Improved Characterization of Truck Traffic Volumes and Axle Loads for Mechanistic-Empirical Pavement Design

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and the
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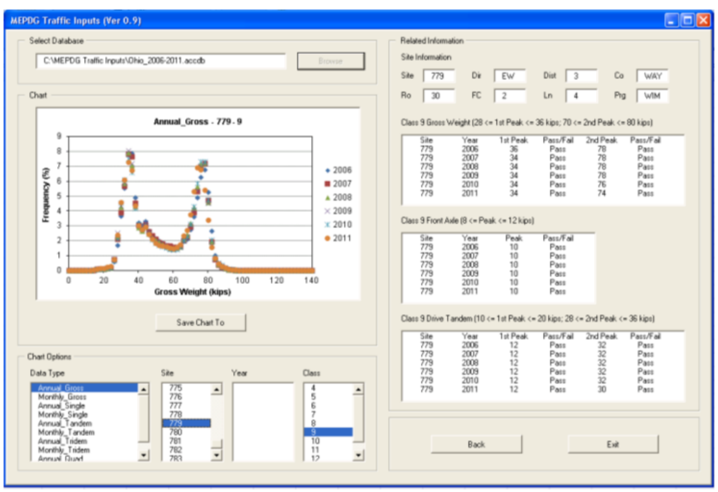

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16. Abstract

The recently developed mechanistic-empirical pavement design guide (MEPDG) requires a multitude of traffic inputs to be defined for the design of pavement structures, including the initial two-way annual average daily truck traffic (AADTT), directional and lane distribution factors, vehicle class distribution, monthly adjustment factors, hourly truck distribution factors, traffic growth rate, axle load spectra by truck class (Class 4 to Class 13) and axle type (single, tandem, tridem, and quad), and number of axles per truck. Since it is not always practical to obtain site-specific traffic data, the MEPDG assimilates a hierarchal level concept that allows pavements to be designed using statewide averages and MEPDG default values without compromising the accuracy of the pavement design. In this study, a Visual Basic for Application (VBA) code was developed to analyze continuous traffic monitoring data and generate site-specific and statewide traffic inputs. The traffic monitoring data was collected by 143 permanent traffic monitoring sites (93 automated vehicle classifier (AVC) and 50 weigh-in-motion (WIM) sites) distributed throughout the State of Ohio from 2006 to 2011. The sensitivity of the MEPDG to the various traffic inputs was evaluated using two baseline pavement designs, one for a new flexible pavement and one for a new rigid pavement. Key performance parameters for the flexible pavement included longitudinal (top-down) fatigue cracking, alligator (bottom-up) fatigue cracking, transverse (low-temperature) cracking, rutting, and smoothness (expressed using IRI), while key performance parameters for the rigid pavement included transverse cracking (% slabs cracked), joint faulting, and smoothness. The sensitivity analysis results revealed that flexible pavements are moderately sensitive to AADTT, growth rate, vehicle class distribution, and axle load spectra; and not sensitive to hourly distribution factors, monthly adjustment factors, and number of axles per truck. Furthermore, it was found that rigid pavements are moderately sensitive to AADTT, growth rate, hourly distribution factors, vehicle class distribution, and axle load spectra; and not sensitive to monthly adjustment factors and number of axles per truck. Therefore, it is recommended to estimate the AADTT and the vehicle class distribution from site-specific short-term or continuous counts and obtain the truck growth rate from ODOT Modeling and Forecasting Section (Certified Traffic). As for the other traffic inputs, statewide averages can be used for the hourly distribution factors, axle load spectra, and number of axles per truck; and MEPDG defaults can be used for the monthly adjustment factors.

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Abstract

The recently developed mechanistic-empirical pavement design guide (MEPDG) requires a multitude of traffic inputs to be defined for the design of pavement structures. These inputs include (a) base-year traffic data such as the initial two-way annual average daily truck traffic (AADTT), (b) traffic volume adjustment factors (directional and lane distribution factors, vehicle class distribution, monthly adjustment factors, hourly truck distribution factors, and traffic growth factors), (c) axle load spectra by truck class (Class 4 to Class 13) and axle type (single, tandem, tridem, and quad), and (d) general traffic inputs (lateral truck traffic wander, number of axles per truck, axle configuration and wheelbase distributions, and tire characteristics and inflation pressure).

