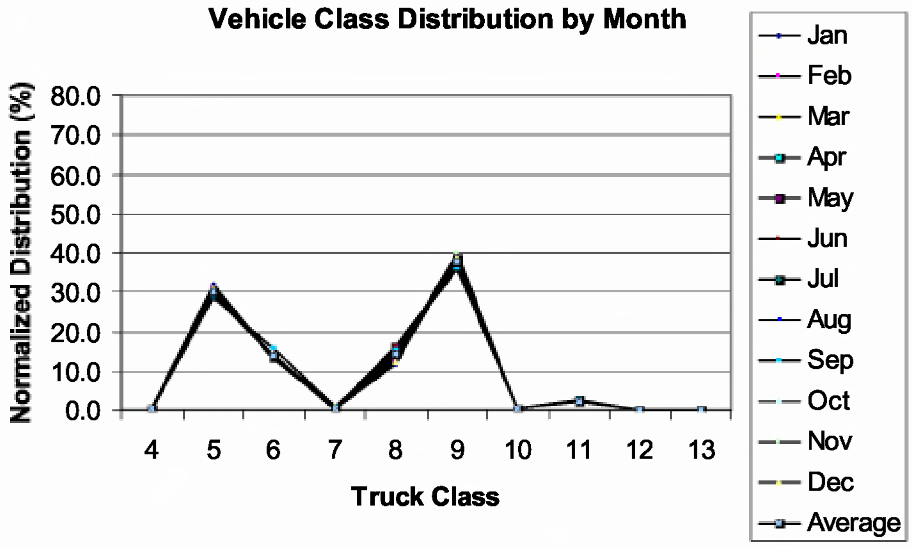

FIGURE B.34. Monthly Class Distribution for Station 430038 (US 67, Cabot)

Figure B.35 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 460286 on State Highway 245. The plots are consistent with the historical data and throughout the 12 different months.

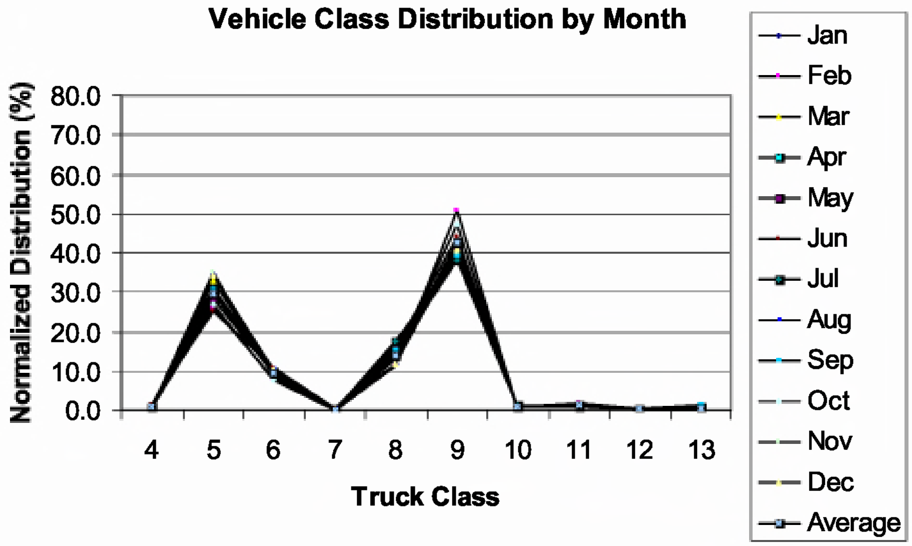

FIGURE B.35. Monthly Class Distribution for Station 460286 (SH 245, Texarkana)

Figure B.36 presents the average monthly class distribution plots for 12 months for station 600870 on State Highway 440. Unexpected changes in distribution between truck Classes 8 and 9 occurred in January 2004. After discarding the wrong data, the plot of average monthly class distributions is shown in Figure B.37.

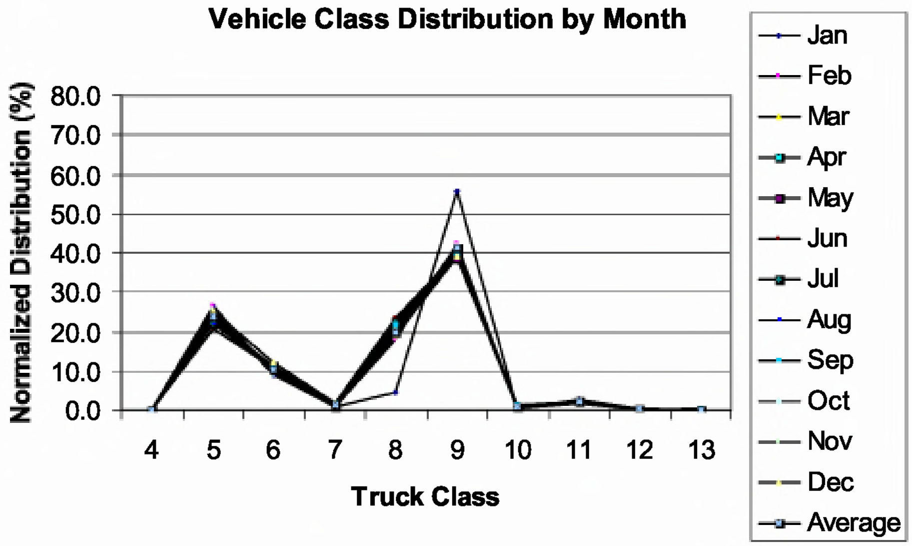

FIGURE B.36. Monthly Class Distribution for Station 600870 (SH 440, Rixey)

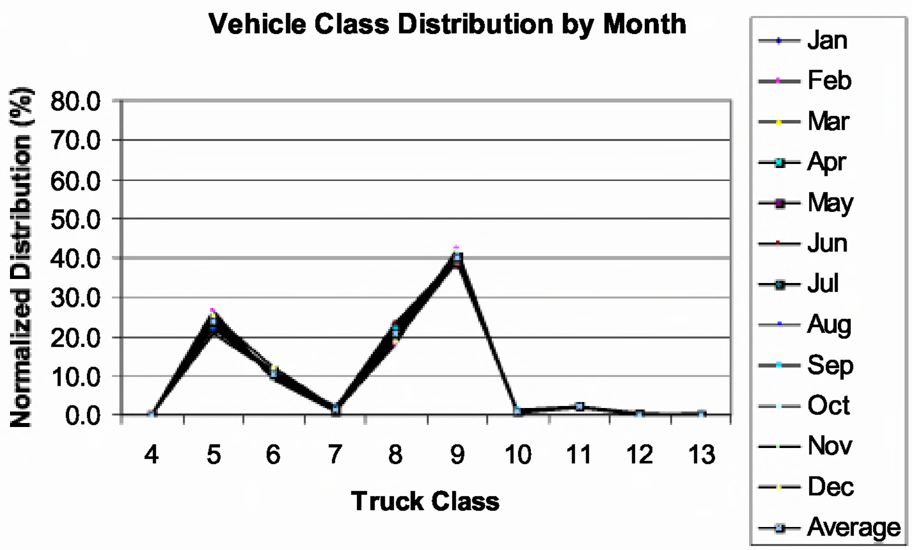

FIGURE B.37. Adjusted Monthly Class Distribution for Station 600870

Figure B.38 presents the average monthly class distribution plots for 12 months (i.e., January through December) for station 350512 on a frontage road of Interstate I-530. Most of trucks on this roadway are class 5.

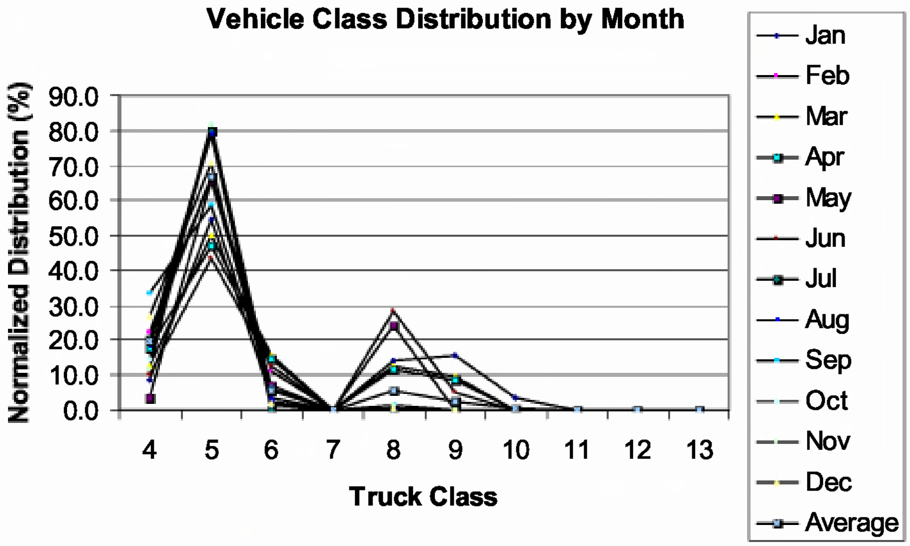

FIGURE B.38. Monthly Class Distribution for Station 350512 (Frontage, I-530)

APPENDIX C. EVALUATION OF AUTOMATED WEIGHT DATA

Figure C.1 presents the plot of gross vehicle weight (GVW) distribution for station 170064. Each distribution curve has two peaks that are within the expected ranges of 32,000±4,000 lb. and 76,000±4,000 lb. Figure C.2 shows graphs of front axle weights, and the peaks are within the expected range of 10,000±2,000 lb. Figure C.3 illustrates the average front axle weights of unloaded trucks (GVW = 28,000 - 36,000lb.), fully loaded trucks (72,000 - 80,000 lb.), and partially loaded trucks (36,000 – 72,000 lb.). The average weights of front axles for all loading conditions are between 8,000 and 12,000lb. The front axle is heavier when the truck is loaded. Figure C.5 shows the average weights of drive tandem axles for different loading conditions. The average drive tandem axle weights for fully loaded trucks are within the expected range of 33,000±3,000 lb. The plots do not show any problems, so the weight data from WIM station 170064 are selected for further analyses.

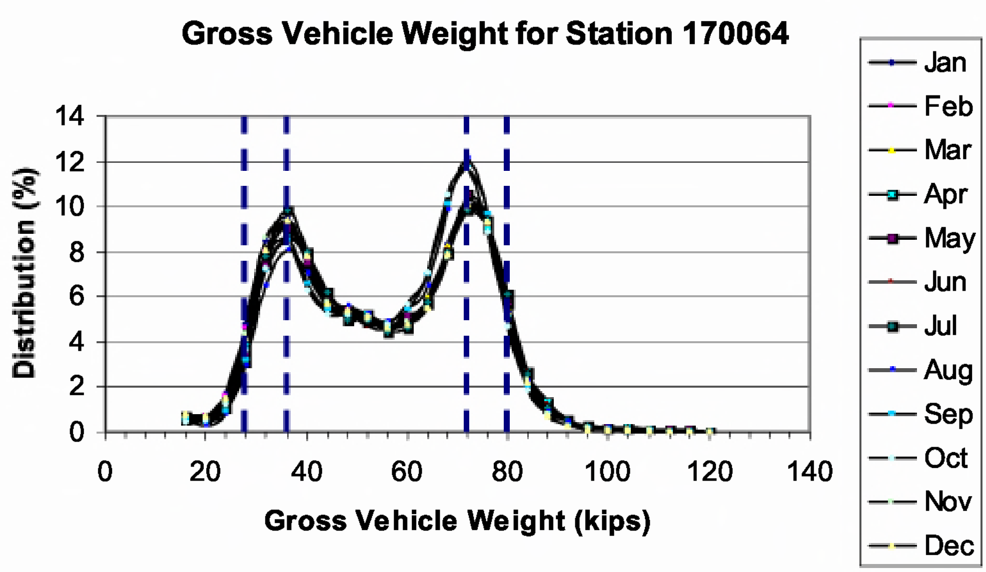

FIGURE C.1. Gross Vehicle Weight Distributions for Station 170064 (I-540, Alma)

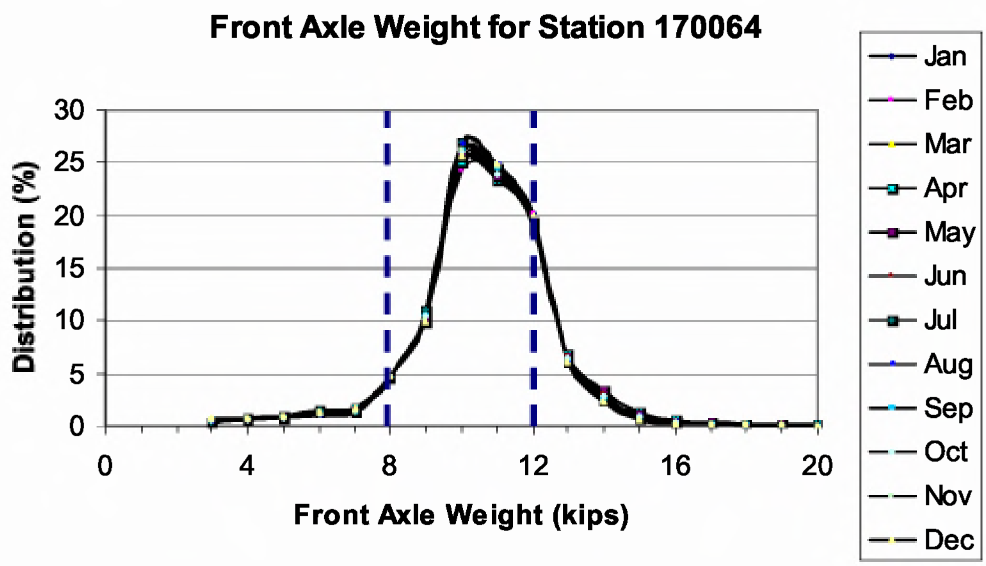

FIGURE C.2. Front Axle Weight Distributions for Station 170064 (I-540, Alma)

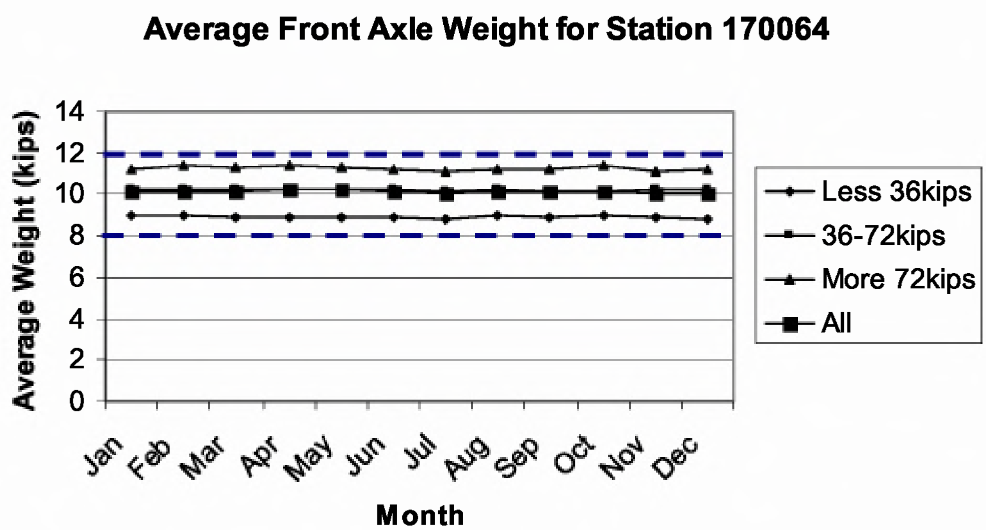

FIGURE C.3. Average Front Axle Weights for Station 170064

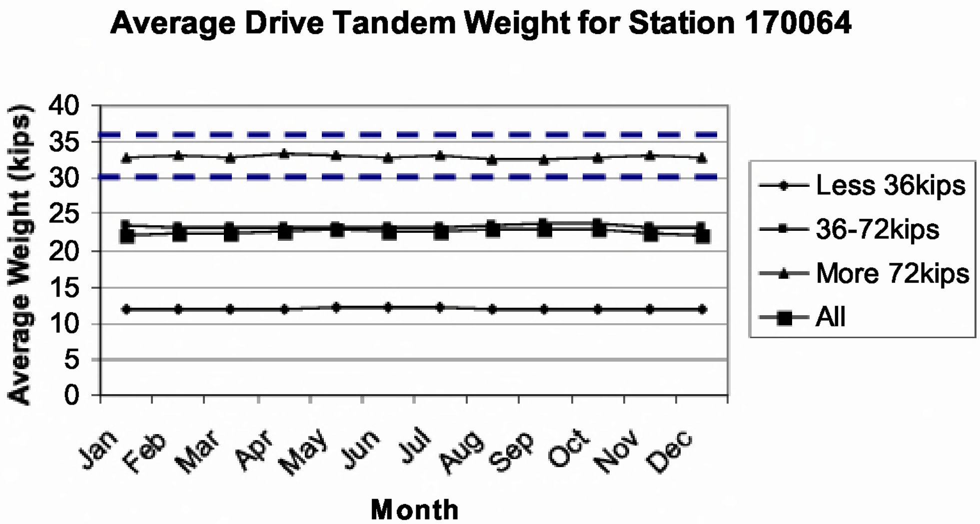

FIGURE C.4. Average Drive Tandem Axle Weights for Station 170064

Figure C.5 presents the plot of gross vehicle weight (GVW) distribution for station 430037. The distribution curves are not consistent. Some peaks are within the expected range of 76,000±4,000 lb, some are shifted to the left. These problems show that the WIM scale is probably failed. Figure C.6 shows the plot of front axle weight distribution, and the peaks for all curves are within the expected range of 10,000±2,000 lb. Figure C.7 illustrates the average front axle weights of unloaded, partially loaded, and fully loaded trucks. The average weights of front axles for the unloaded trucks are out of the range of 10,000±2,000lb. The average weights of front axles for the fully loaded trucks are out of the limits in April and May. Figure C.8 shows the average drive tandem axle weights for different loading conditions. The average drive tandem axle weights for fully loaded trucks are out of the expected range of 33,000±3,000 lb in April and May. The problems shown in Figures C.7 and C.8 confirm the scale failure. Thus, the weight data from WIM station 430037 are not selected for further analyses, and the calibration should be immediately checked.

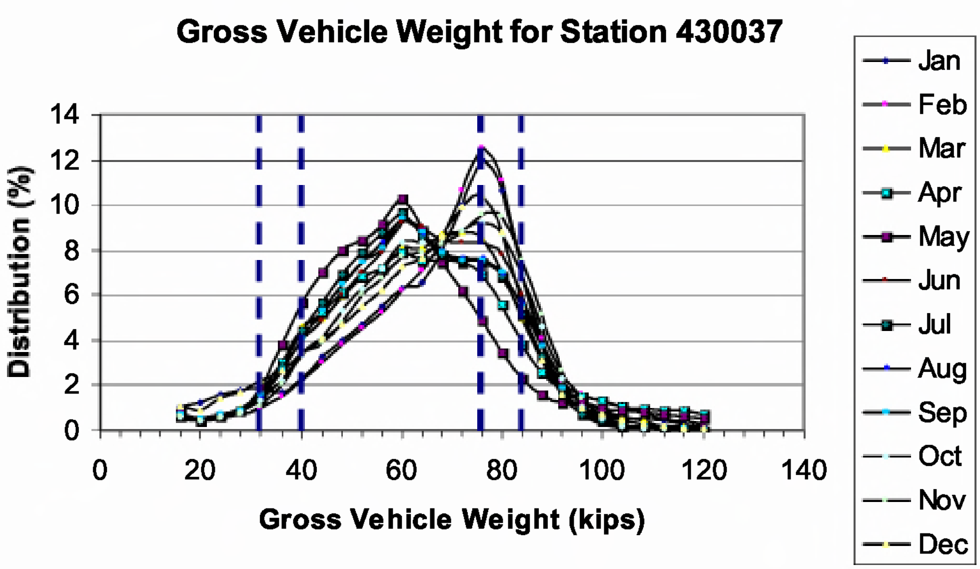

FIGURE C.5. Gross Vehicle Weight Distributions for Station 430037 (I-40, Lonoke)

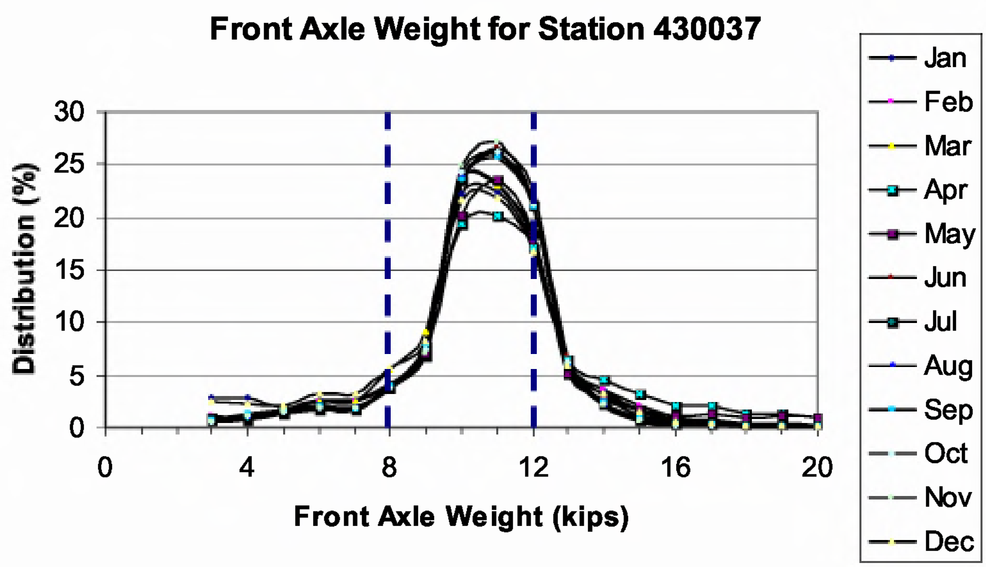

FIGURE C.6. Front Axle Weight Distributions for Station 430037 (I-40, Lonoke)

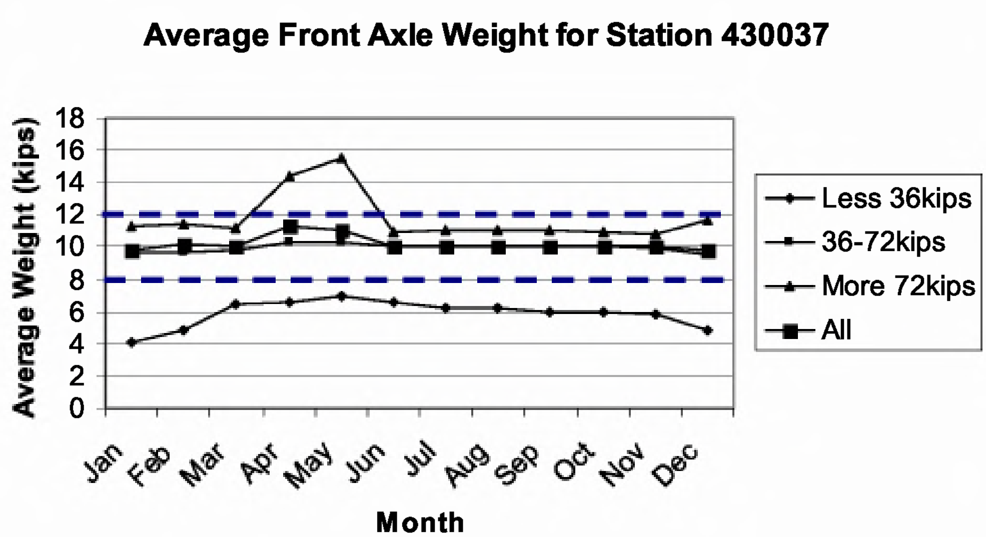

FIGURE C.7. Average Front Axle Weights for Station 430037

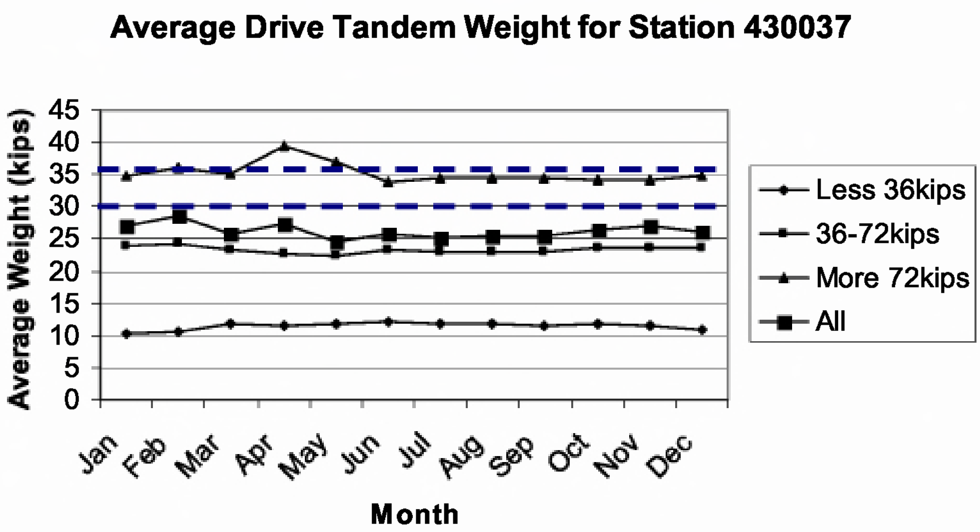

FIGURE C.8. Average Drive Tandem Axle Weights for Station 430037

Figure C.9 presents the plot of gross vehicle weight (GVW) distribution for station 460006. The distribution curves are consistent. The only peaks for loaded trucks are shown and within the expected range of 76,000±4,000 lb. This is not an ideal but acceptable case. Figure C.10 shows the plot of front axle weight distribution, and the peaks for all curves are within the expected range of 10,000±2,000 lb. Figure C.11 illustrates the average front axle weights of unloaded, partially loaded, and fully loaded trucks. The average front axle weights for the unloaded trucks are close to 8,000lb. Figure C.12 shows the average weights of drive tandem axles based on the ranges of gross vehicle weights. The average drive tandem axle weights for fully loaded trucks are within the expected range of 33,000±3,000 lb. Based on the plots, the weight data from WIM station 460006 are selected for further analyses.

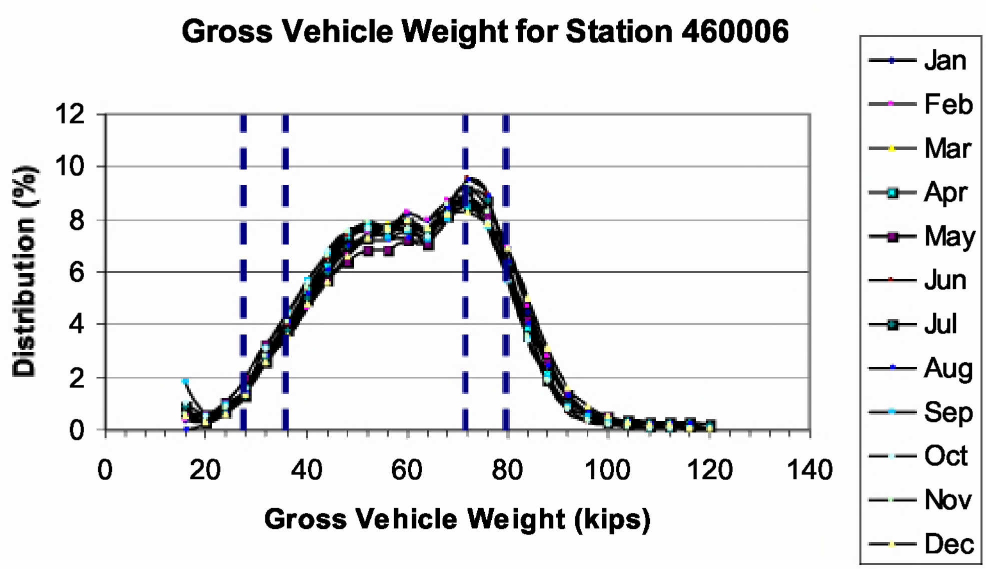

FIGURE C.9. Gross Weight Distributions for Station 460006 (Texarkana, Miller)

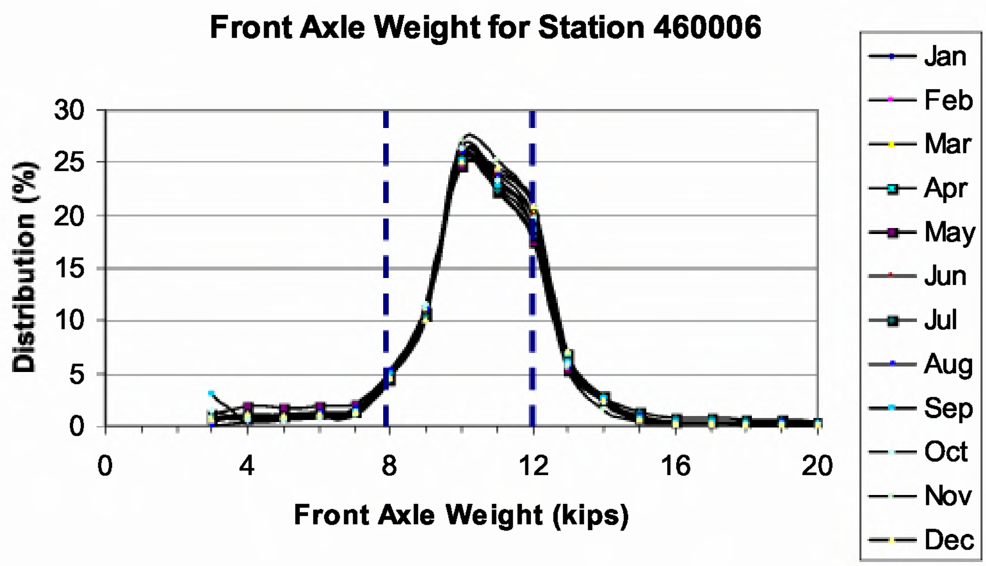

FIGURE C.10. Front Axle Weight Distributions for Station 460006 (Texarkana, Miller)

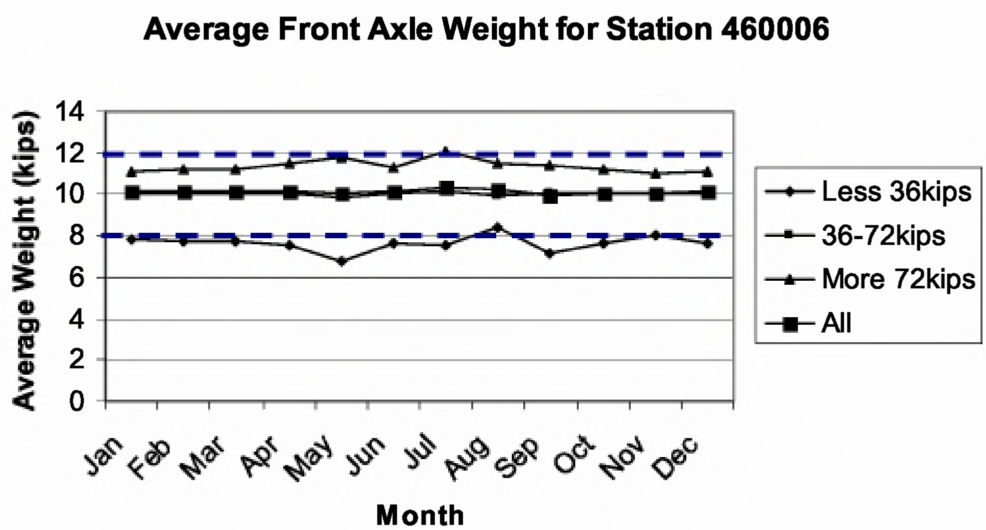

FIGURE C.11. Average Front Axle Weights for Station 460006

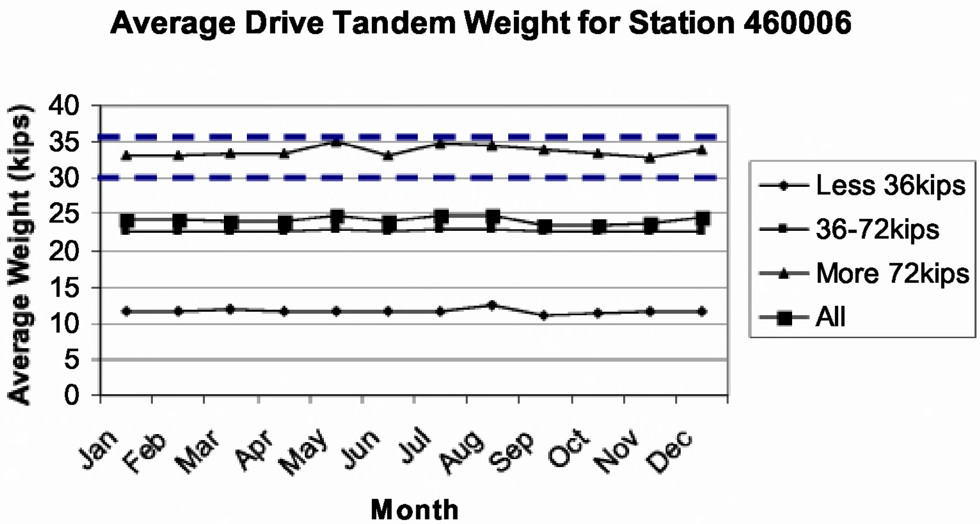

FIGURE C.12. Average Drive Tandem Axle Weights for Station 460006

Figure C.13 presents the plot of gross vehicle weight (GVW) distribution for station 481524. The distribution curves are not consistent. The peaks for loaded trucks from April through September are shifted to the left. These problems may be due to the WIM scale failure or the changes in truck flow. Figure C.14 shows the plot of front axle weight distribution, and the peaks for all curves are within the expected range of 10,000±2,000 lb. Figure C.15 illustrates the average front axle weights of unloaded, partially loaded, and fully loaded trucks. Figure C.16 shows the average weights of drive tandem axles based on the ranges of gross vehicle weights. Figures C.15 and C.16 show the curves are moved up and down between the summer (April through September) and the winter (October through March). The problems shown in Figures C.15 and C.16 confirm the shift of load distributions in Figure C.13 is due to the WIM scale failure but not the changes in truck flow. Thus, the weight data from WIM station 481524 are not selected for further analyses, and the calibration of the scale should be immediately checked.

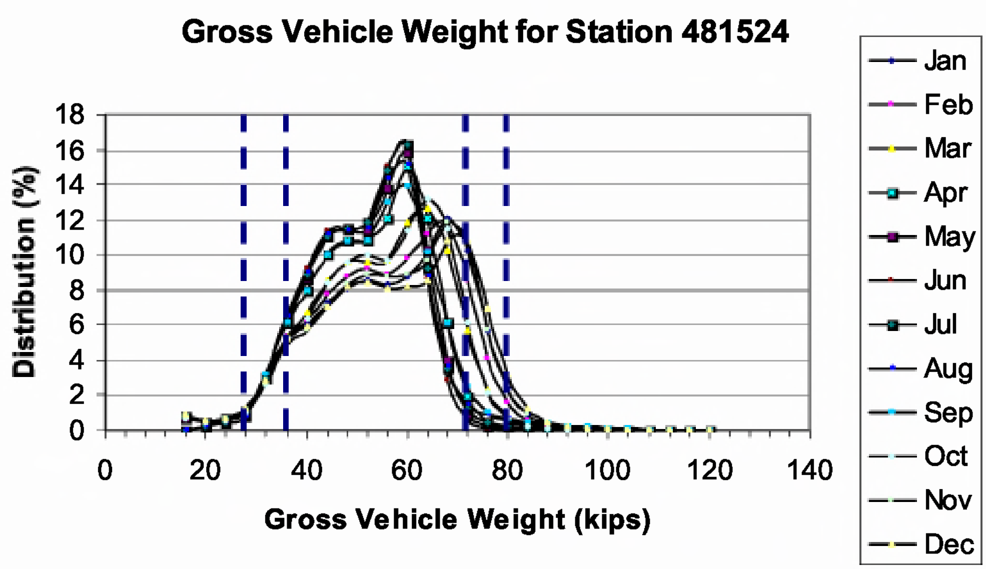

FIGURE C.13. Gross Weight Distributions for Station 481524 (Brinkley, Monroe)

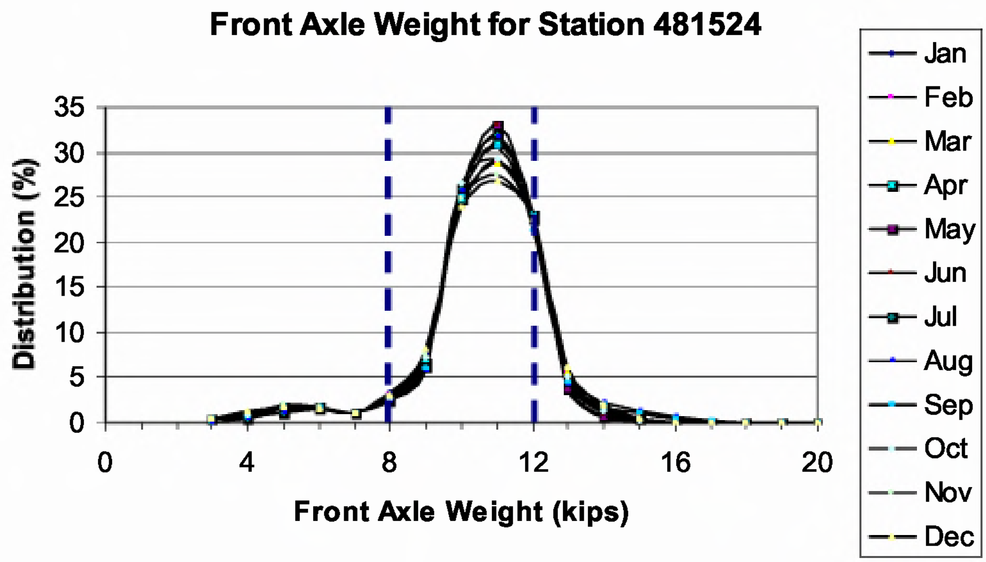

FIGURE C.14. Front Axle Weight Distributions for Station 481524 (Brinkley, Monroe)

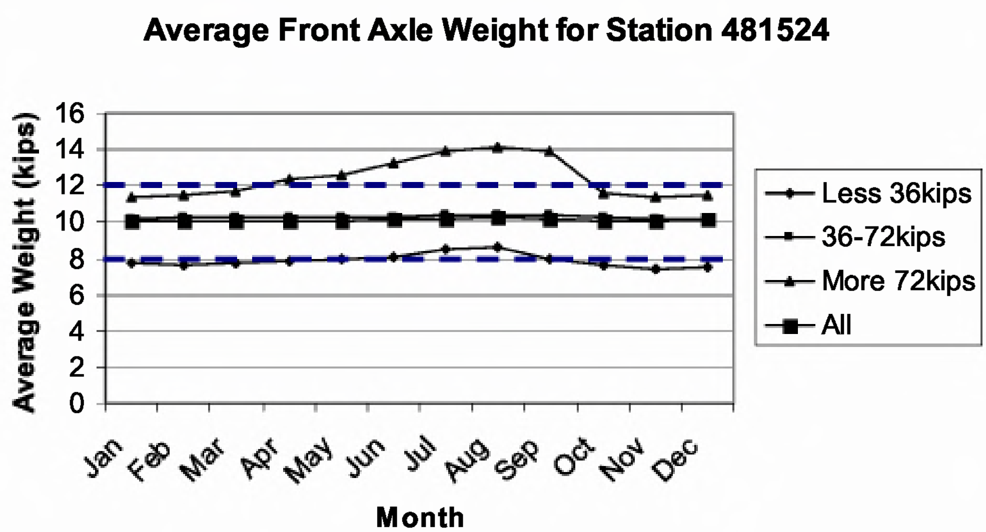

FIGURE C.15. Average Front Axle Weights for Station 481524

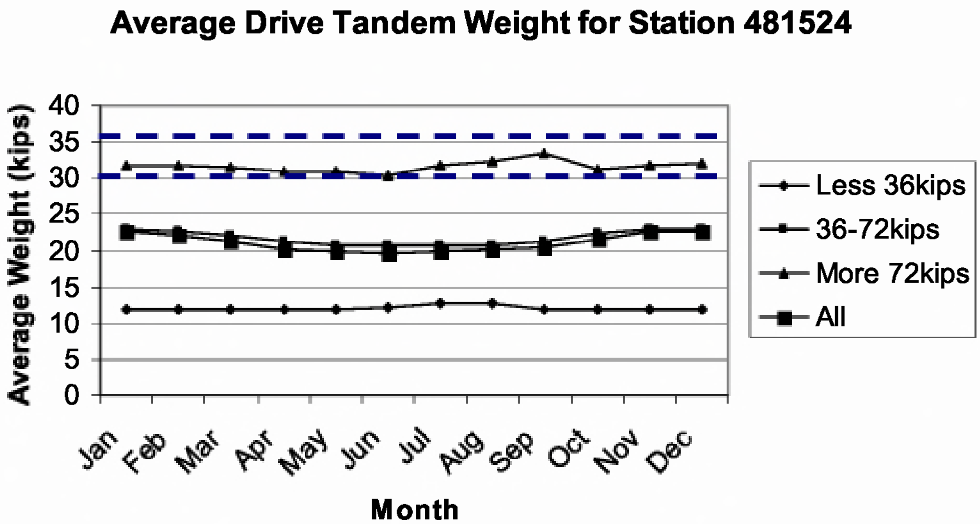

FIGURE C.16. Average Drive Tandem Axle Weights for Station 481524

Figures C.17 through C.20 present the data from Station 580236. The distribution curves in Figure C.17 are not consistent. Figure C.19 and C.20 also show that the data are fluctuated, but they are still within the limits. There is no evidence that the scale is failed, there may be changes of traffic flow over months. Thus, the data from this station are selected for further analyses.

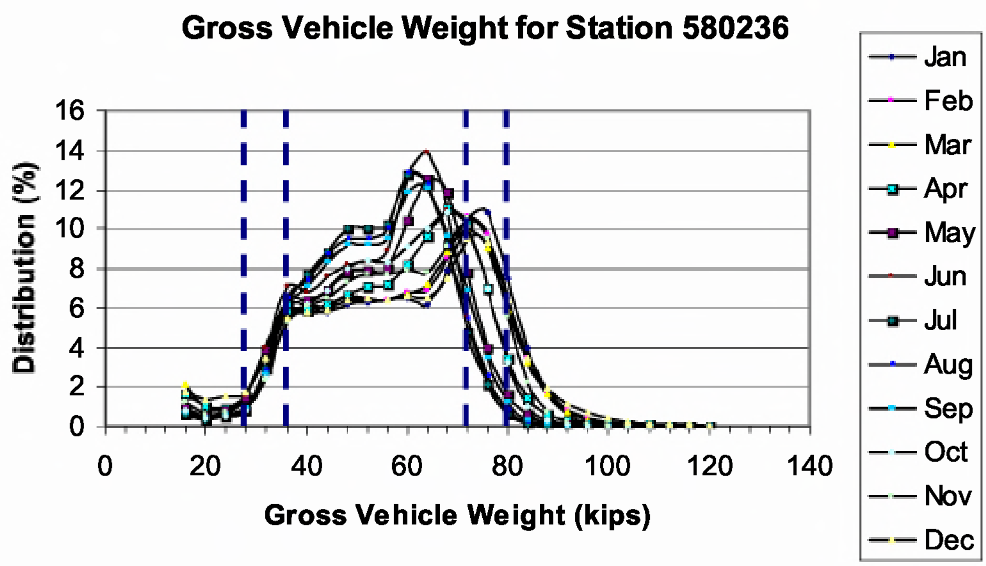

FIGURE C.17. Gross Vehicle Weights for Station 580236 (Russellville, Pope)

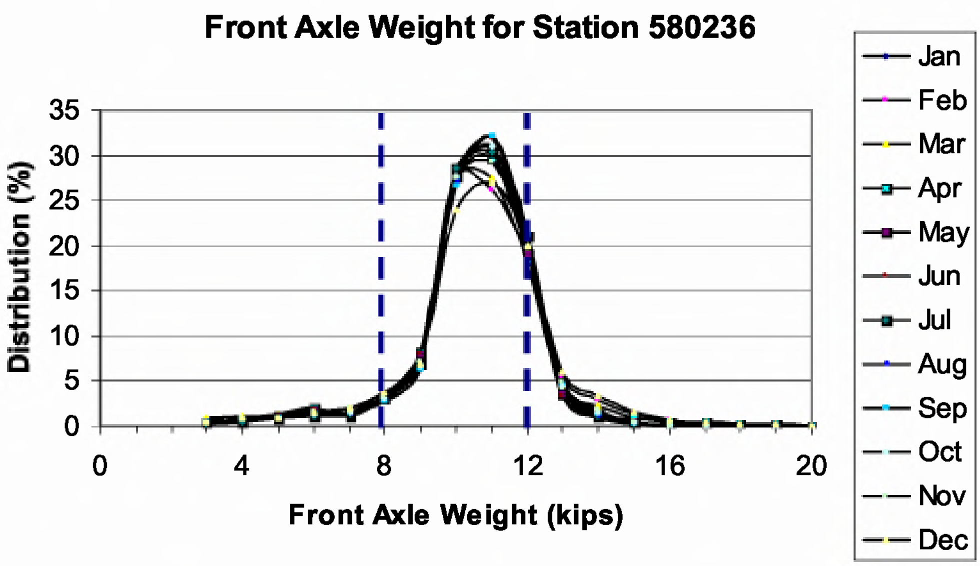

FIGURE C.18. Front Axle Weight Distributions for Station 580236 (Russellville, Pope)

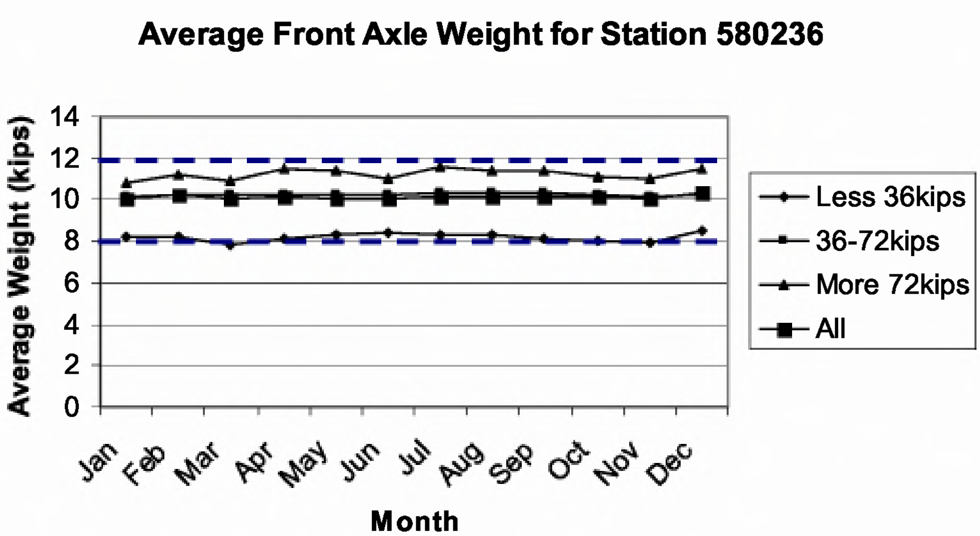

FIGURE C.19. Average Front Axle Weights for Station 580236

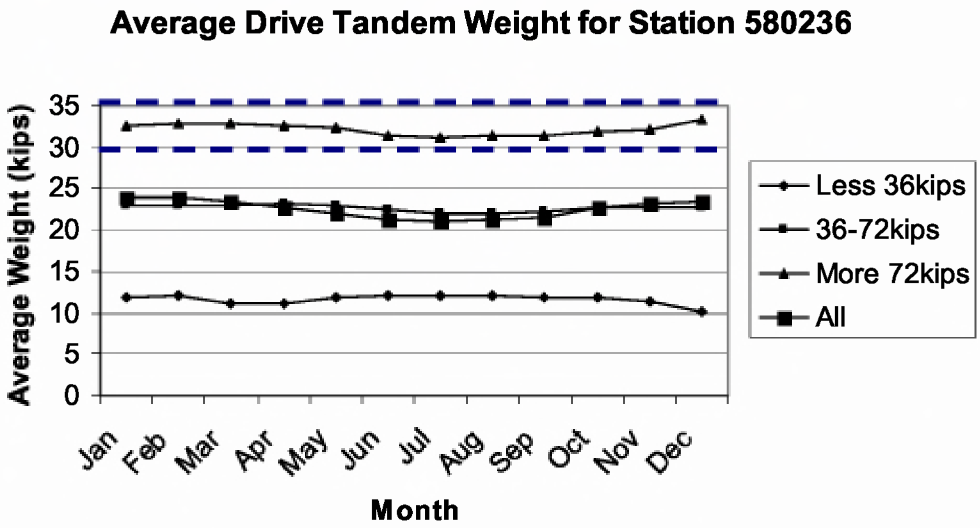

FIGURE C.20. Average Drive Tandem Axle Weights for Station 580236

Figure C.21 presents the plot of gross vehicle weight (GVW) distribution for station 680025. The distribution curves are not consistent. Some peaks are within the expected range of 76,000±4,000 lb, some are shifted to the left. These problems show that the WIM scale is probably failed. Figure C.22 shows the plot of front axle weight distribution, and the peaks for all curves are within the expected range of 10,000±2,000 lb. However, the curves are not consistent, and they vary differently comparing to the plots from other stations presented above. Figure C.23 illustrates the average front axle weights of unloaded, partially loaded, and fully loaded trucks. The average weights of front axles for the unloaded trucks and loaded trucks are out of the range of 10,000±2,000lb. Figure C.8 shows the average weights of drive tandem axles. The average drive tandem axle weights for fully loaded trucks are out of the expected range of 33,000±3,000 lb for several months. The problems shown in Figures C.22 through C.24 confirm the scale failure. Thus, the weight data from WIM station 680025 are not selected for further analyses, and the scale calibration should be immediately checked.