Since it is not always practical to obtain site-specific traffic data, the MEPDG assimilates a hierarchal level concept that allows pavements to be designed using statewide averages and MEPDG default values without compromising the accuracy of the pavement design. In this study, a Visual Basic for Application (VBA) code was developed to analyze continuous traffic monitoring data and generate site-specific and statewide traffic inputs. The traffic monitoring data was collected by 143 permanent traffic monitoring sites (93 automated vehicle classifier (AVC) and 50 weigh-in-motion (WIM) sites) distributed throughout the State of Ohio from 2006 to 2011.

The sensitivity of the MEPDG to the various traffic inputs was evaluated using two baseline pavement designs, one for a new flexible pavement and one for a new rigid pavement. Key performance parameters for the flexible pavement included longitudinal (top-down) fatigue cracking, alligator (bottom-up) fatigue cracking, transverse (low-temperature) cracking, rutting, and smoothness (expressed using IRI), while key performance parameters for the rigid pavement included transverse cracking (% slabs cracked), joint faulting, and smoothness.

The sensitivity analysis results revealed that flexible pavements are moderately sensitive to AADTT, growth rate, vehicle class distribution, and axle load spectra; and not sensitive to hourly distribution factors, monthly adjustment factors, and number of axles per truck. Furthermore, it was found that rigid pavements are moderately sensitive to AADTT, growth rate,

hourly distribution factors, vehicle class distribution, and axle load spectra; and not sensitive to monthly adjustment factors and number of axles per truck. Therefore, it is recommended to estimate the AADTT and the vehicle class distribution from site-specific short-term or continuous counts and obtain the truck growth rate from ODOT Modeling and Forecasting Section (Certified Traffic). As for the other traffic inputs, statewide averages can be used for the hourly distribution factors, axle load spectra, and number of axles per truck; and MEPDG defaults can be used for the monthly adjustment factors.

Chapter 1
Introduction

1.1 Problem Statement

Traffic is one of the primary inputs in pavement design. Traditional pavement design procedures account for traffic using the equivalent single axle loads (ESAL's) accumulated during the life of the pavement structure (*1*). This procedure is based on converting each individual axle with a specific weight and configuration into an equivalent number of standard 18-kip single axle loads. The equations used in this procedure are based on outdated data obtained from road tests performed over a two year time period in the late 1950's in Ottawa, Illinois. Since these tests were carried out at a single test site, these equations may not be representative of the various environments, materials, and drainage conditions encountered at other locations. Another limitation of these equations is that testing was conducted over a two year time span, which is a relatively short period in terms of pavement design since it does not account for the effect of the environment on the performance of the pavement structure. Furthermore, the size and volume of vehicles have significantly increased over the last six decades, and therefore this procedure is not representative of current vehicle loads and pavement designs. Finally, this procedure introduces a degree of uncertainty that is difficult to quantify because it depends on the pavement type and structure, pavement condition, environmental conditions, and the failure criteria being evaluated. As a result, the use of ESAL's can limit the accuracy of the resulting pavement design.

Recent efforts under the auspices of the National Cooperative Highway Research Program (NCHRP) have resulted in the development of a Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures (*2*). The recently developed design guide, referred to thereafter as the mechanistic-empirical pavement design guide (MEPDG), offers unique features that have long been recognized as limitations in the previous American Association of State Highway and Transportation Officials (AASHTO) design guides. Among these features are the introduction of mechanistic-empirical procedures in predicting performance; the accommodation of changes in material properties over time; and the representation of traffic using axle load spectra by axle type. To fully utilize these features, a multitude of project-specific input data need to be defined including the proposed pavement structure, material properties, traffic information, and environmental conditions. Since it is not always practical to obtain this information, the MEPDG assimilates a hierarchal level concept upon which data may be input. Three input levels are suggested in the MEPDG for traffic characterization; the highest input level (Level 1) requires project-specific traffic data, while the lowest input level (Level 3) relies on national (default) traffic inputs. The selection of the design input level primarily depends on data availability and the importance of the pavement structure under investigation.