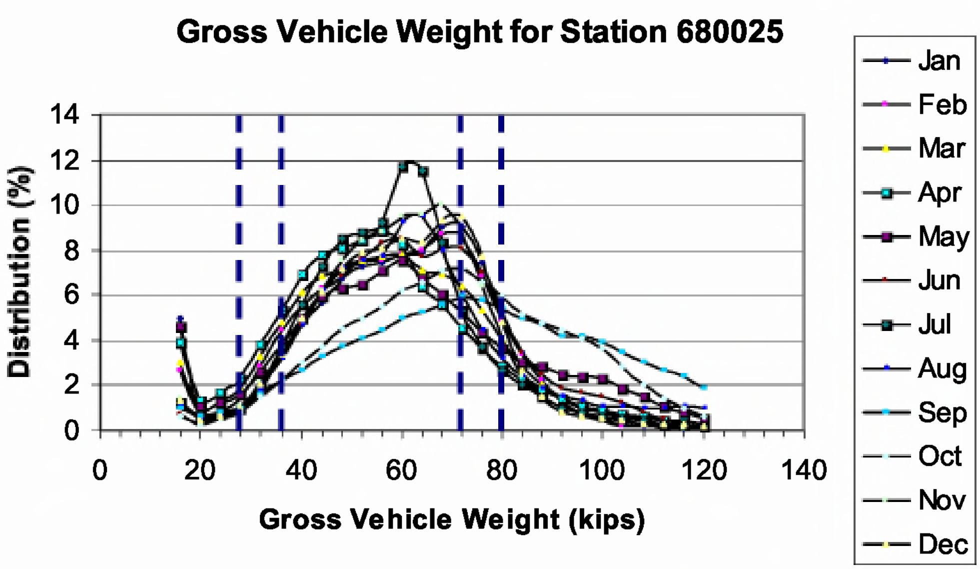

FIGURE C.21. Gross Weight Distributions for Station 680025 (Forrest City, St Francis)

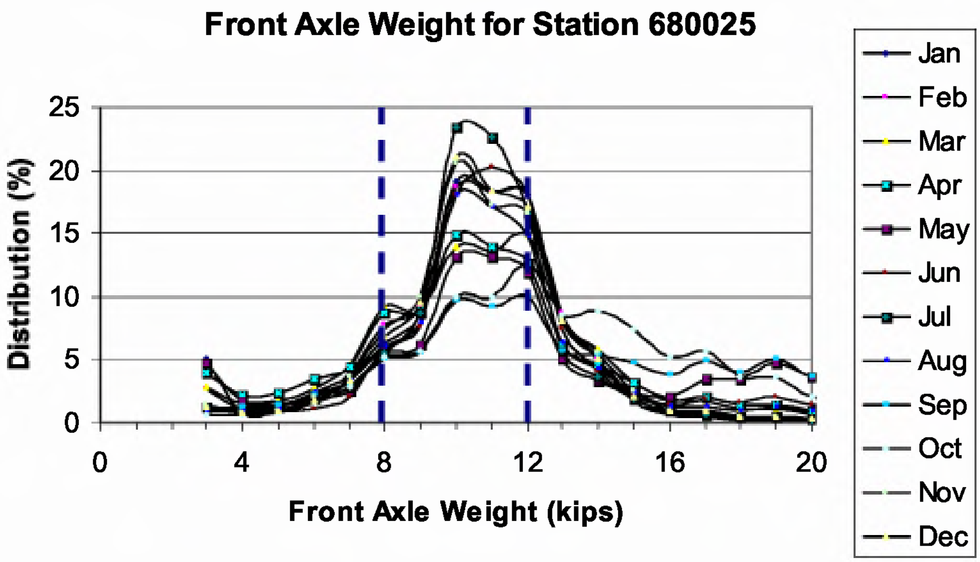

FIGURE C.22. Front Axle Weight Distributions for Station 680025

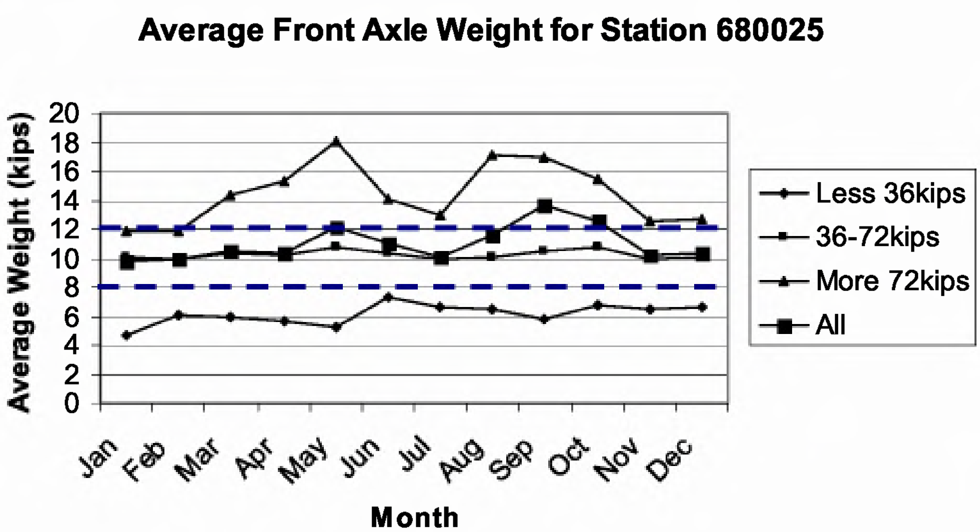

FIGURE C.23. Average Front Axle Weights for Station 680025

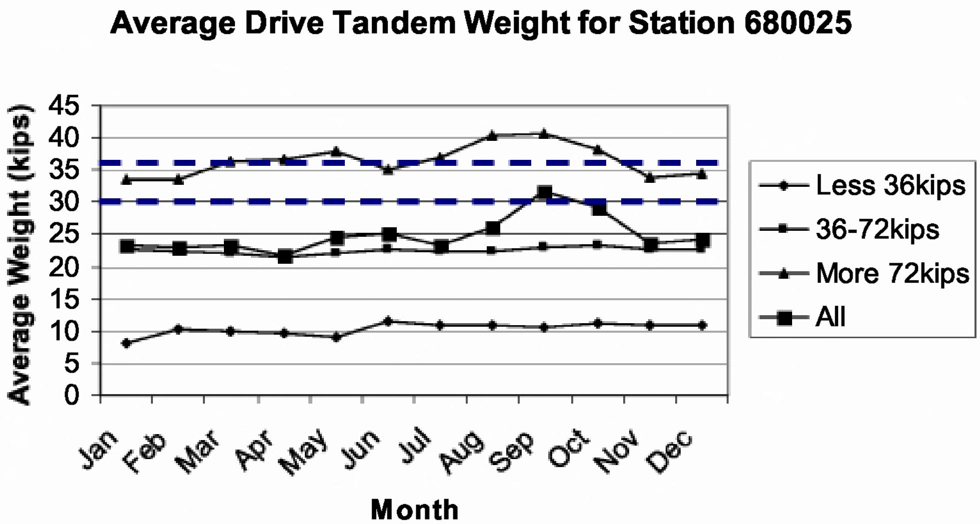

FIGURE C.24. Average Drive Tandem Axle Weights for Station 680025

Figures C.25 through C.28 present the data from Station 071813. The data from December 2003 through February 2004 and January 2005 have some problems. The curves for these months have lower peaks, as shown in Figure C.25. The average front axle weights for unloaded trucks in these months shown in Figure C.27 are lower than the 8,000 lb. limit. The average drive axle weights for fully loaded trucks in those months are higher than the upper limit as shown in Figure C.28.

Figures C.29 and C.30 show examples of the problems occurred in January 2005. The two peaks are shifted to the right. A significant number of trucks are over the 80,000 lb. legal weight limit. The front axle weights are also shifted to the right. The data for other "problem" months have similar trends. The scale was failed in those months. The data for those months are discarded. Figures C.31 and C.32 show graphs of adjusted dataset. The curves are consistent, and the average front axle weights are about within the limits. Thus, the adjusted dataset is selected for further analyses.

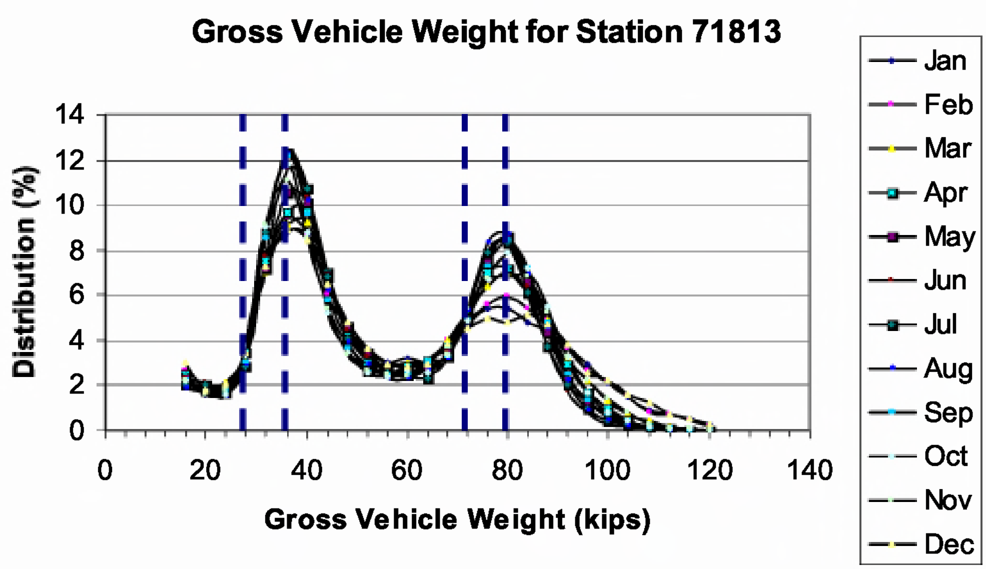

FIGURE C.25. Gross Weight Distributions for Station 071813 (Thornton, Calhoun)

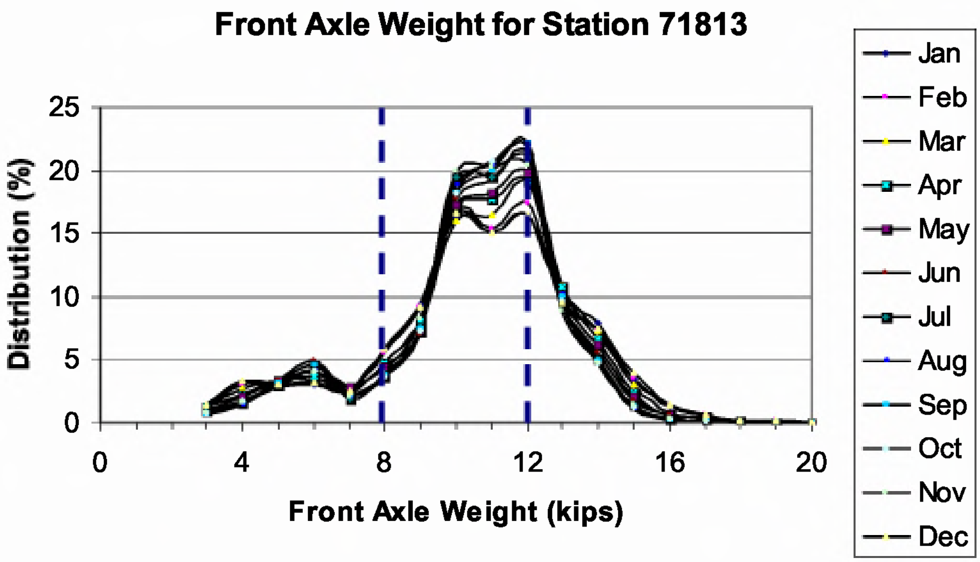

FIGURE C.26. Front Axle Weight Distributions for Station 071813

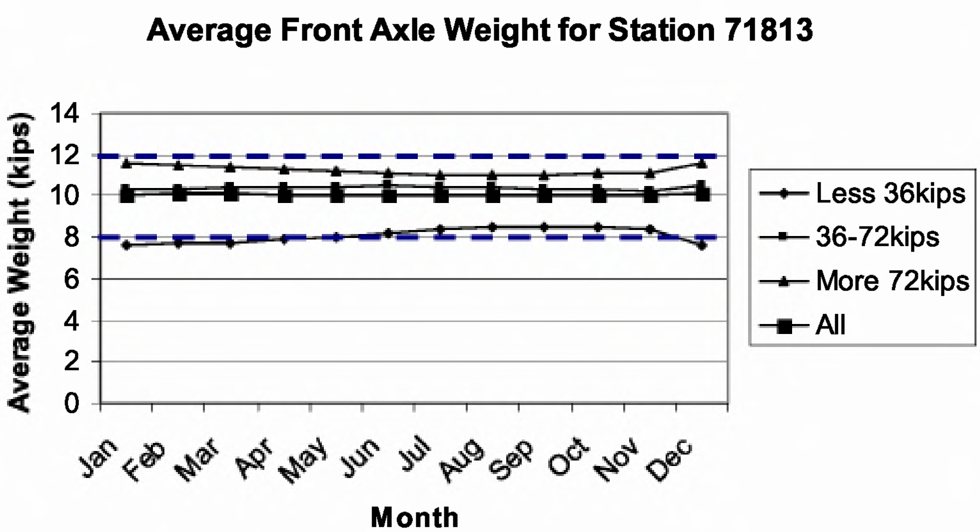

FIGURE C.27. Average Front Axle Weights for Station 071813

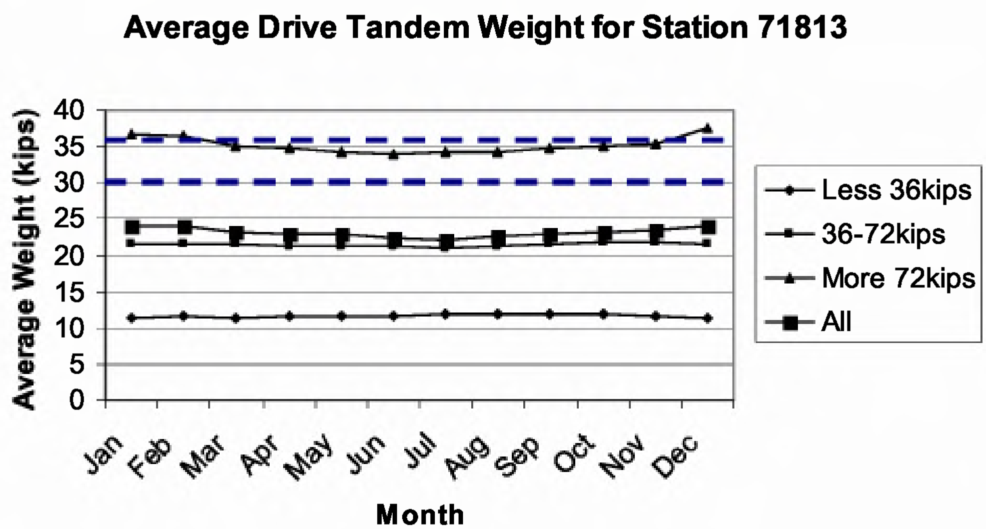

FIGURE C.28. Average Drive Tandem Axle Weights for Station 071813

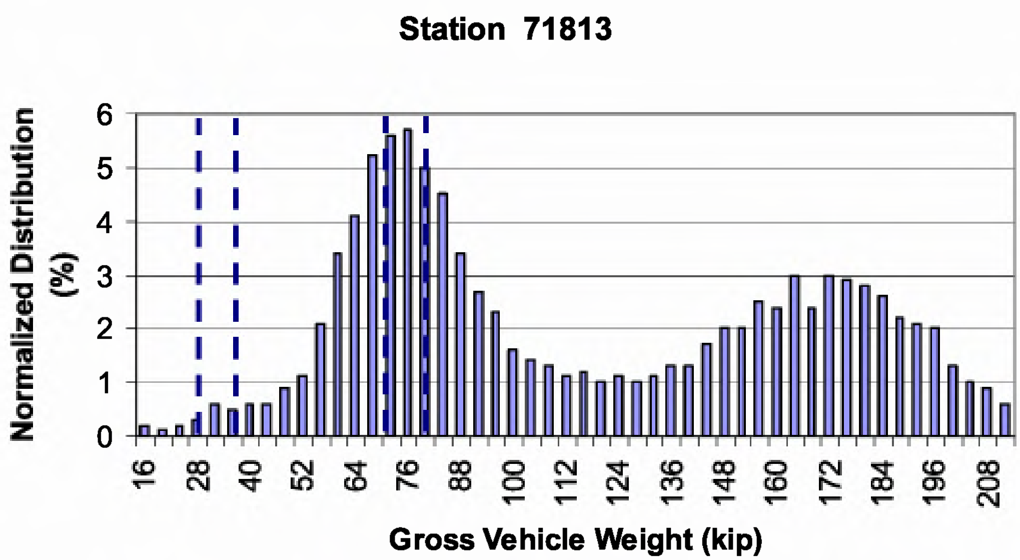

FIGURE C.29. Gross Weight Distribution from Station 071813 in January 2005

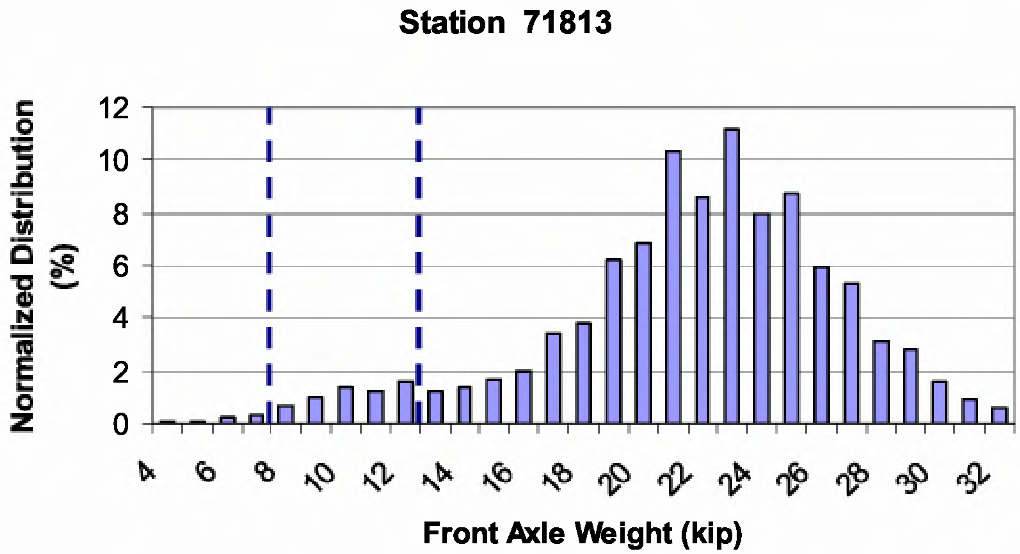

FIGURE C.30. Front Axle Weight Distribution from Station 071813 in January 2005

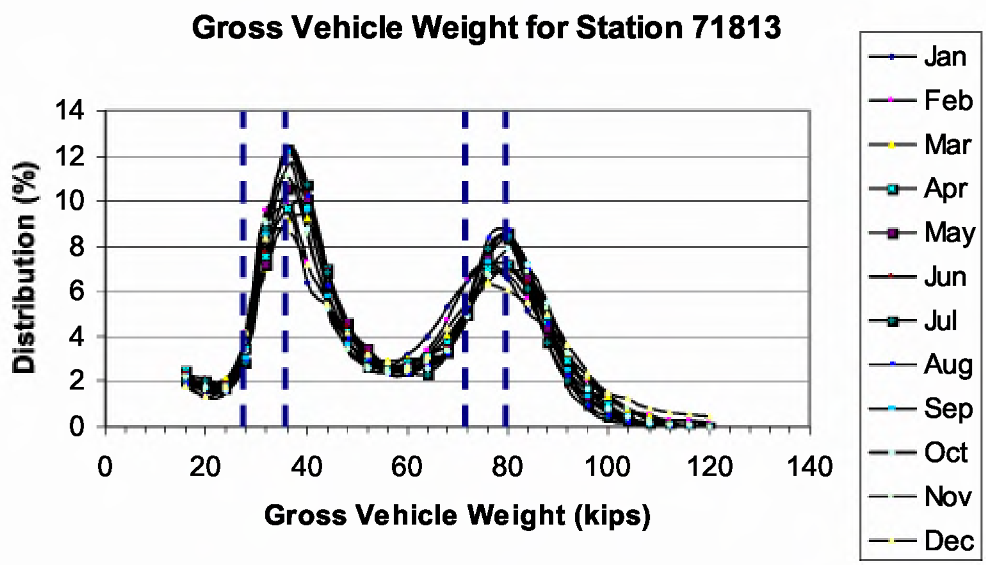

FIGURE C.31. Adjusted Gross Vehicle Weight Distributions for Station 071813

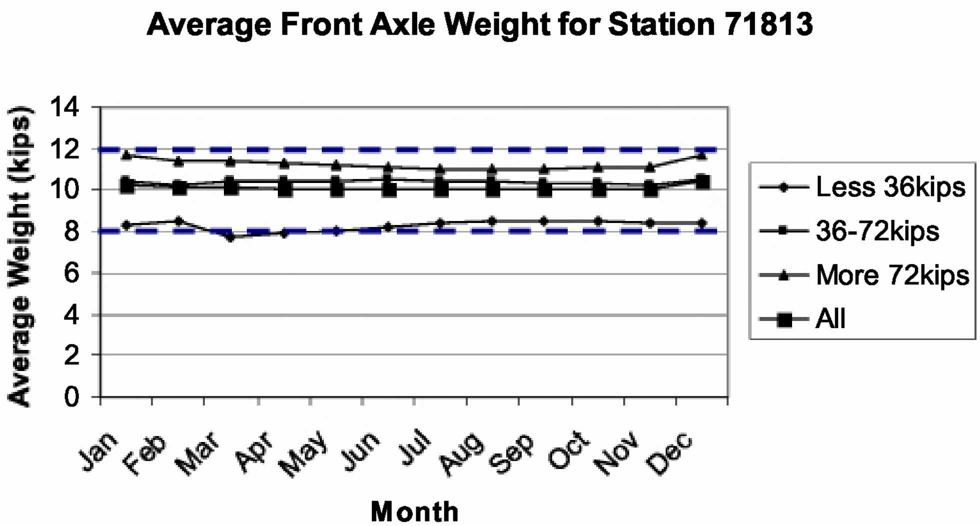

FIGURE C.32. Adjusted Average Front Axle Weights for Station 071813

Figure C.33 shows a plot of weight data from Station 230001. The plot includes the data collected in September 2004 to show the influence of misclassified vehicle data on the vehicle weight distributions. The second peak for the data in September is shifted to the left. Figures C.34 through C.37 show the plots of adjusted dataset after the data collected in September 2004 were discarded. There is no significant problem with the adjusted dataset. Thus, the adjusted dataset for Station 230001 was selected for further analyses.

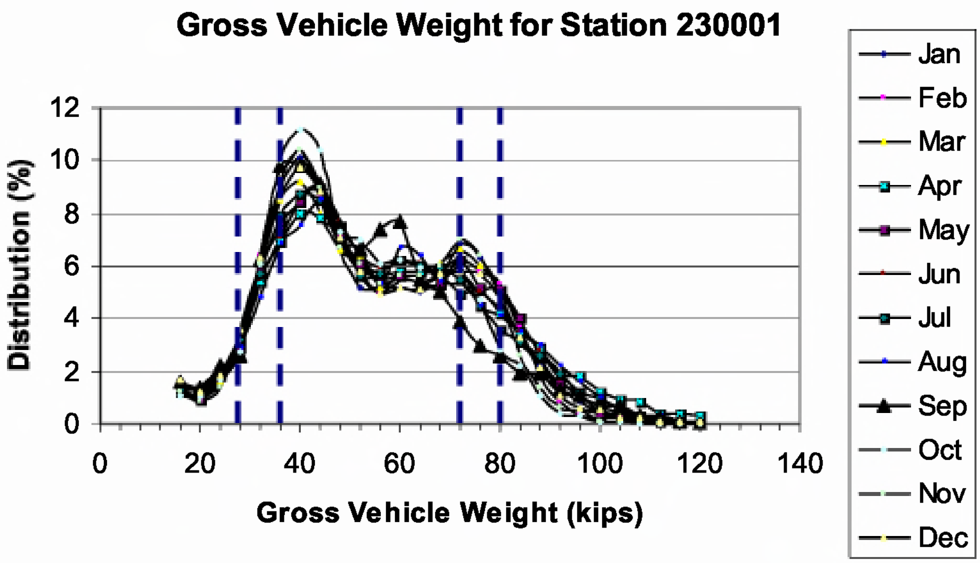

FIGURE C.33. Gross Weight Distributions for Station 230001 (Damascus, Faulkner)

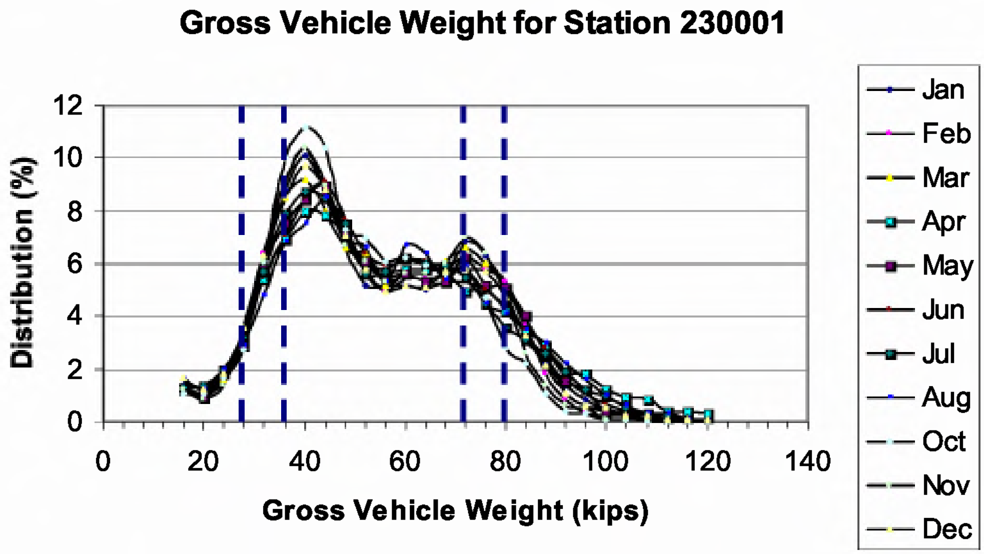

FIGURE C.34. Gross Weight Distributions for Adjusted Dataset

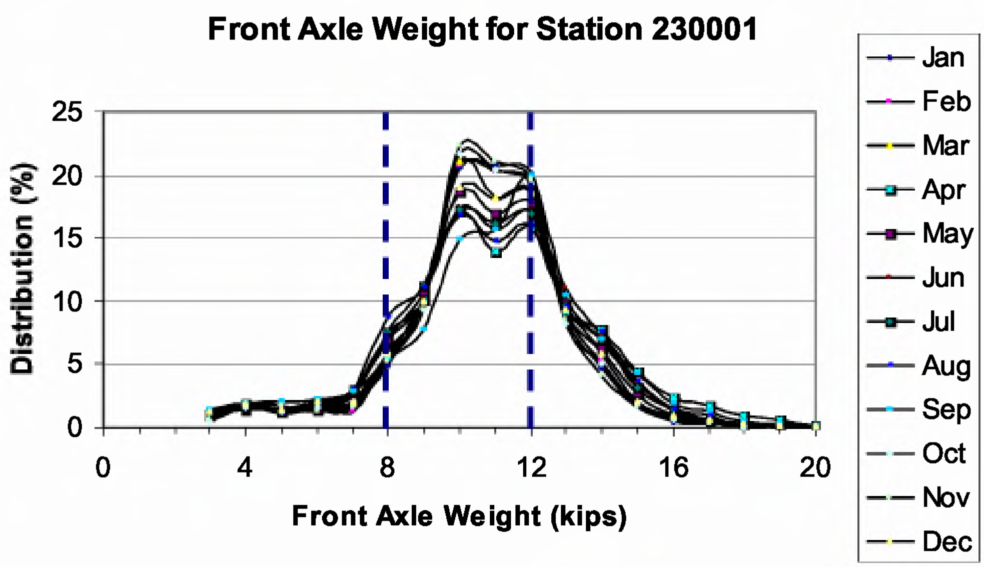

FIGURE C.35. Front Axle Weight Distributions for Station 230001

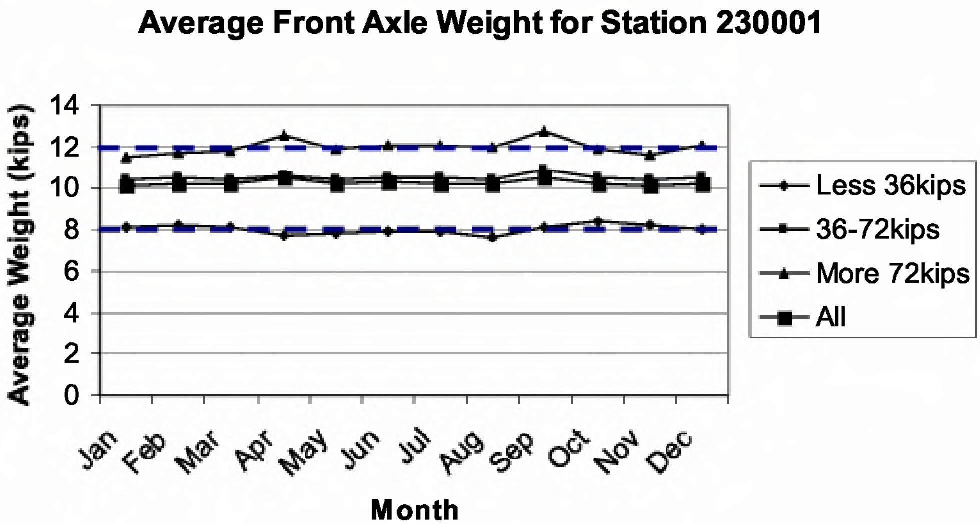

FIGURE C.36. Average Front Axle Weights for Station 230001

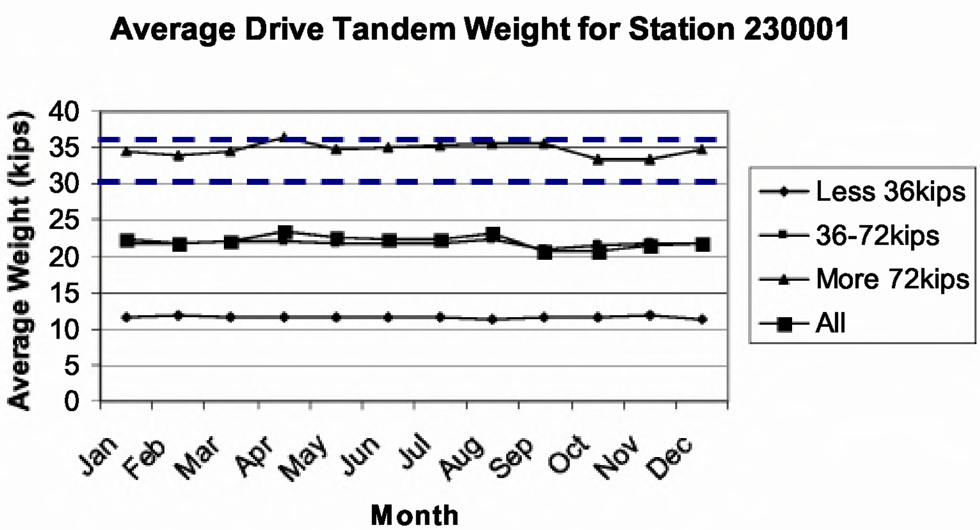

FIGURE C.37. Average Drive Tandem Axle Weights for Station 230001

Figures C.38 through C41 show the plots of weight data from Station 281983. The plots present the same problems as shown in the plots for Station 680025. Thus, the dataset from Station 680025 is not selected for further analyses, and the calibration of this station should be immediately checked.

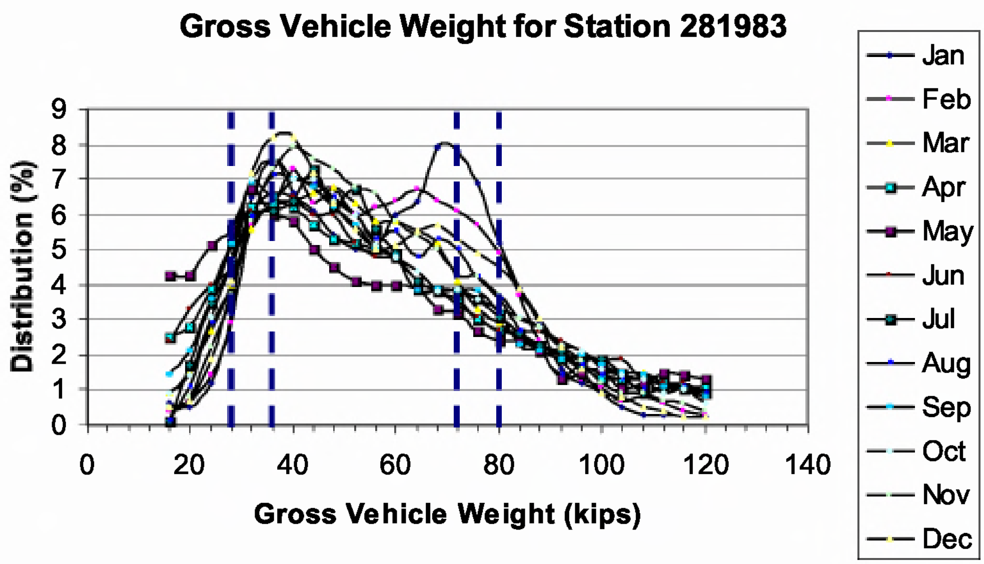

FIGURE C.38. Gross Weight Distributions for Station 281983 (Light, Greene)

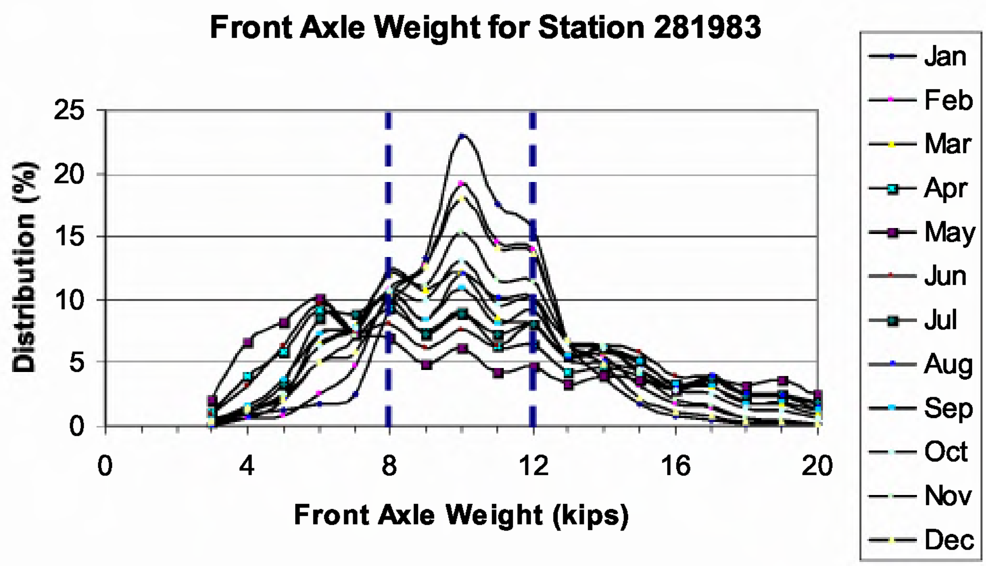

FIGURE C.39. Front Axle Weight Distributions for Station 281983

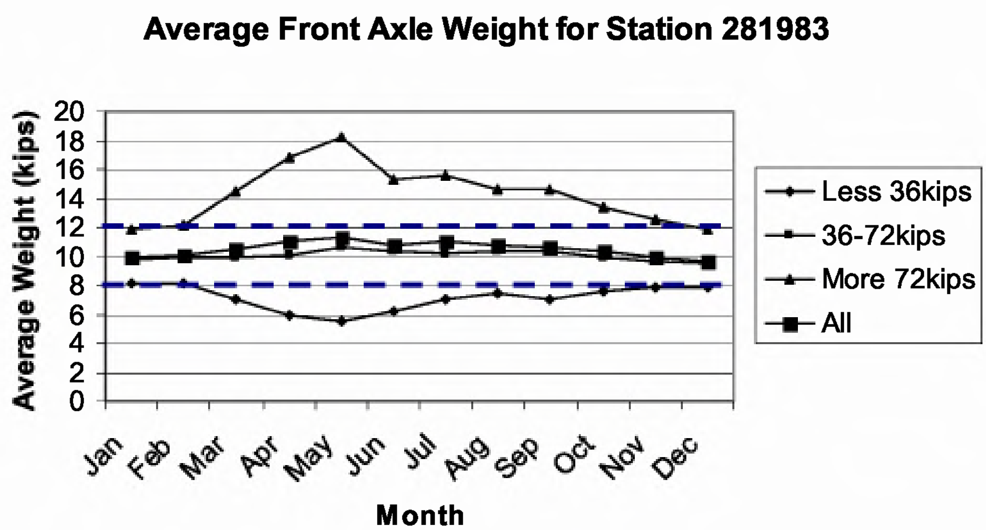

FIGURE C.40. Average Front Axle Weights for Station 281983

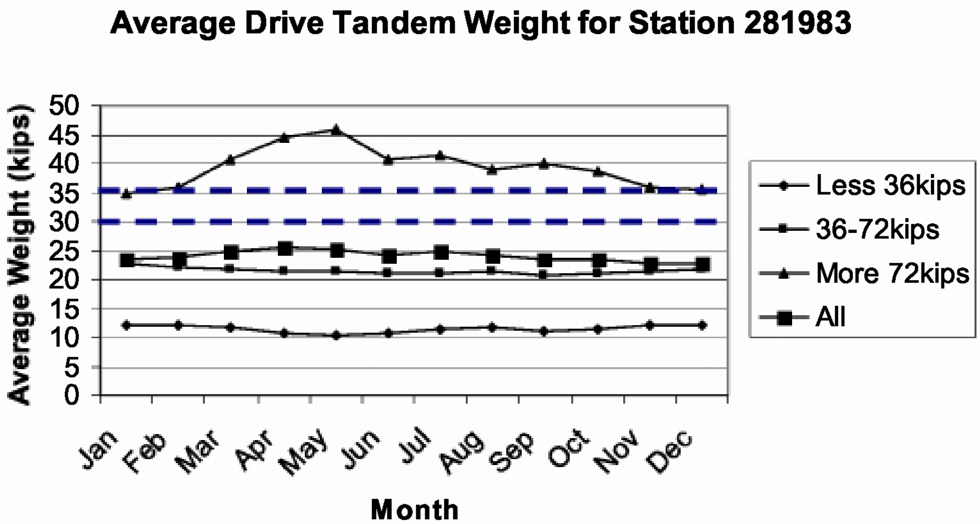

FIGURE C.41. Average Drive Tandem Axle Weights for Station 281983

Figures C.42 through C.45 show the plots of weight data from Station 720034. The vehicle weight distributions change over months, as shown in Figure C.42. However, the weight data still vary within the limits, as shown in Figures C.43 through C.45. Thus, the data from Station 720034 are selected for further analyses.

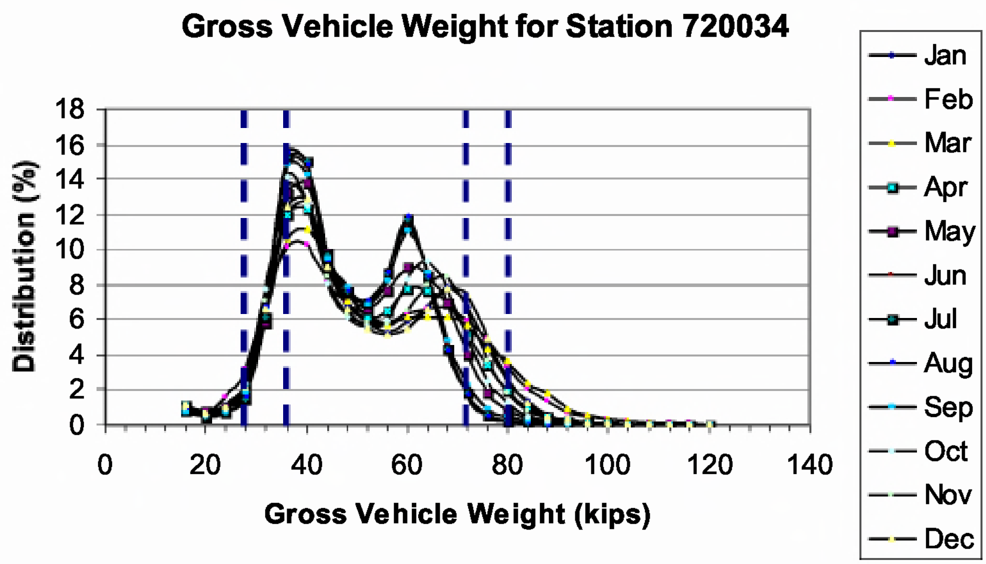

FIGURE C.42. Gross Weight Distributions for Station 720034 (Tonitown, Washington)

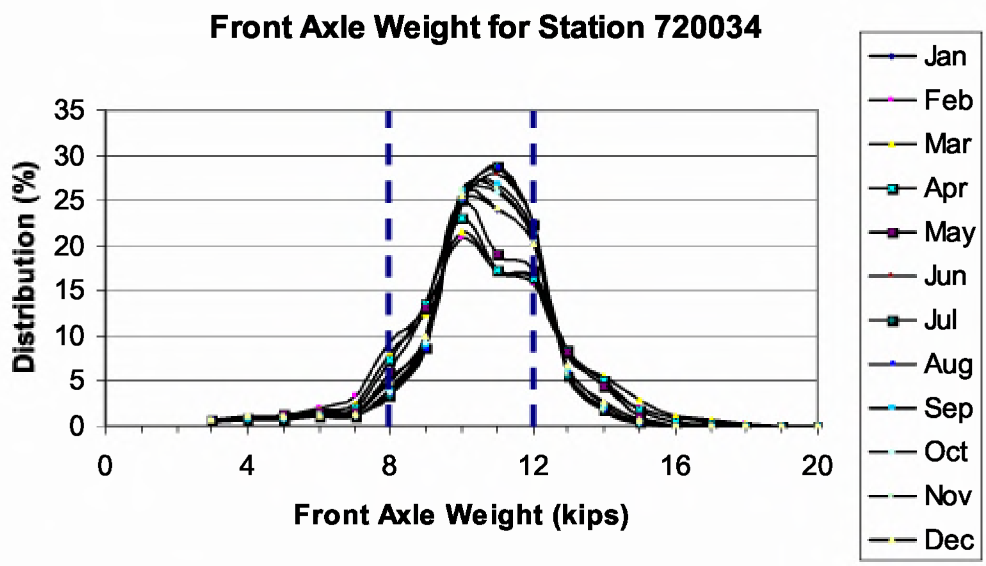

FIGURE C.43. Front Axle Weight Distributions for Station 720034

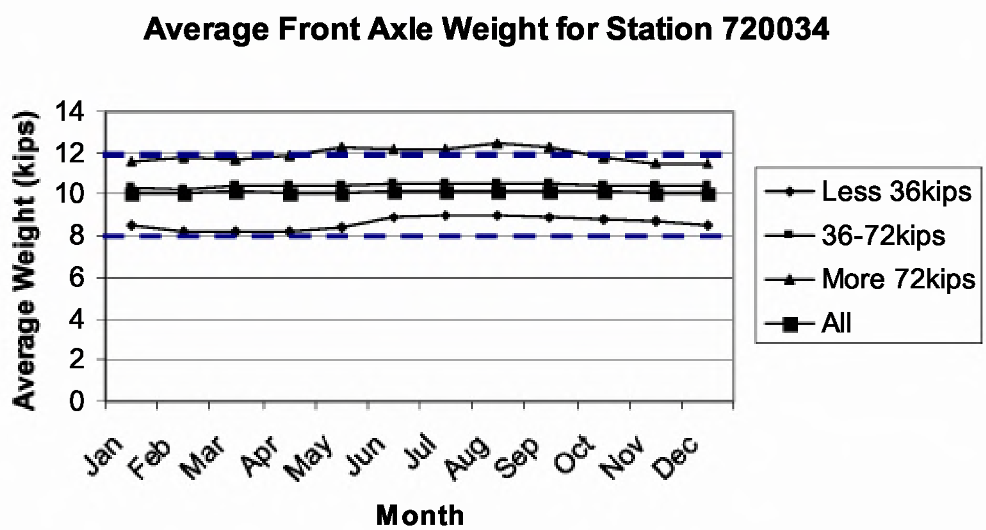

FIGURE C.44. Average Front Axle Weights for Station 720034

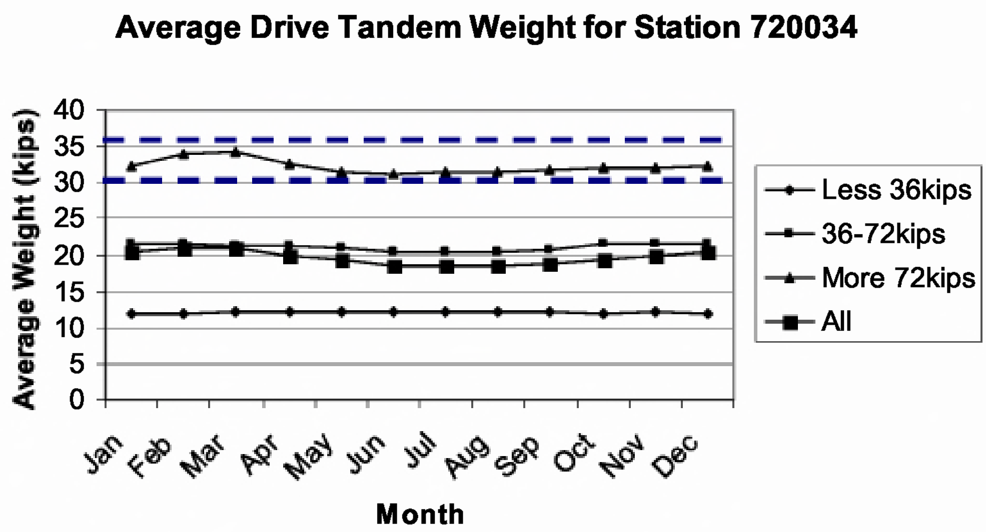

FIGURE C.45. Average Drive Tandem Axle Weights for Station 720034

Figures C.46 through C.49 show the plots of weight data from Station 730068. The distribution curves in Figure C.46 vary over months. The two peaks of the curves are higher during the summer and lower during the winter. During the winter months, the number of vehicles over 100,000 lb. also increases. The problem indicates the scale failure. Figure C.48 show the average front axle weights for the fully loaded vehicles are much higher than the upper limit of 12,000 lb. Figures C.47 and C.49 also show some problem. Thus, the WIM scale at Station 730068 should be recalibrated immediately. The data from this station are not included for further analyses.

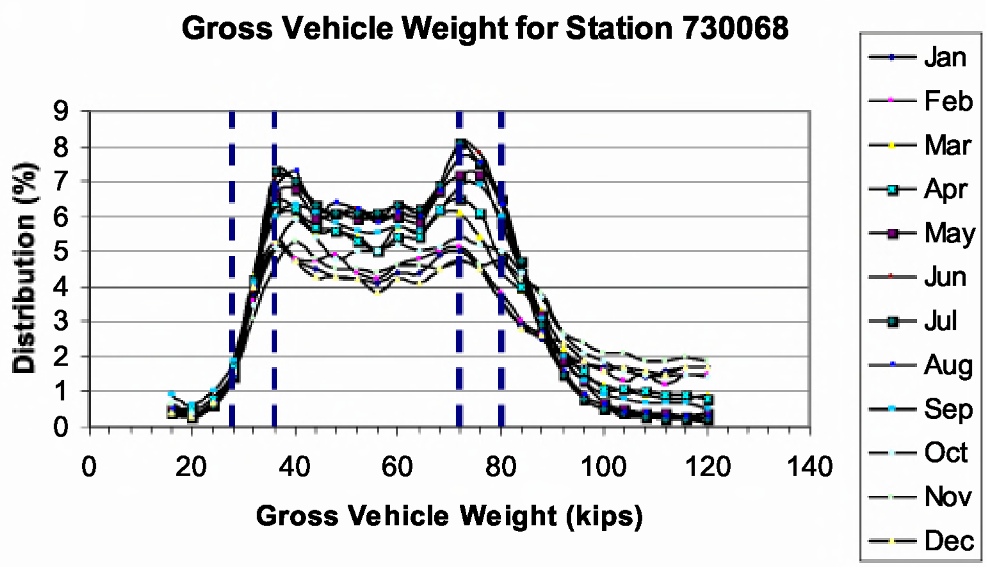

FIGURE C.46. Gross Weight Distributions for Station 730068 (Bald Knob, White)

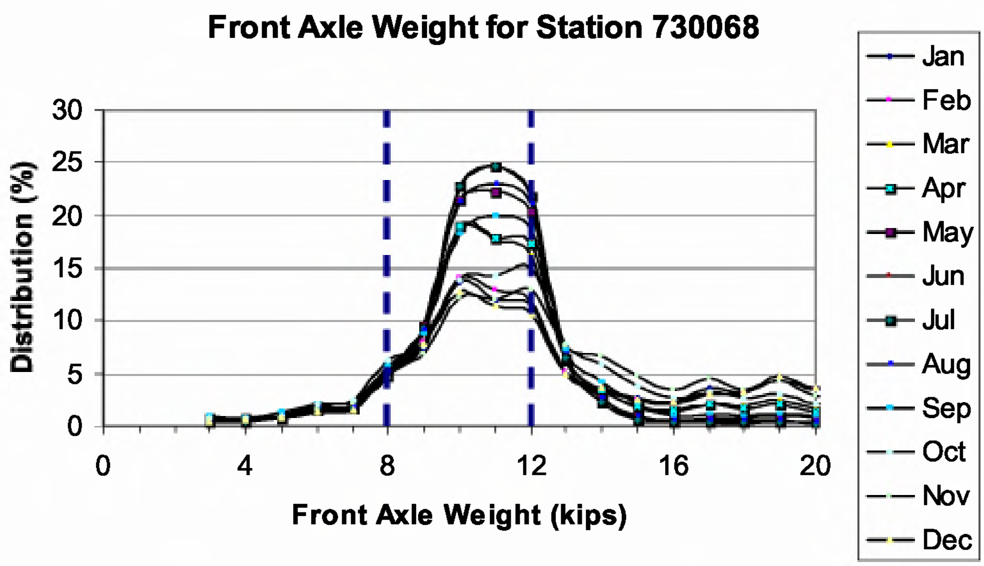

FIGURE C.47. Front Axle Weight Distributions for Station 730068

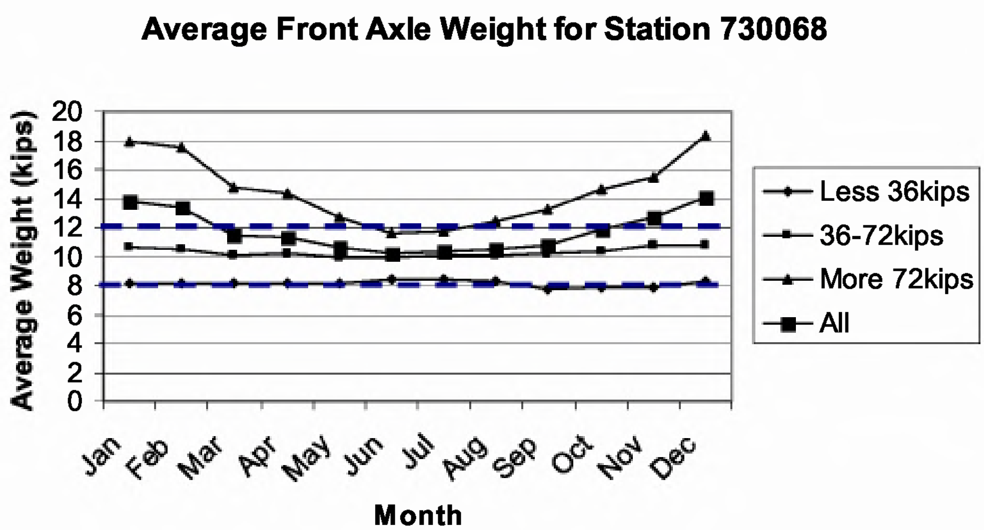

FIGURE C.48. Average Front Axle Weights for Station 730068

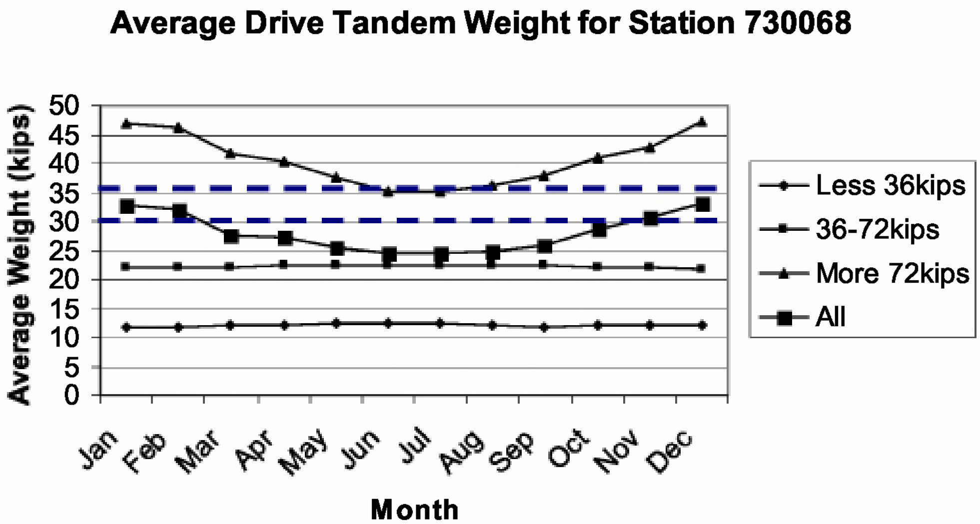

FIGURE C.49. Average Drive Tandem Axle Weights for Station 730068

Figure C.50 through C.53 show the plots of weight data from Station 171651. Figure C.51 indicates that a significant number of front axles is out of the expected range of 10,000±2,000 lb. In Figures C.52, the average front axle curves unloaded and fully loaded trucks are out of the range of 10,000±2,000 lb. Figure C.53 shows the average drive tandem axles for fully loaded trucks are higher than the expected limit of 36,000 lb. The problems shown in the plots indicate the WIM scale is failed. Thus, the data from Station 171651 are not included for further analyses.