To accommodate the transition to the mechanistic-empirical pavement design approach, the MEPDG requires more detailed traffic information. The traffic inputs required by the MEPDG include (a) base-year traffic data such as the initial two-way annual average daily truck traffic (AADTT), (b) traffic volume adjustment factors (directional and lane distribution factors, vehicle class distribution, monthly adjustment factors, hourly truck distribution factors, and traffic growth factors), (c) axle load spectra by truck class (Class 4 to Class 13) and axle type (single, tandem, tridem, and quad), and (d) general traffic inputs (lateral truck traffic wander, number of axles per truck, axle configuration and wheelbase distributions, and tire characteristics and inflation pressure).

Accordingly, to advance the implementation of the MEPDG in Ohio, there is an urgent need for an automated tool to assemble traffic volume and axle load information from operational traffic monitoring systems within the state. This tool shall be capable of generating traffic inputs in a format that can be directly imported into the MEPDG. This research is very timely and critical given the fact that several states have already started using the MEPDG in the design of their pavement structures and that the Ohio Department of Transportation (ODOT) is expected to adopt this new design method in the near future.

1.2 Objectives of Study

The main objectives of this study are to:

1. Develop a methodology to obtain the required MEPDG traffic inputs at the various input levels using available traffic monitoring data.
2. Implement the developed methodology into user-friendly software that can be used by ODOT engineers to generate the required MEPDG traffic inputs.

1.3 Report Organization

This report is organized into eleven chapters. Chapter 2 presents a literature review of subjects pertinent to this study. It provides an overview of the required traffic inputs for the MEPDG. Chapter 3 reviews ODOT current traffic characterization practices for pavement design. Chapter 4 discusses the traffic monitoring practices used in the State of Ohio to collect traffic data. Chapter 5 describes the traffic monitoring dataset used in the development of the MEPDG traffic inputs. Chapter 6 outlines the quality control measures implemented on the traffic monitoring data. Chapter 7 describes the Visual Basic for Application (VBA) code that was developed in this study to analyze the traffic data. Chapter 8 presents the traffic analysis results obtained from the VBA code. Chapter 9 evaluates the effect of the various MEPDG traffic inputs on pavement design. Chapter 10 summarizes and concludes the findings of this study. Finally, Chapter 11 provides recommendations for implementation of the MEPDG with regard to traffic in the State of Ohio.

Chapter 2
Literature Review

2.1 Introduction

The recently developed MEPDG represents a significant improvement over the previously used AASHTO design guides. One of the major modifications to the MEPDG is traffic characterization. The MEPDG does not use the ESAL approach that is employed in previous AASHTO design guides. Instead, it follows a more rational approach that is based on describing traffic in terms of axle numbers by axle type and axle load distributions. It also accounts for temporal variations in traffic by using hourly distribution, monthly adjustment, and annual growth factors. The advantage of this approach is that it allows for implementing a more fundamental pavement design procedure based on mechanistic-empirical principles that enables the accumulation of damage over time.

2.2 Hierarchical Approach

To accommodate the transition to the mechanistic-empirical pavement design approach, a multitude of project-specific input data need to be defined including the proposed pavement structure, material properties, traffic information, and environmental conditions. Since it is not always practical to obtain this information, the MEPDG assimilates a hierarchal level concept upon which data may be input. Three input levels are suggested in the MEPDG for traffic characterization. The highest input level (Level 1) requires project-specific vehicle classification and axle load distributions over a sufficiently long period of time to establish monthly variations. The second input level (Level 2) requires project-specific traffic volume counts and percent truck data, but relies on representative regional vehicle classification and axle weight data. And the lowest input level (Level 3) requires project-specific traffic volume counts and percent truck data, but relies on national traffic inputs that are the default values in the MEPDG software. These default values were obtained using data collected by the Long Term Pavement Performance (LTPP) program over a period of twenty years across the United States and Canada. The selection of the design input level primarily depends on data availability and the importance of the pavement structure under investigation.