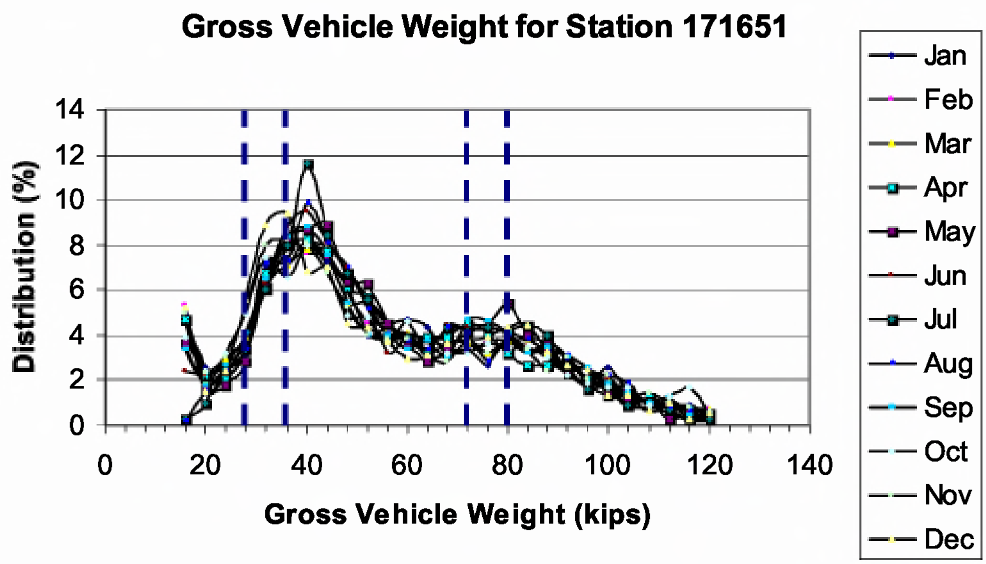

FIGURE C.50. Gross Weight Distributions for Station 171651 (Natural Dam)

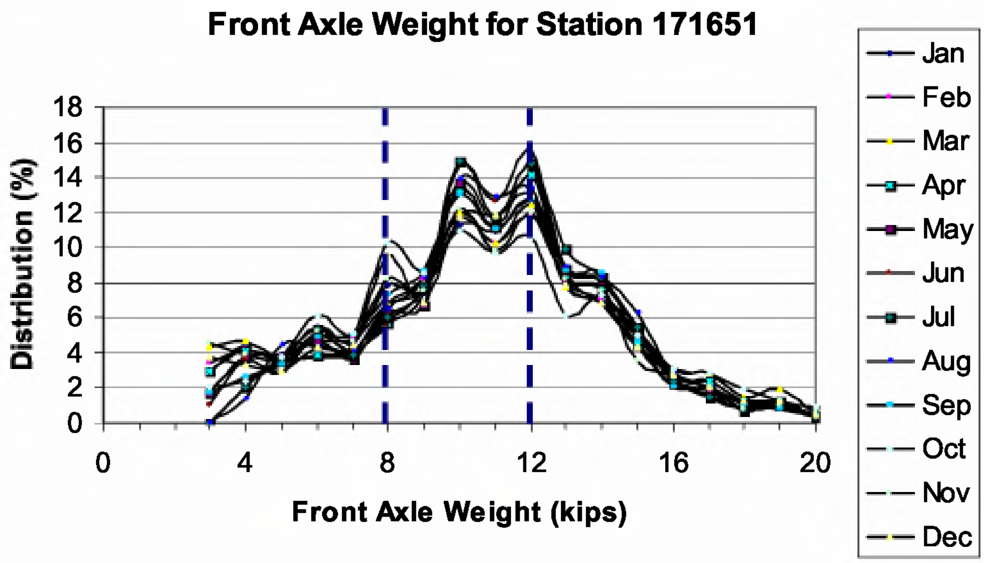

FIGURE C.51. Front Axle Weight Distributions for Station 171651

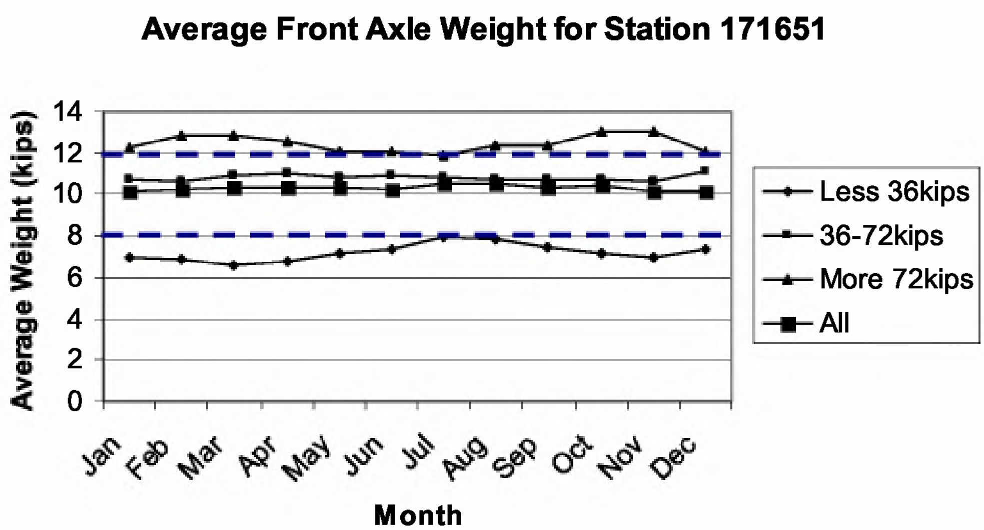

FIGURE C.52. Average Front Axle Weights for Station 171651

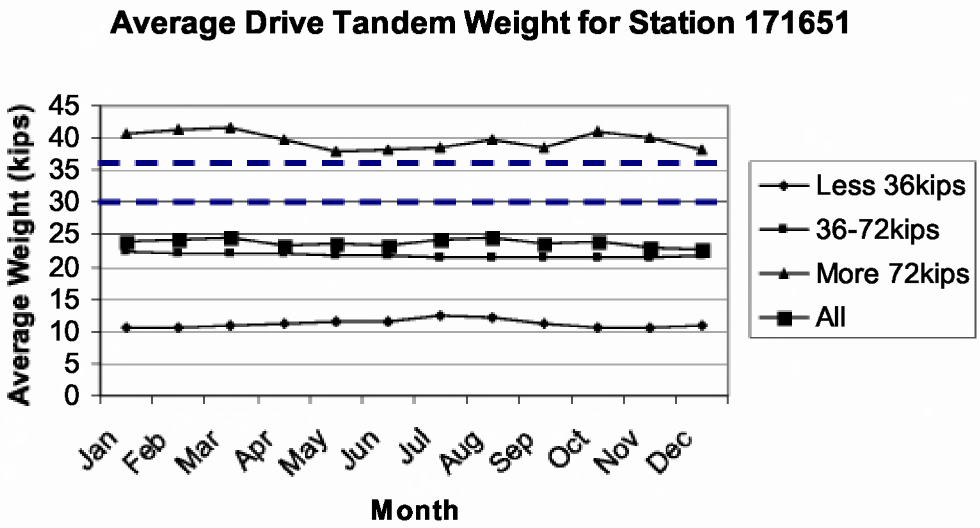

FIGURE C.53. Average Drive Tandem Axle Weights for Station 171651

Figures C.54 through C.57 show the plots of weight data from Station 290002. The peaks of unloaded and loaded trucks shown in Figure C.54 are slightly shifted to the right. The scale may be over-calibrated. The scale seems to weigh the front axles correctly because Figures C.55 and C.56 do not show any serious problems. However, the scale seems to overweigh the drive tandem axles for fully loaded trucks, as shown in Figure C.57. The curve for the drive tandem axles should be in the range of 33,000±3,000lb. The scale at this station may fail to weigh heavier trucks, and heavier trucks significantly influence the performance of pavements. Thus, the weight data from this station are not included for further analyses.

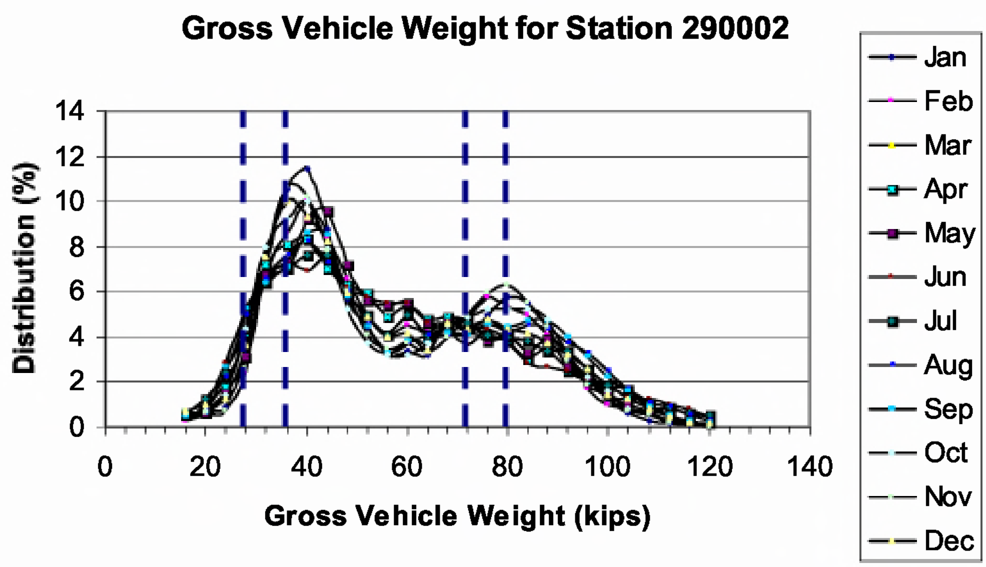

FIGURE C.54. Gross Weight Distributions for Station 290002 (Ozan, Hemstead)

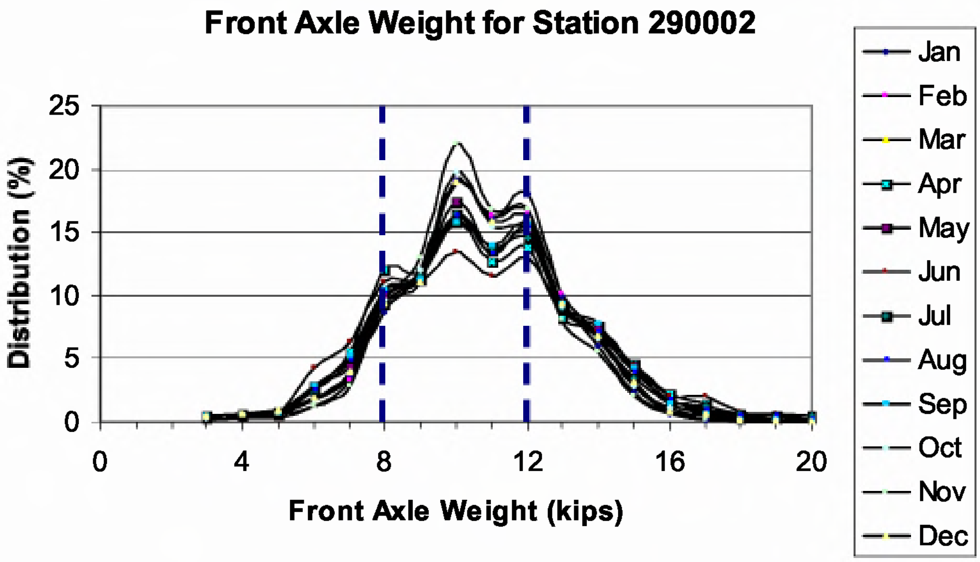

FIGURE C.55. Front Axle Weight Distributions for Station 290002

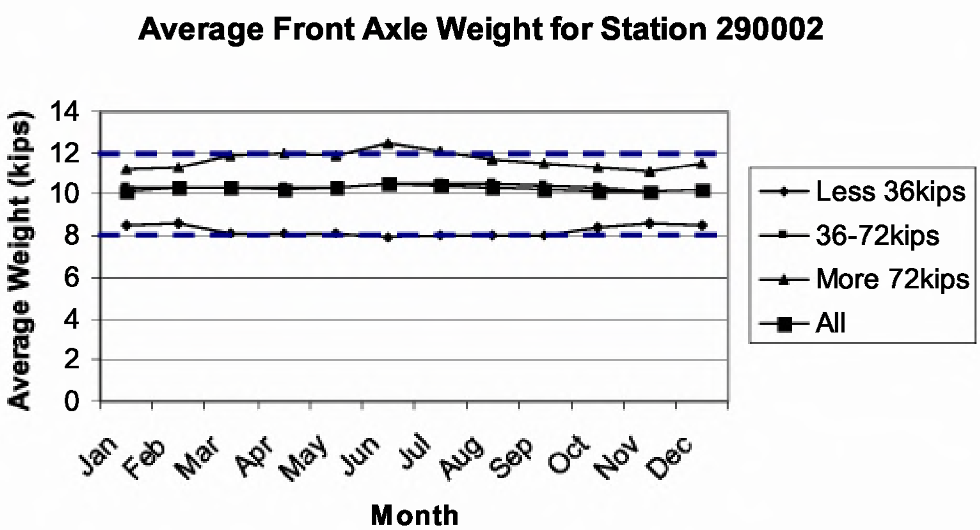

FIGURE C.56. Average Front Axle Weights for Station 290002

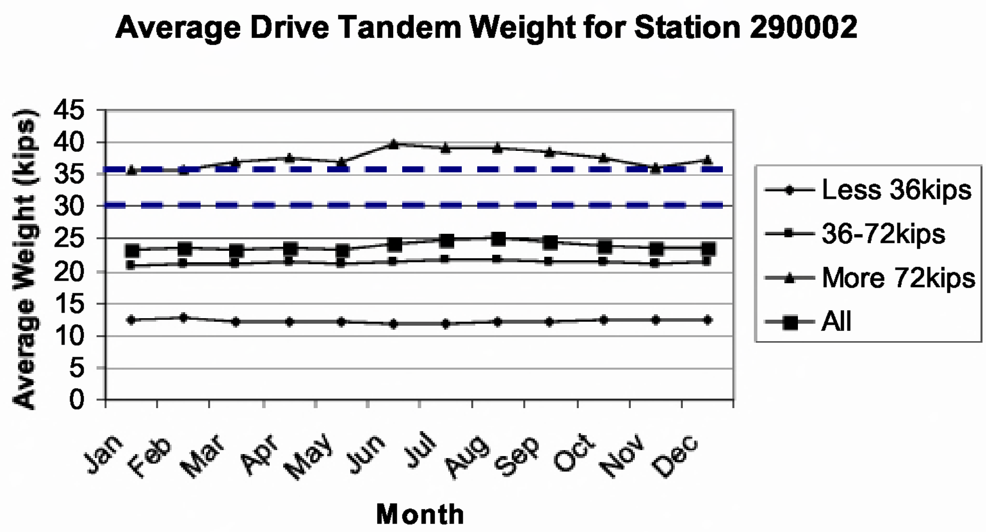

FIGURE C.57. Average Drive Tandem Axle Weights for Station 290002

Figures C.58 through C.61 present the plots of weight data from Station 740035. All of the curves are close to the expected ranges. This is not an ideal but acceptable case. Thus, the weight data from this station are included for further analyses.

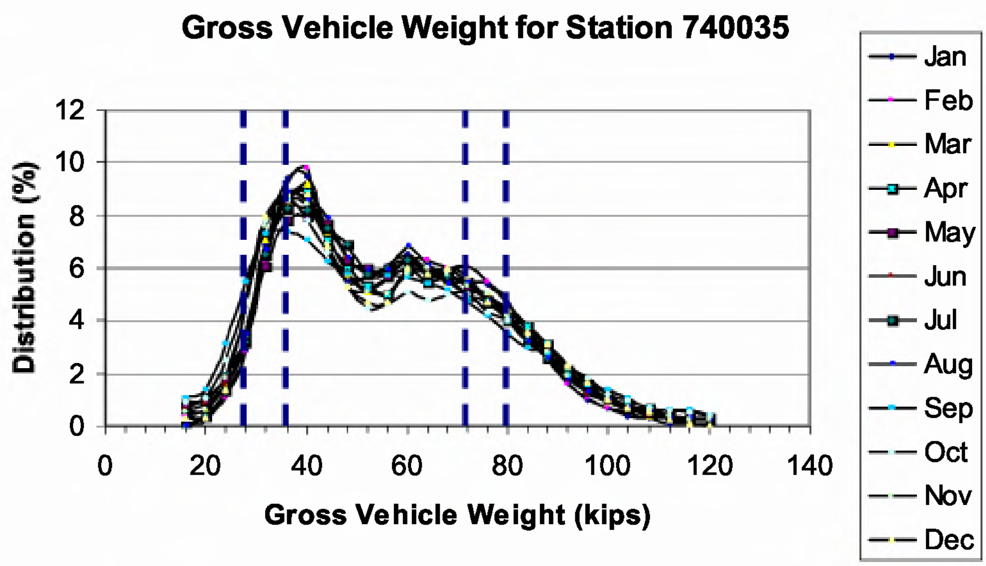

FIGURE C.58. Gross Weight Distributions for Station 740035 (Patterson, Woodruff)

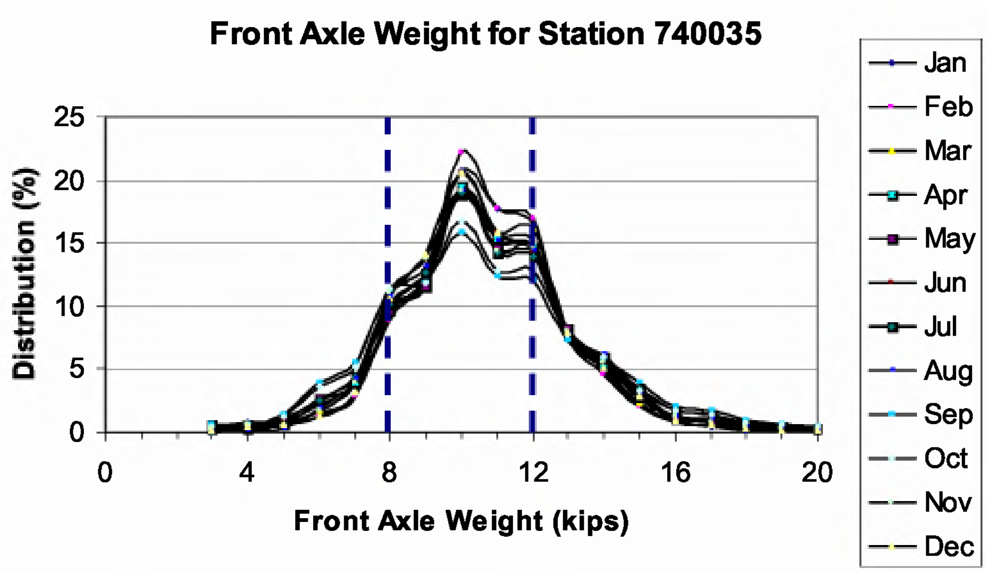

FIGURE C.59. Front Axle Weight Distributions for Station 740035

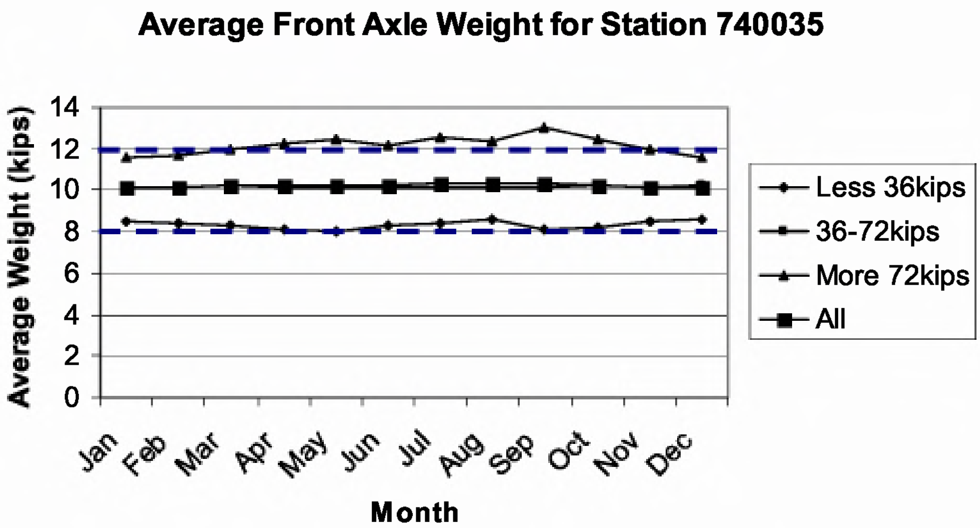

FIGURE C.60. Average Front Axle Weights for Station 740035

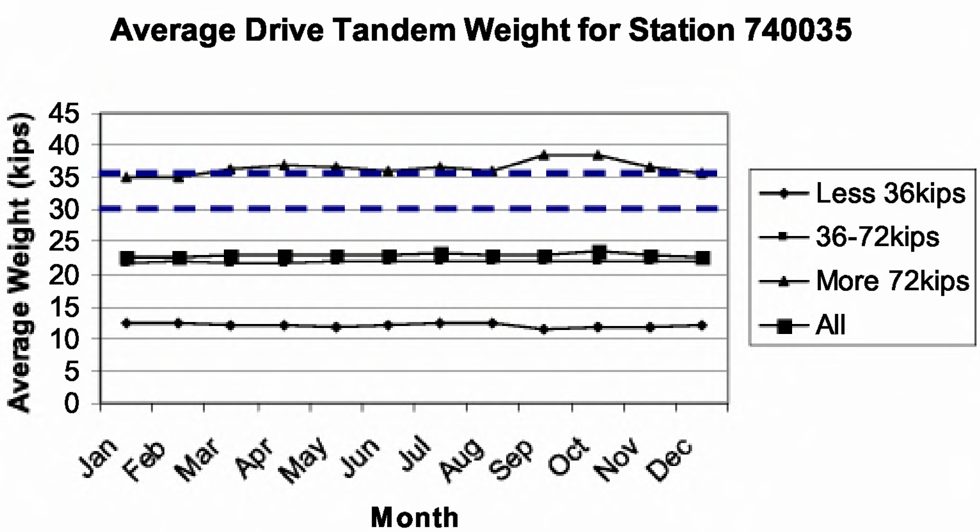

FIGURE C.61. Average Drive Tandem Axle Weights for Station 740035

Figures C.62 through C.65 show the plots of weight data from Station 750010. The peaks for unloaded and fully loaded trucks shown in Figure C.62 are shifted to the right. The plots for this station are similar to those for Station 290002. Thus, the weight data from this station are not included for further analyses, and the calibration of this station should be checked.

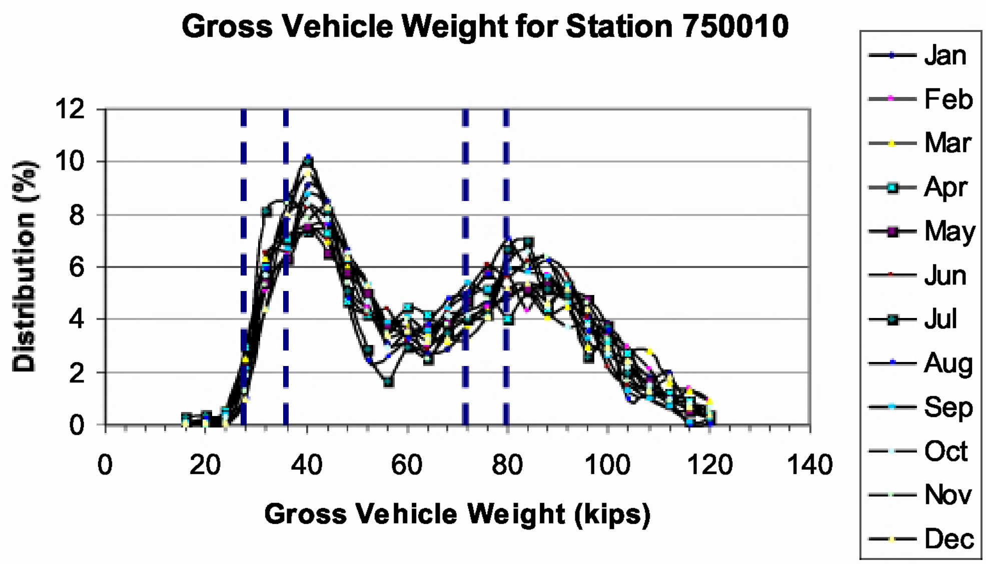

FIGURE C.62. Gross Weight Distributions for Station 750010 (Havana, Yell)

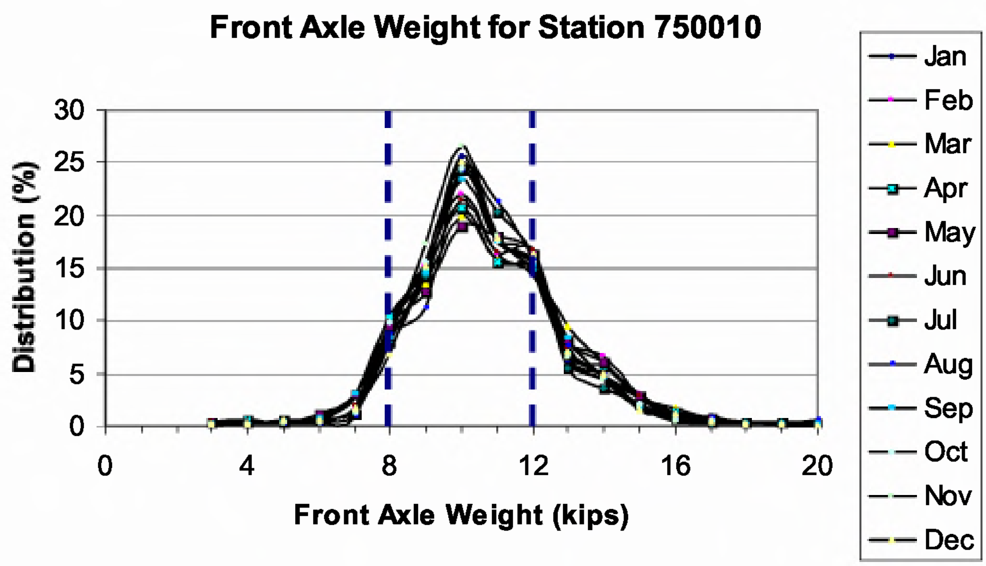

FIGURE C.63. Front Axle Weight Distributions for Station 750010

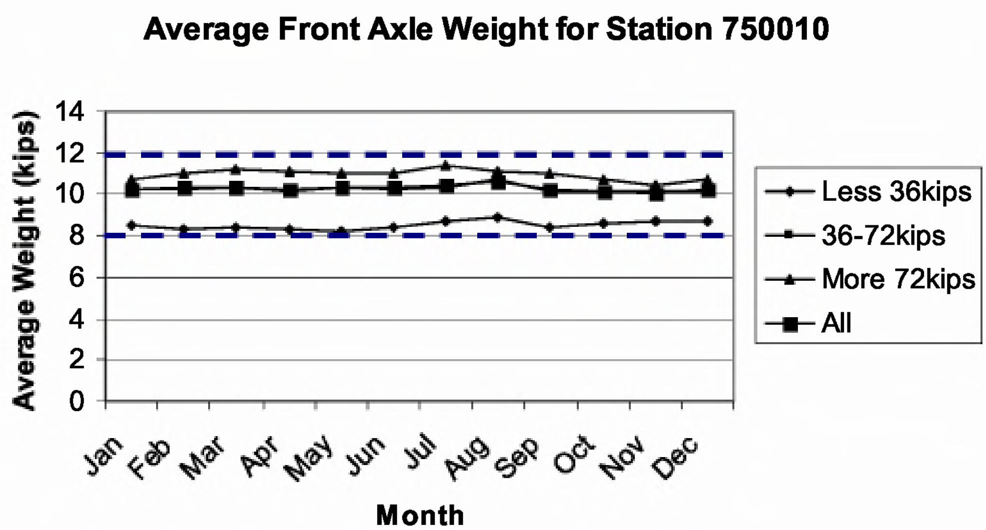

FIGURE C.64. Average Front Axle Weights for Station 750010

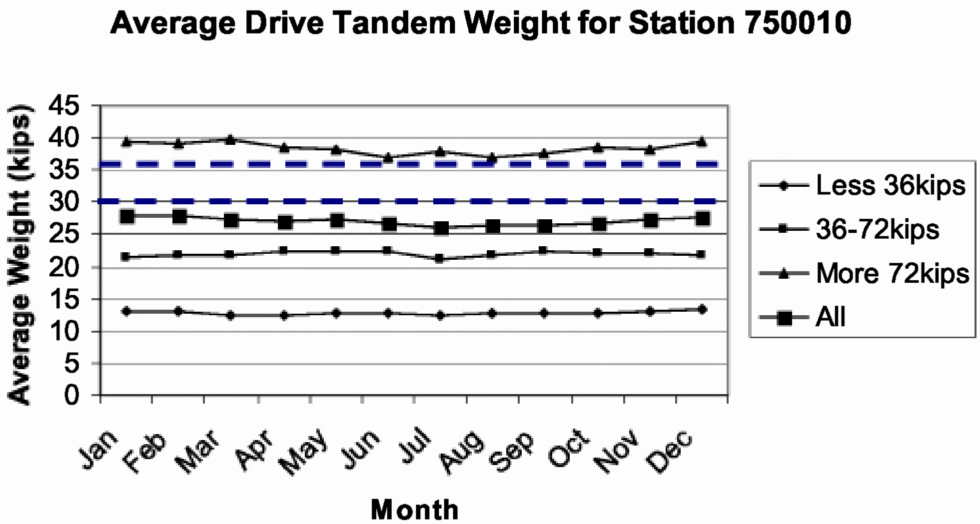

FIGURE C.65. Average Drive Tandem Axle Weights for Station 750010

Figures C.62 through C.65 show the plots of weight data from Station 480037. The plots do not show any serious problems. Thus, the weight data from this station are included for further analyses.

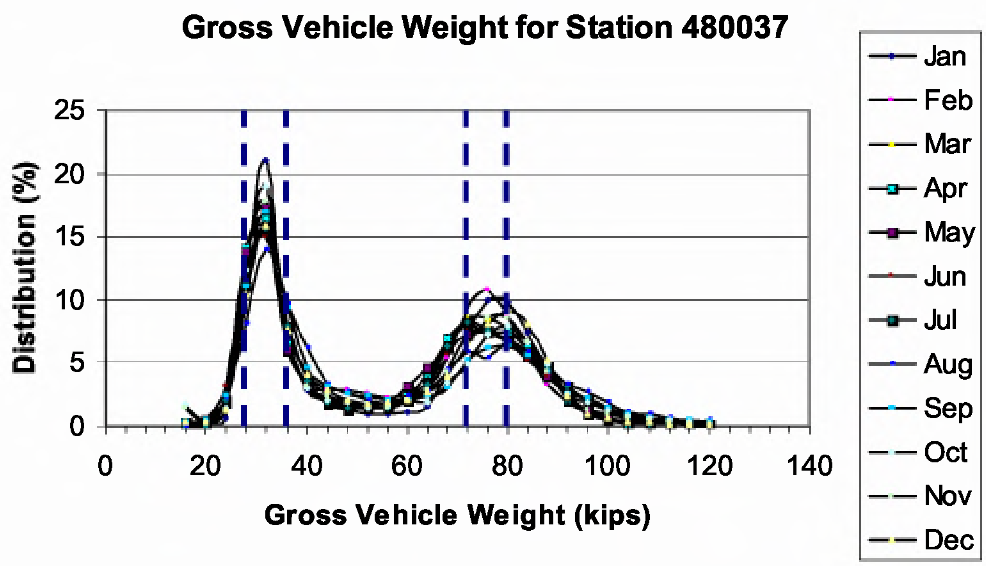

FIGURE C.66. Gross Weight Distributions for Station 480037 (Brinkley, Monroe)

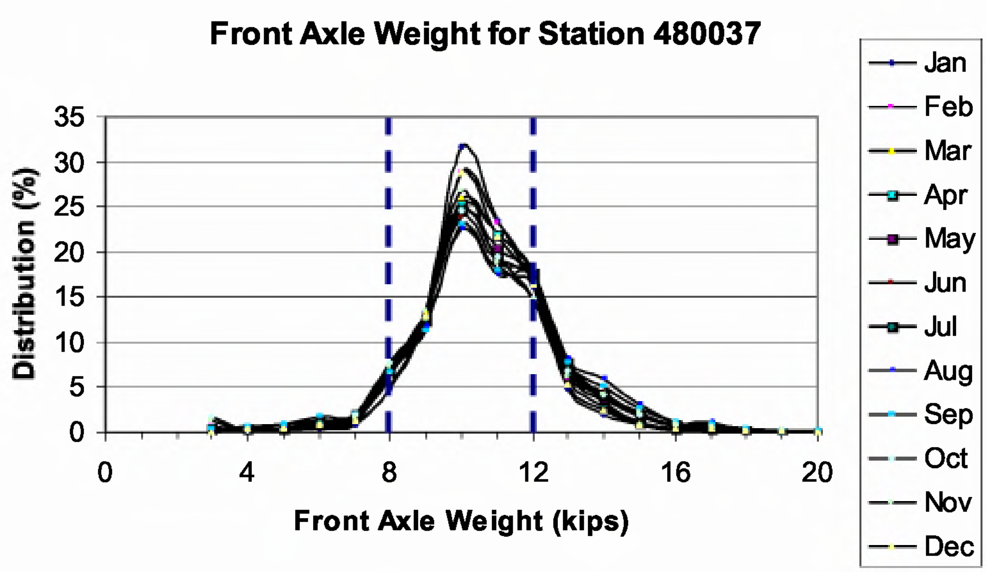

FIGURE C.67. Front Axle Weight Distributions for Station 480037

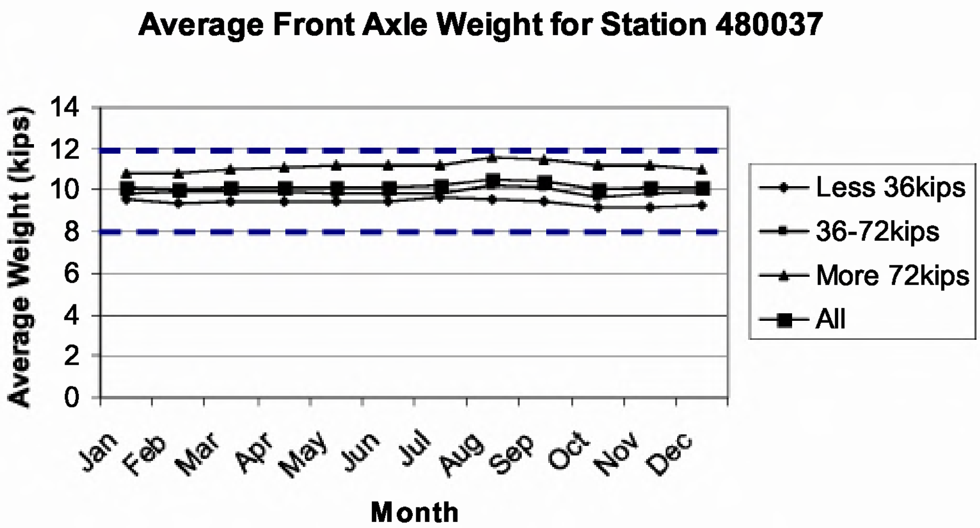

FIGURE C.68. Average Front Axle Weights for Station 470037

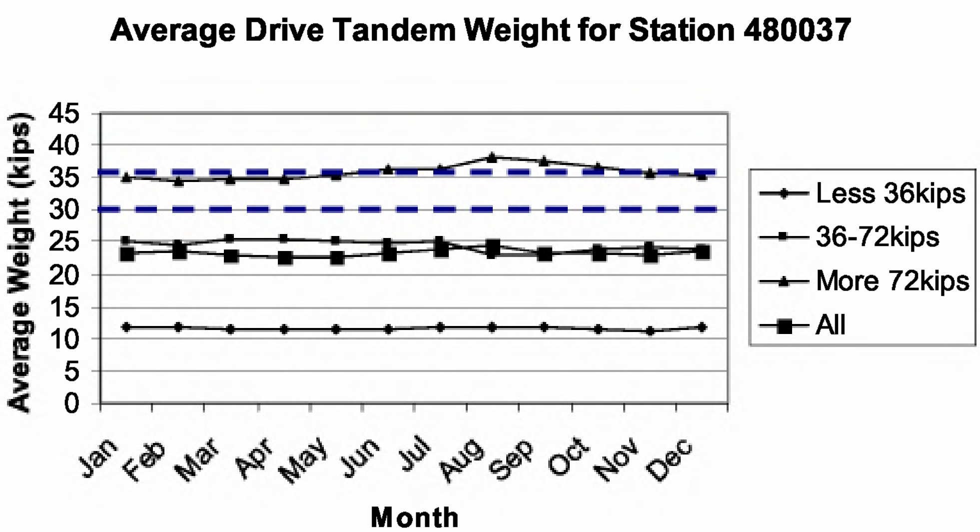

FIGURE C.69. Average Drive Tandem Axle Weights for Station 480037

Figures C.70 through C.73 show the plots of weight data from Station 670027. The weight data are fluctuated. The plots are similar to those for Station 290002. Thus, the weight data from this station are not included for further analyses, and this station should be recalibrated.

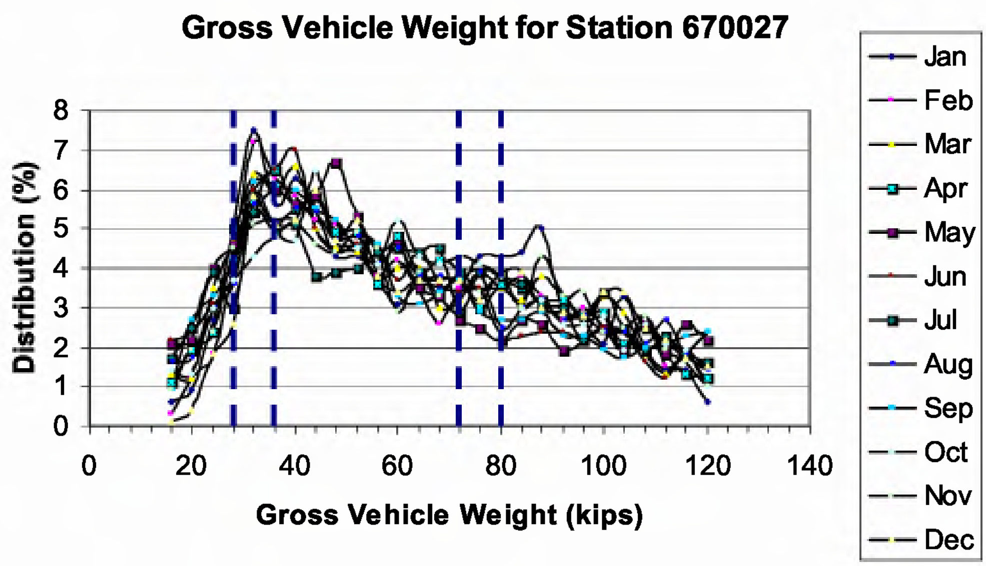

FIGURE C.70. Gross Weight Distributions for Station 670027 (Cave City, Sharp)

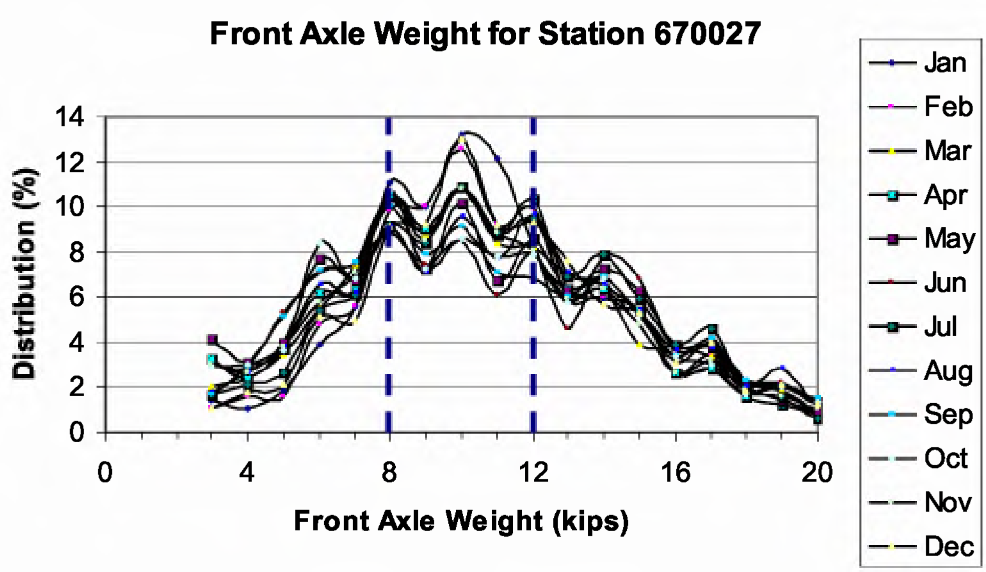

FIGURE C.71. Front Axle Weight Distributions for Station 670027

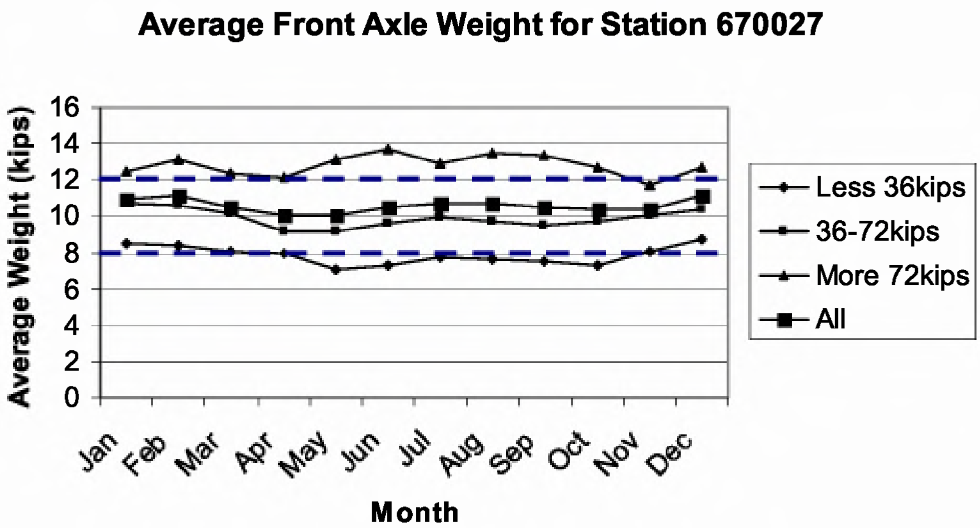

FIGURE C.72. Average Front Axle Weights for Station 670027

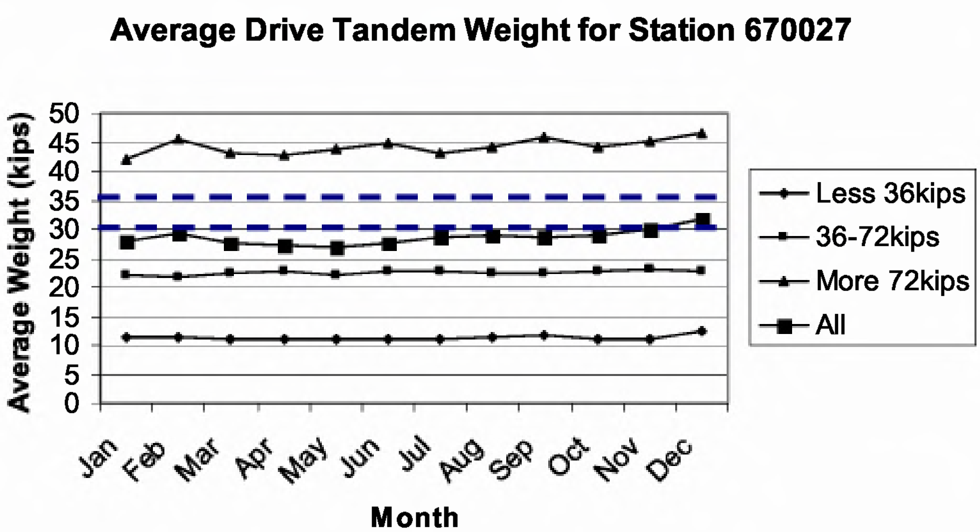

FIGURE C.73. Average Drive Tandem Axle Weights for Station 670027

Figures C.74 through C.77 show the plots of weight data from Station 680032. The weight data are too fluctuated. Compared to the plots of "Good" weight datasets, it is obvious that this scale is failed. Thus, the weight data from this station are not included for further analyses.

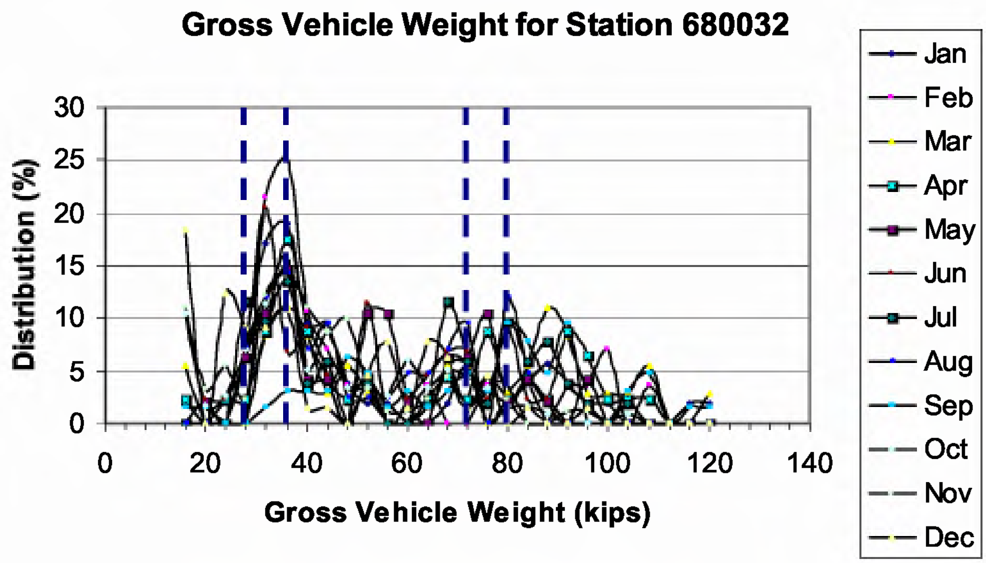

FIGURE C.74. Gross Weight Distributions for Station 680032 (Madison, St Francis)

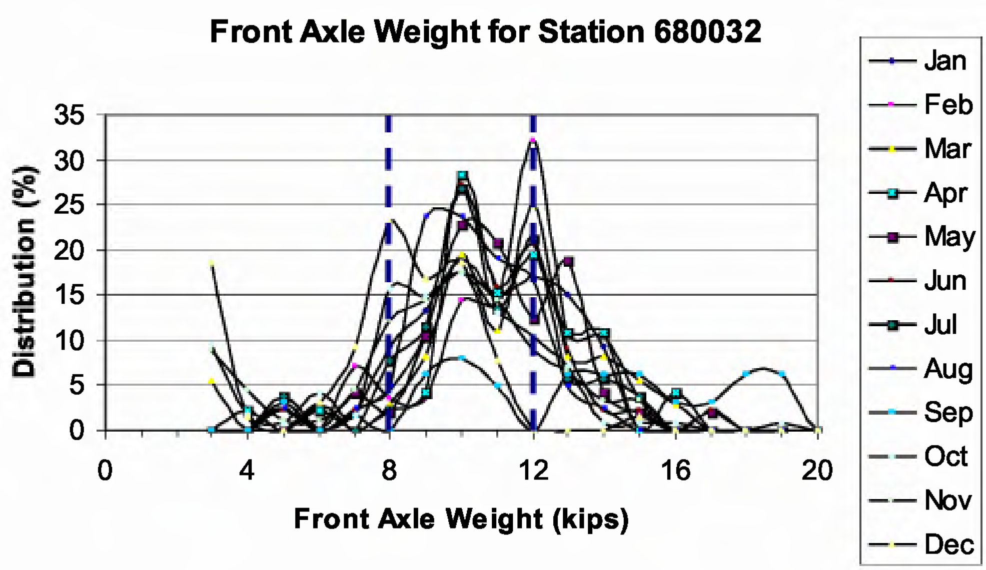

FIGURE C.75. Front Axle Weight Distributions for Station 680032

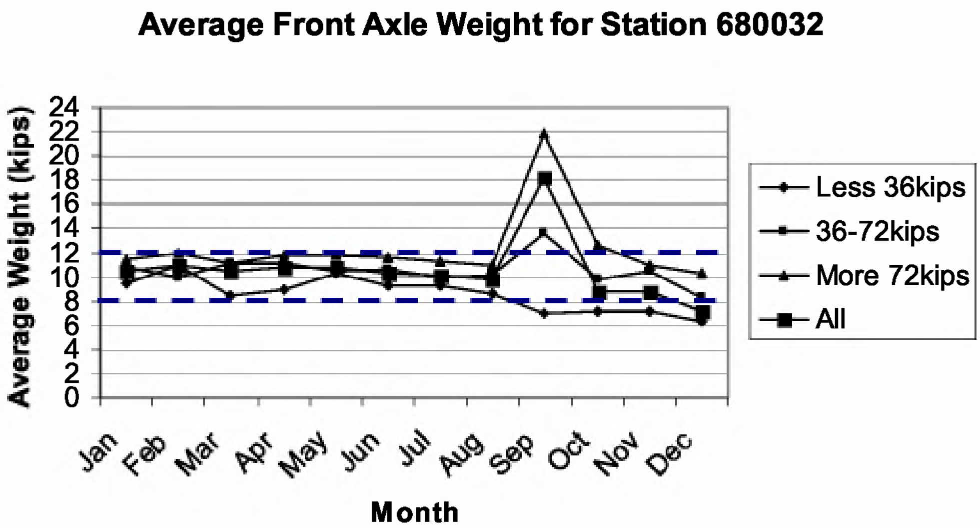

FIGURE C.76. Average Front Axle Weights Based on Gross Vehicle Weights

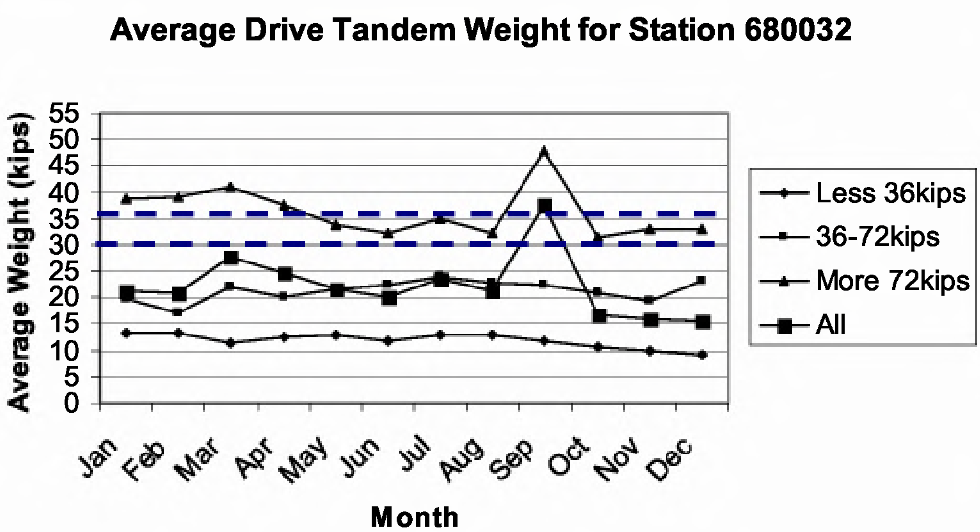

FIGURE C.77. Average Drive Tandem Axle Weights Based on Gross Vehicle Weights

Figures C.78 through C.81 show the plots of weight data from Station 180002. The gross vehicle weights are mostly less than 20,000, as shown in Figure C.78. The other plots show the weight data also have problems. Thus, it is obvious that this scale is failed. The weight data from this station are not included for further analyses.

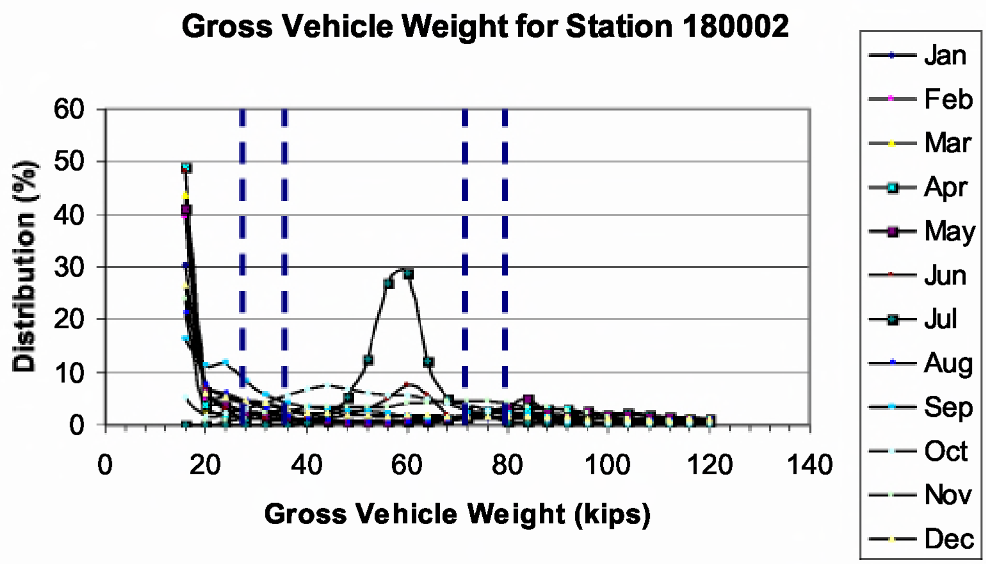

FIGURE C.78. Gross Weight Distributions for Station 180002 (Marion, Crittenden)

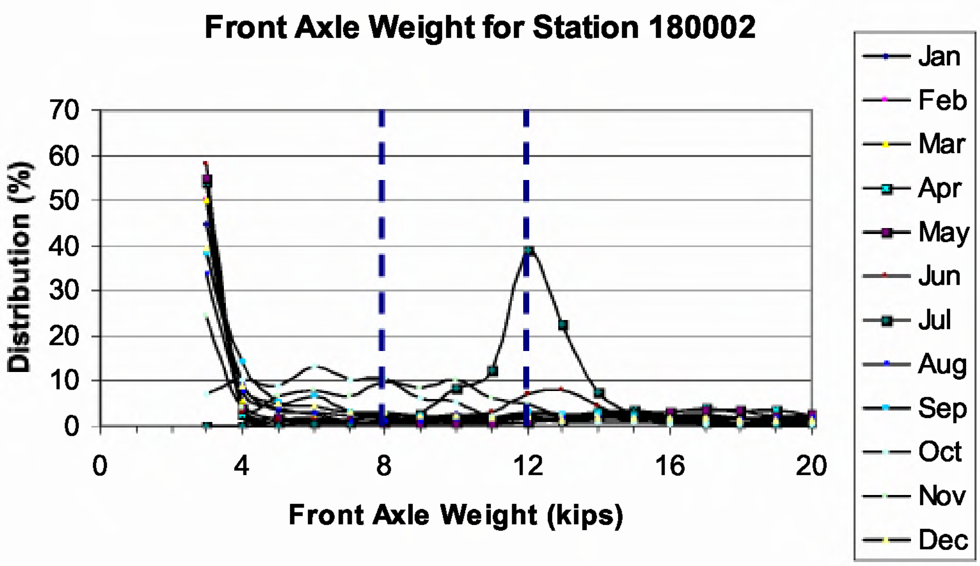

FIGURE C.79. Front Axle Weight Distributions for Station 180002

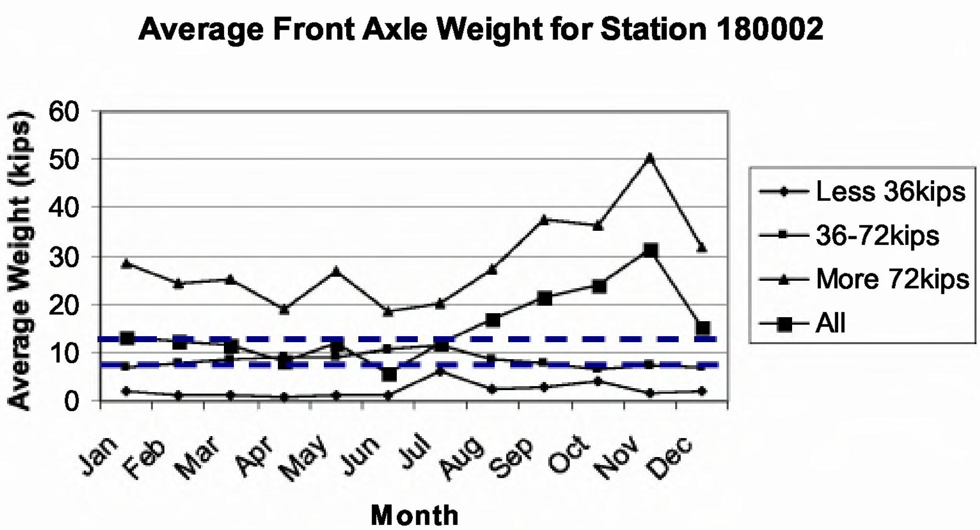

FIGURE C.80. Average Front Axle Weights for Station 180002

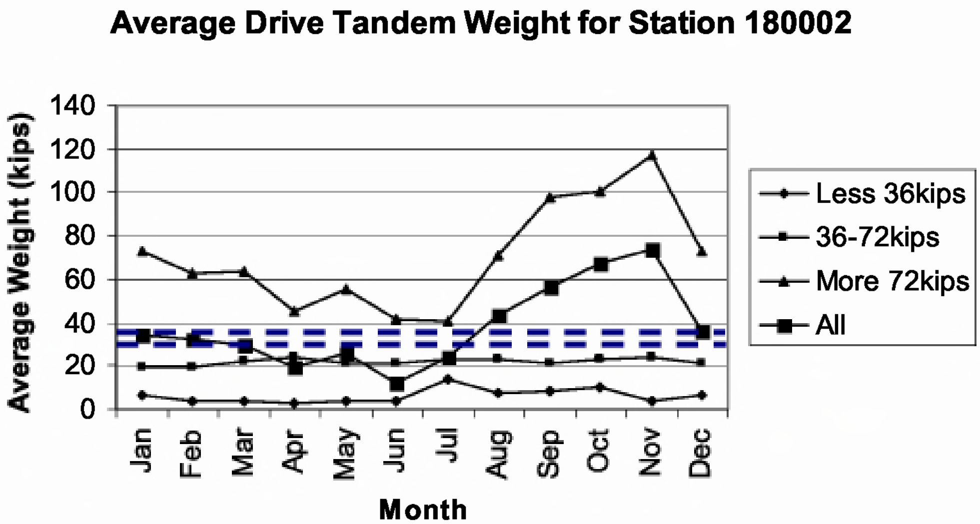

FIGURE C.81. Average Drive Tandem Axle Weights for Station 180002

Figures C.82 through C.85 show the plots of weight data from Station 350314. The location of the peaks for unloaded trucks is shifted to the right, and the locations for the peaks of loaded trucks are fluctuated outside the expected range, as shown in Figure C.82. The curve representing the average front axle weights for unloaded trucks is below the 8,000 lb. limit in Figure C.84. The curve represents the average drive tandem axle weights, shown in Figure C.82, is fluctuated in and out of the expected range. The problems show the WIM scale is not stable. Thus, the weight data from this station are not included for further analyses.

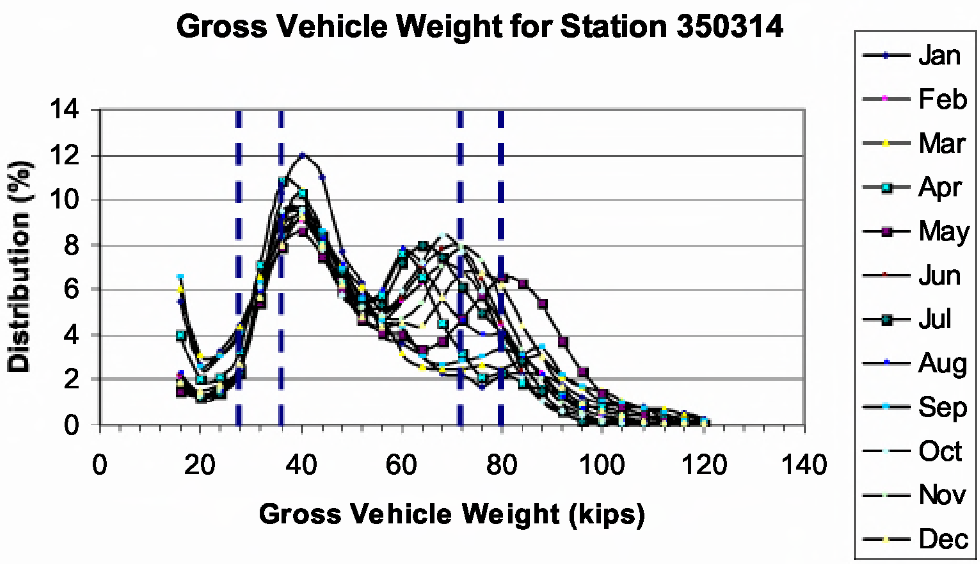

FIGURE C.82. Gross Weight Distributions for Station 350314 (Pine Bluff, Jefferson)

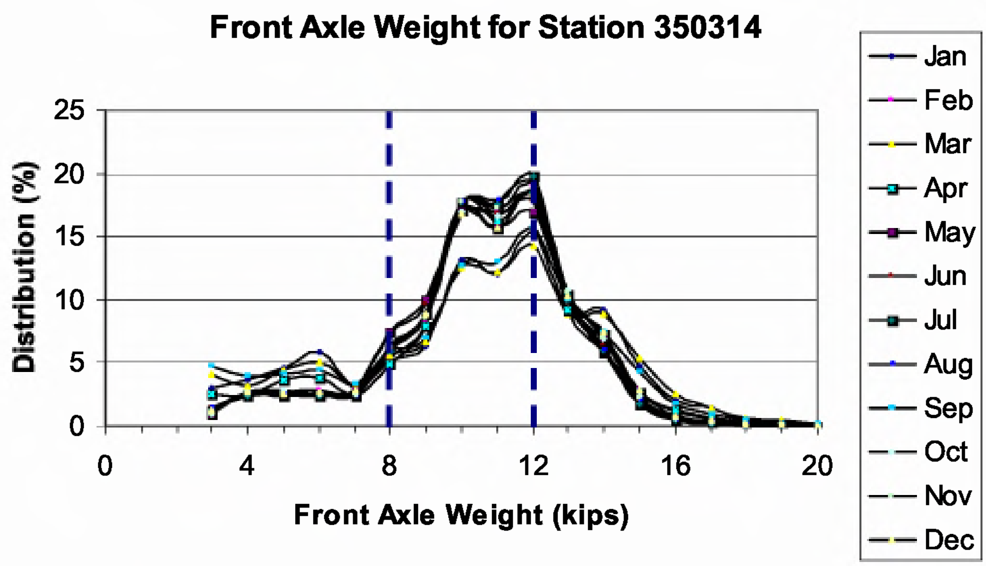

FIGURE C.83. Front Axle Weight Distributions for Station 350314

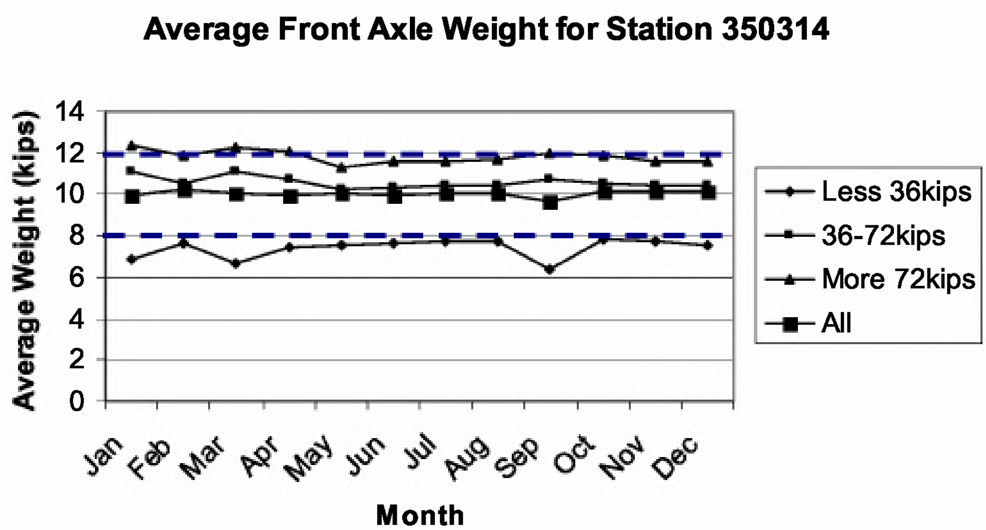

FIGURE C.84. Average Front Axle Weights for Station 350314

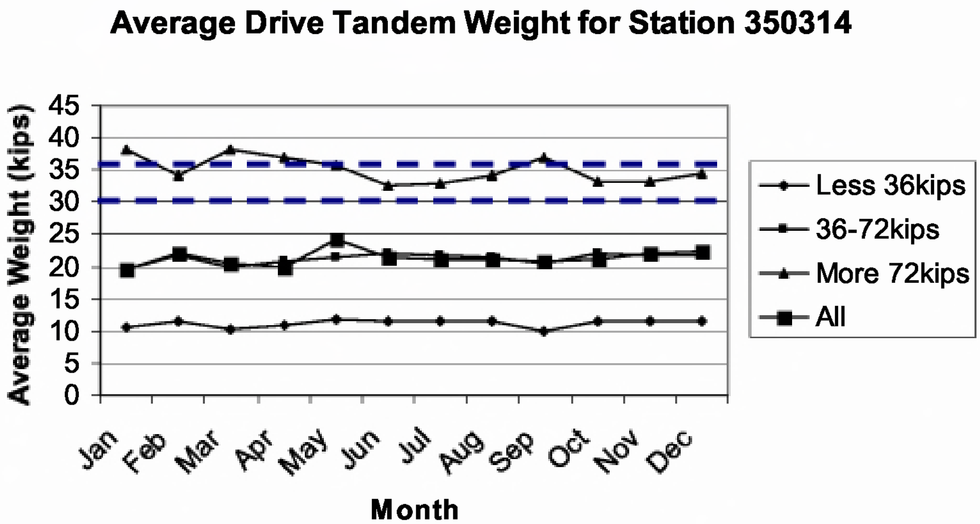

FIGURE C.85. Average Drive Tandem Axle Weights for Station 350314

Figures C.86 through C.89 show the plots of weight data from Station 350215. The location of the peaks for unloaded trucks is within the expected range, but the location of the peaks for loaded trucks is shifted to the right. Figure C.88 shows the lines of average front axle weights for partially and fully loaded trucks are fluctuated and out of the expected range. The curve representing the average drive tandem axle weights, shown in Figure C.89, is also out of the expected range. The problems indicate that the WIM scale of not stable. Thus, the weight data from Station 350215 are not included for further analyses.

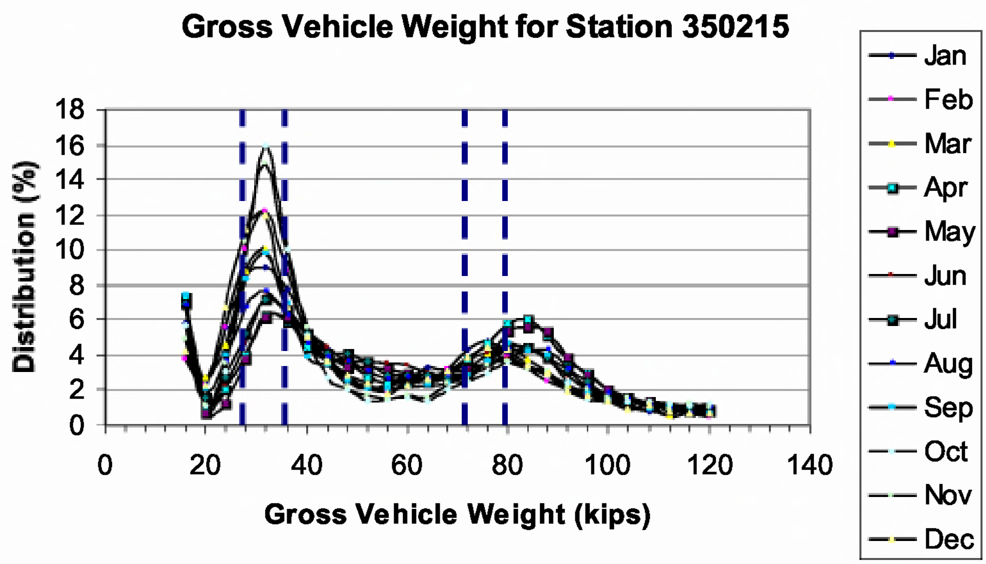

FIGURE C.86. Gross Weight Distributions for Station 350215 (Pine Bluff, Jefferson)

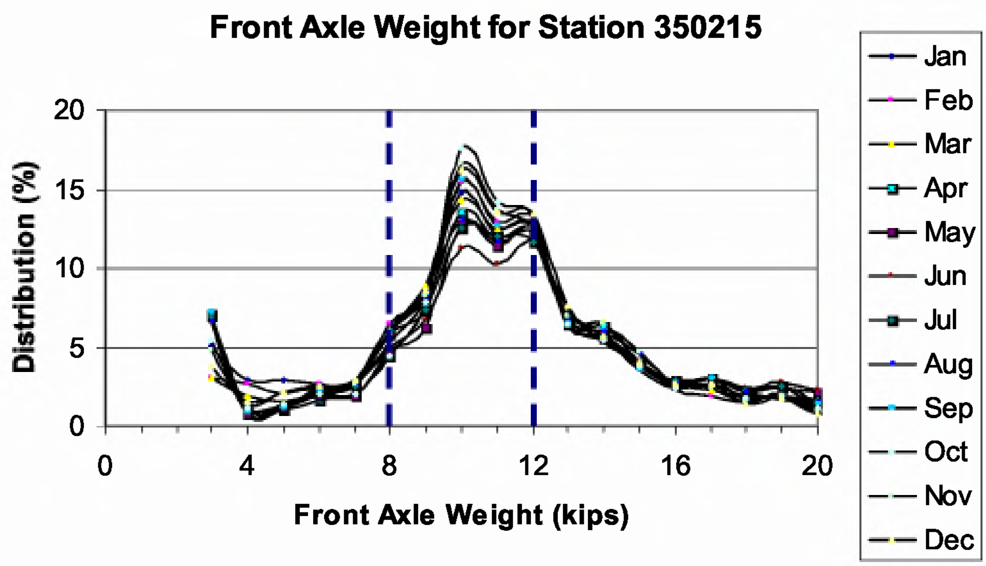

FIGURE C.87. Front Axle Weight Distributions for Station 350215

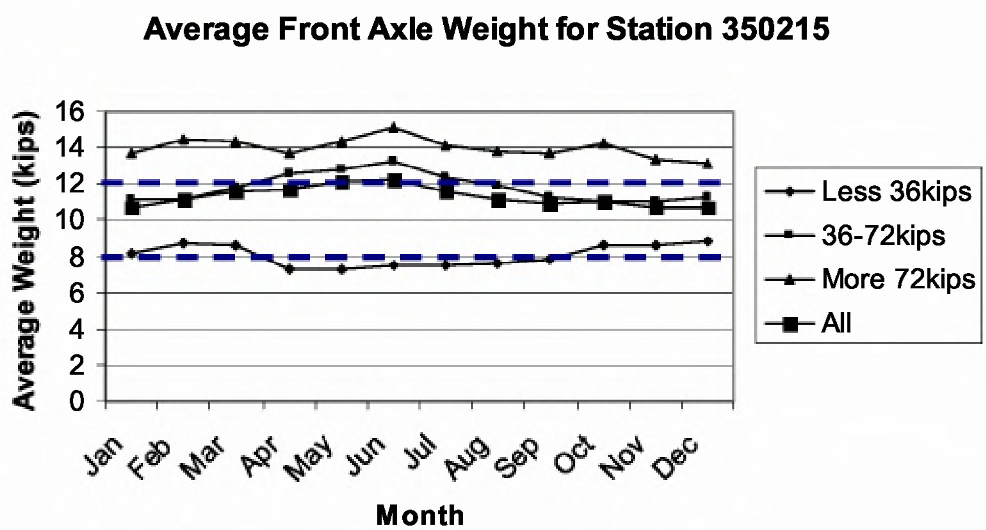

FIGURE C.88. Average Front Axle Weights for Station 350215

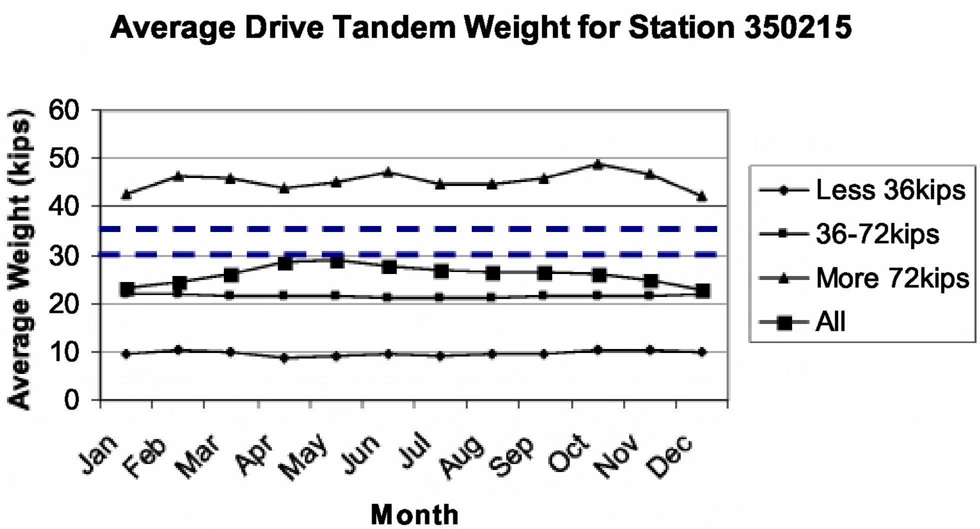

FIGURE C.89. Average Drive Tandem Axle Weights for Station 350215

Figures C.90 through C.93 show the plots of weight data from Station 430038. The plots do not reveal any problems with the weight data. Thus, the data from Station 350215 are included for further analyses.

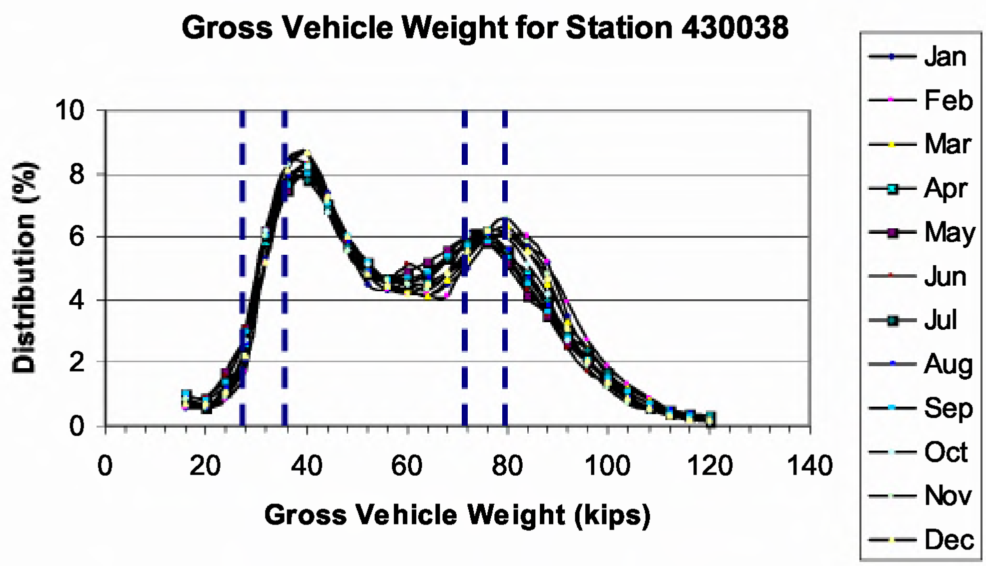

FIGURE C.90. Gross Weight Distributions for Station 430038 (Cabot, Lonoke)

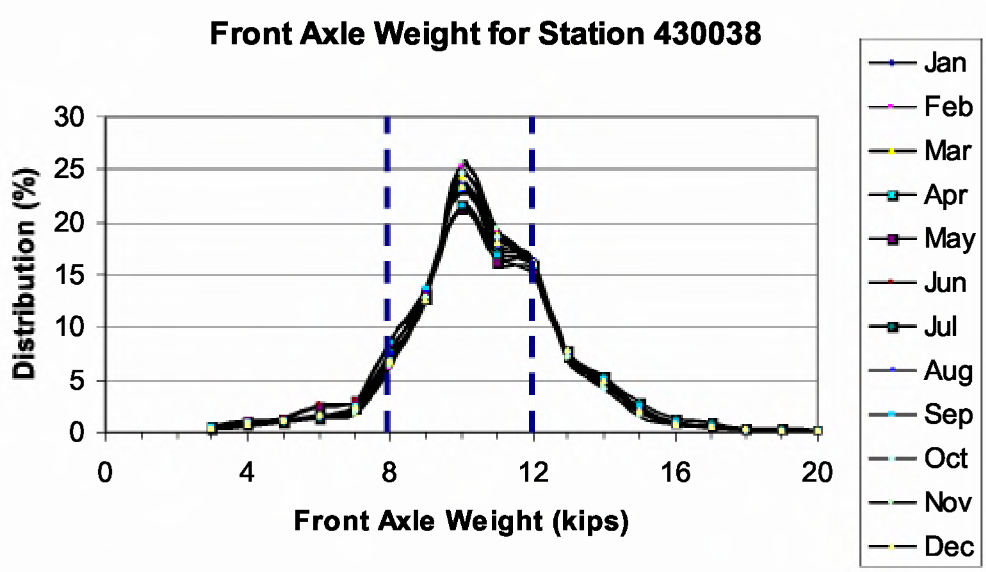

FIGURE C.91. Front Axle Weight Distributions for Station 430038

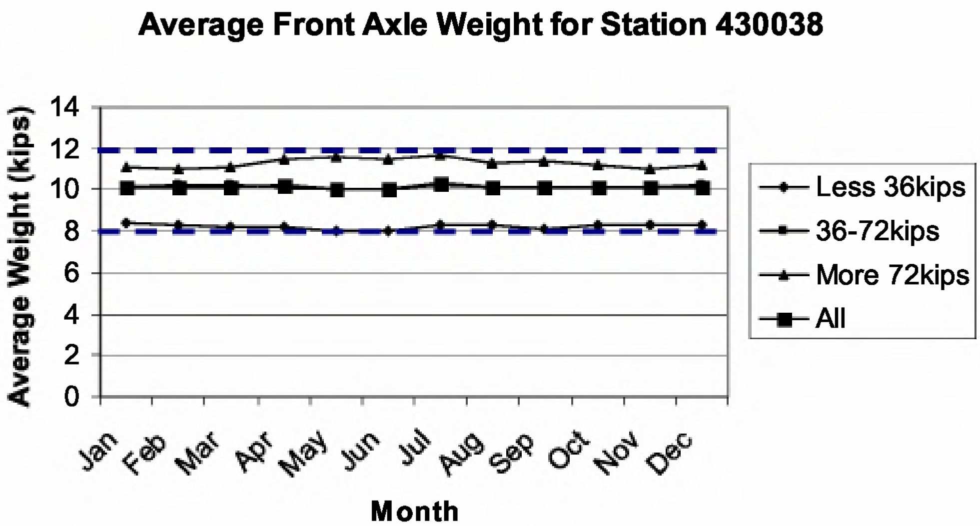

FIGURE C.92. Average Front Axle Weights for Station 430038

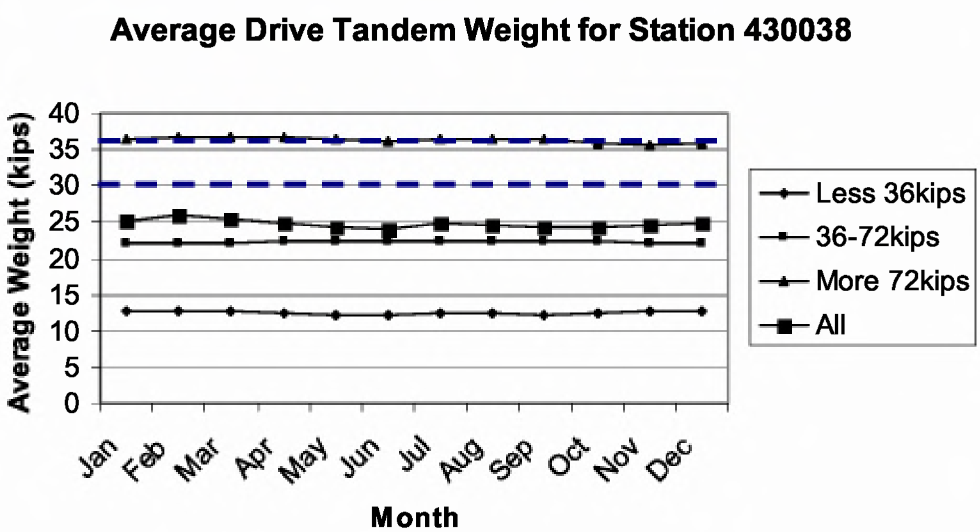

FIGURE C.93. Average Drive Tandem Axle Weights for Station 430038

Figures C.94 through C.97 show the plots of weight data from Station 460286. As shown in Figure C.94, the distribution curves have the two peaks in the expected locations, and then the peaks for loaded trucks start shifting. The curves representing the data for fully loaded trucks, shown in Figures C.96 and C.97, lay outside of the expected ranges from March through September. In addition, the curve for unloaded trucks, shown in Figure C.96 is also out of the expected range during this time frame. The problems show that the scale is not stable. Thus, the weight data from Station 460286 are not included for further analyses.

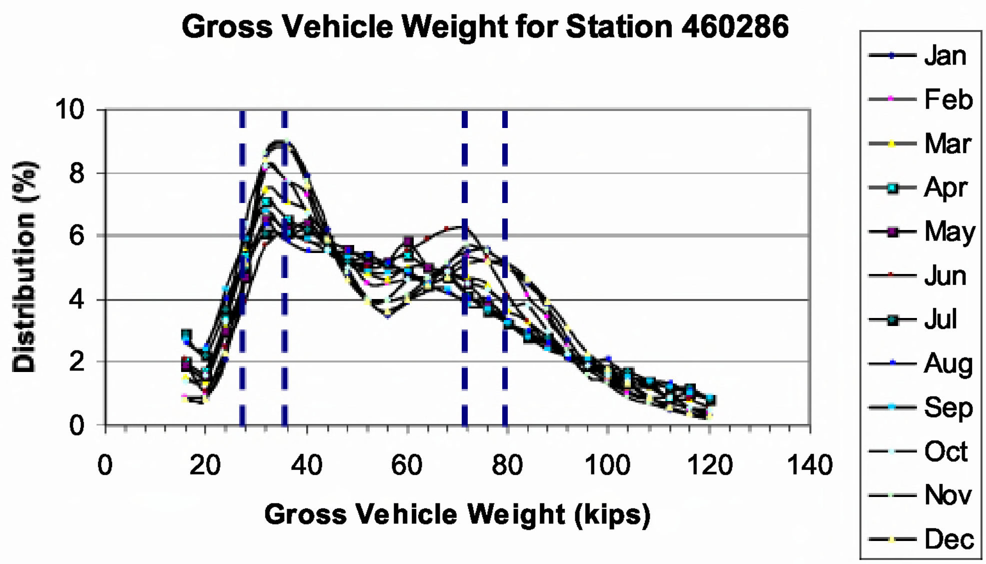

FIGURE C.94. Gross Weight Distributions for Station 460286 (Texarkana, Miller)

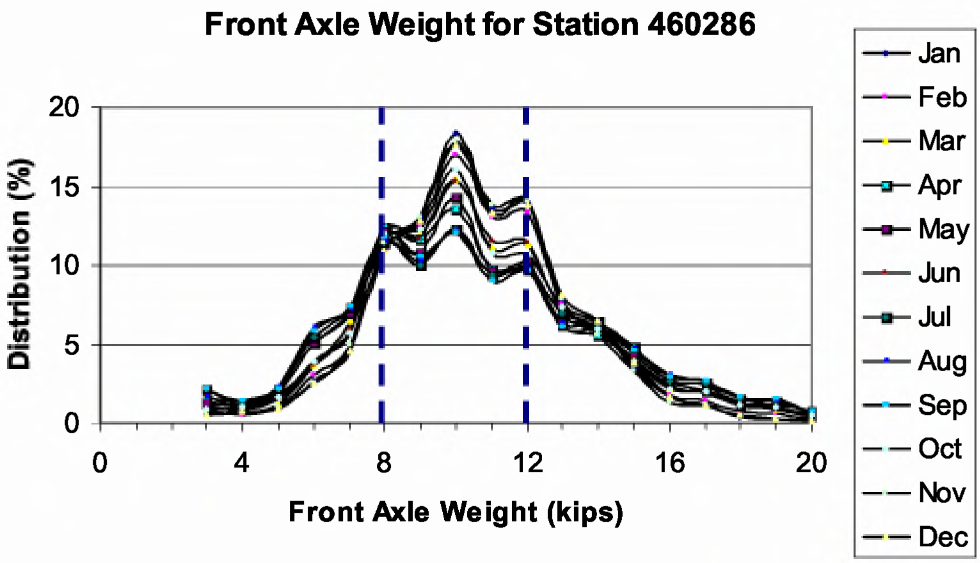

FIGURE C.95. Front Axle Weight Distributions for Station 460286

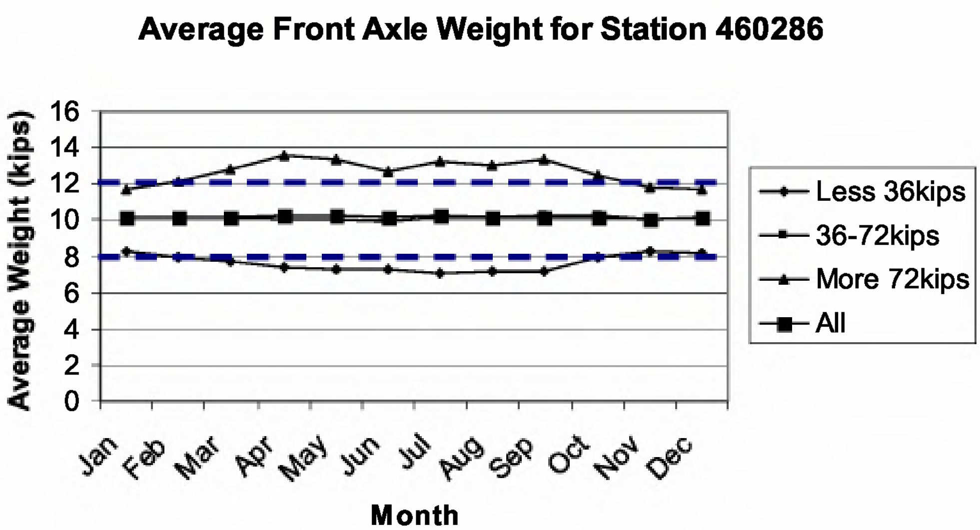

FIGURE C.96. Average Front Axle Weights for Station 460286

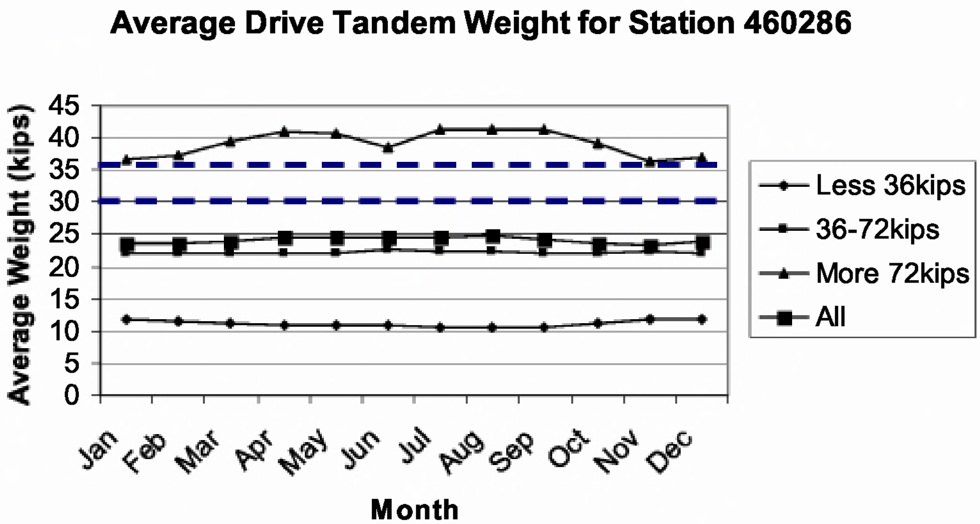

FIGURE C.97. Average Drive Tandem Axle Weights for Station 460286

Figures C.98 through C.101 show the plots of weight data from Station 600870. The peaks for unloaded trucks are close to the expected range, and the peaks for loaded trucks are not clearly defined in Figure C.98. The plots in Figure C.99 do not reveal any problems. The curves shown in Figure C.100 are slightly out of the expected range. The curves representing the average drive tandem axle weights for fully loaded trucks shown in Figure C.101 are over the expected limit, but it may be due to the increase in the number of trucks heavier than the legal load limit of 80,000 lb. This is not an ideal but acceptable situation. Thus, the weight data are included for further analyses.

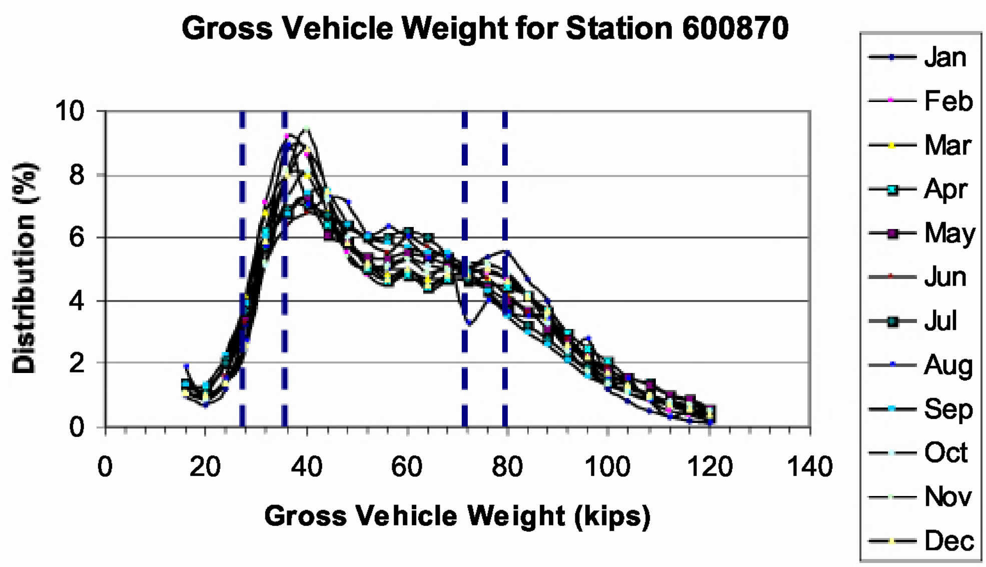

FIGURE C.98. Gross Weight Distributions for Station 600870 (Rixey, Pulaski)

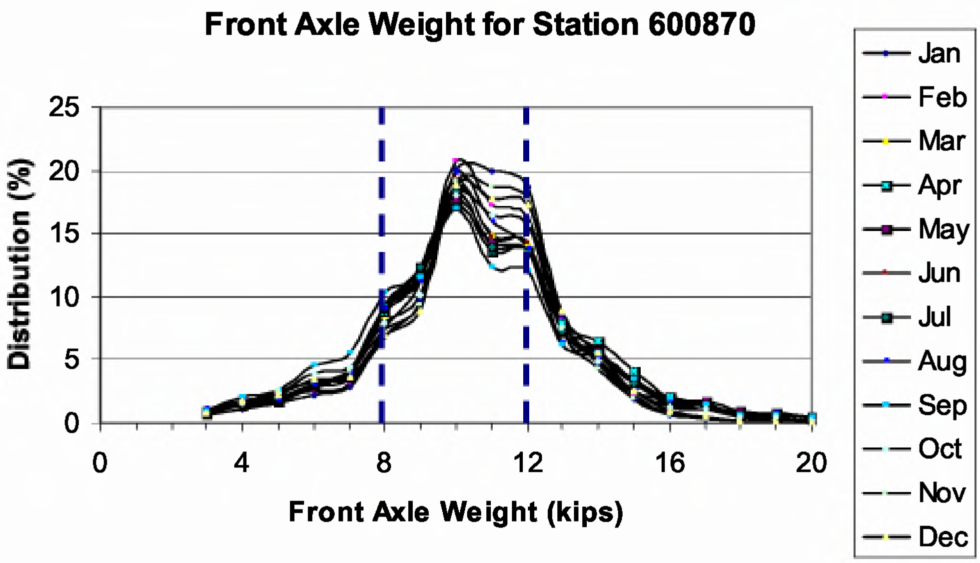

FIGURE C.99. Front Axle Weight Distributions for Station 600870

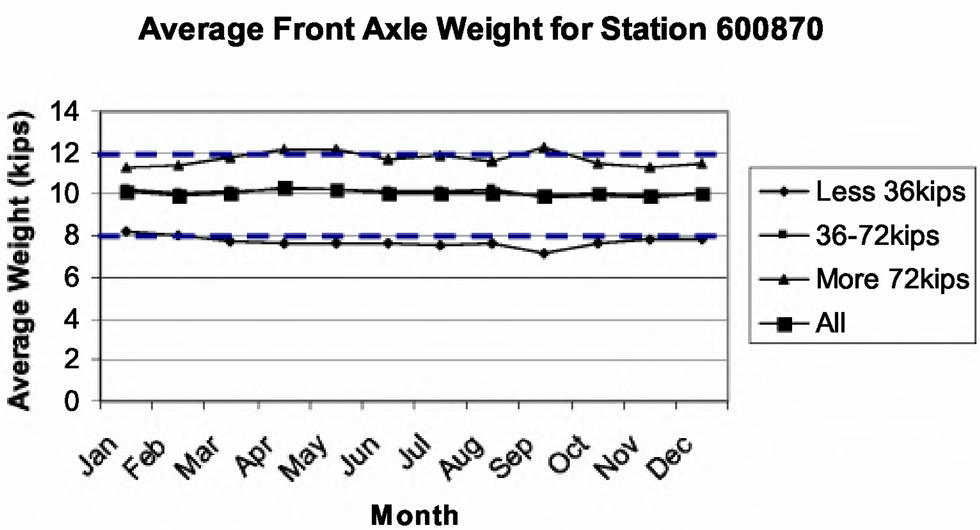

FIGURE C.100. Average Front Axle Weights for Station 600870

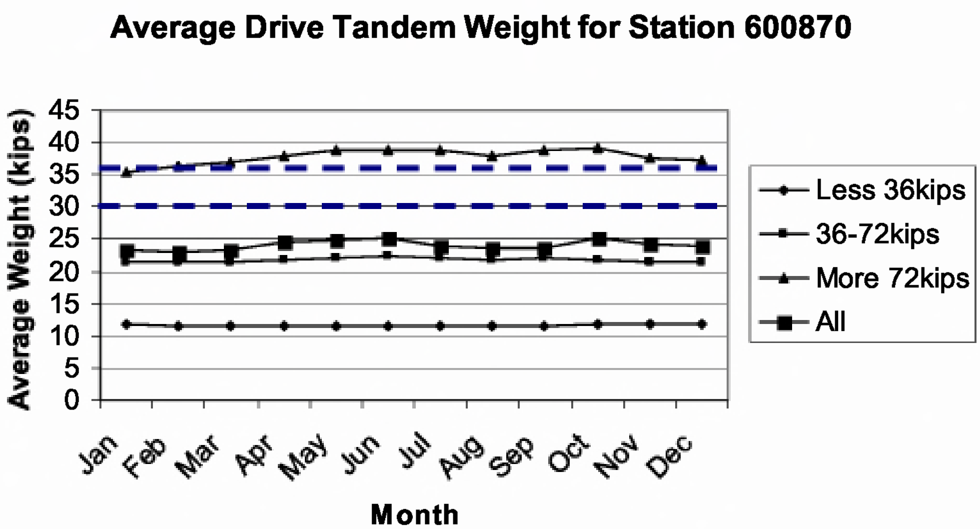

FIGURE C.101. Average Drive Tandem Axle Weights for Station 600870

The weight data from Station 350512 are not evaluated because the number of Class 9 trucks on this road is not significant. Figure C.102 show the weight distribution for data from Station 350512 for one month. The number of Class 9 trucks in each weight bin is very few. Thus, the weight data for this station is not evaluated. Most trucks on this frontage road are Class 5.

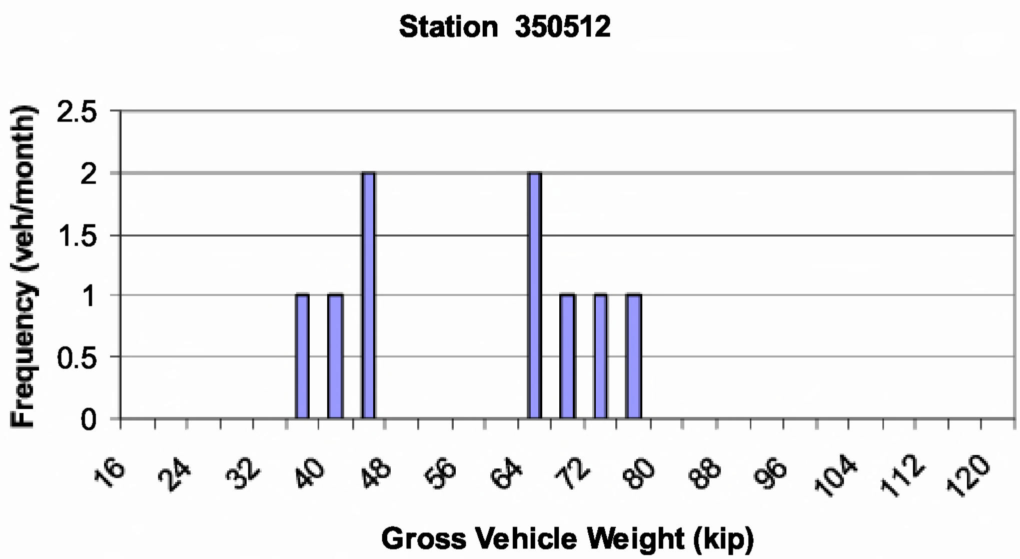

FIGURE C.102. Gross Weight Distributions for Station 350512 (Pine Bluff, Jefferson)