2.3 MEPDG Traffic Inputs

The MEPDG requires defining the same traffic inputs regardless of the type of the pavement structure (flexible or rigid) and design type (new or rehabilitated). The traffic inputs required by the MEPDG include: (a) base-year traffic data such as the initial two-way annual average daily truck traffic (AADTT), (b) traffic volume adjustment factors (directional and lane distribution factors, vehicle class distribution, monthly adjustment factors, hourly truck distribution factors, and traffic growth factors), (c) axle load spectra by truck class (Class 4 to Class 13) and axle type (single, tandem, tridem, and quad), and (d) general traffic inputs (lateral truck traffic wander, number of axles per truck, axle and wheel base configurations, and tire characteristics and inflation pressure).

State highway agencies collect traffic data according to the Federal Highway Administration (FHWA) Traffic Monitoring Guide (TMG); (*3*). The required traffic inputs for the MEPDG can be assembled by combining information from multiple traffic monitoring sources such as automated traffic recorders (ATR), automated vehicle classifiers (AVC), and weigh-in-motion (WIM) systems. These technologies vary in their capability. For example, ATRs are used to obtain vehicle counts; AVCs are used to obtain vehicle counts and vehicle classification; and WIM systems are used to obtain vehicle counts, vehicle classification, and individual axle weight and spacing. Traffic information collected using these systems are recorded according to a standard data format as documented in Section 6 of the FHWA TMG. The following subsections describe the process for analyzing this data to obtain the MEPDG traffic inputs.

2.3.1 Base Year AADTT

The MEPDG uses the annual average daily truck traffic (AADTT) as the basis of the calculation of truck (Class 4 through 13) volumes. Alternatively, the user may input the annual average daily traffic (AADT) and the percent of trucks (T%), and the MEPDG will calculate the AADTT. The AADTT represents the total truck traffic traveling in both directions on a roadway segment over a twenty four hour period. When continuous traffic monitoring data is available, the FHWA TMG suggests using the following equation to calculate the AADTT:

$$AADTT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} ADTT_{ijk}\right)\right] \tag{1}$$

where $ADTT_{ijk}$ is the average daily truck traffic for day k of day-of-week i and month j; i is the day of the week (1 to 7 for Sunday to Saturday, respectively); j is the month of the year (1 to 12 for January to December, respectively); k = 1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week; and n = the number of days of that day of the week during that month (usually between 1 and 5, depending on the calendar and the number of missing days).

The previous equation averages truck volumes based on the day of the week for all twelve months before it calculates the annual average daily value. This approach limits the bias from missing days of data, which might be significant especially when those missing days are unequally distributed across months or days of the week (*3*). Additionally the MEPDG recommends using the average of the three most recent years with adequate date in the calculation of the base year AADTT to further limit any bias due to annual variations.

Since it is not feasible to obtain continuous traffic monitoring data for all locations, state highway agencies typically estimate the AADTT using a combination of short term counts and seasonal adjustment factors that account for the day of week and monthly variations in traffic. The procedure for obtaining these seasonal adjustment factors is discussed in detail in later chapters.

2.3.2 Traffic Volume Adjustment Factors

Traffic volume adjustment factors are used to account for the directional and lane distribution of truck traffic, vehicle (truck) class distribution, monthly and hourly variations in truck traffic, and growth of truck traffic during the design period. The accuracy of these traffic inputs is critical because of their influence on the design of the pavement structure.

2.3.2.1 Directional and Lane Distribution Factors

The directional distribution factor (DDF) quantifies the difference in truck volume between the two directions. While the DDF varies for each individual truck class, the MEPDG uses the same distribution factor for all class. Furthermore, the MEPDG recommends using the predominant truck class DDF (usually Class 9) in the analysis when there is an obvious variation between the two directions. This value is generally assumed to be 50% unless available regional or local traffic data indicates a disproportional truck distribution.

The truck lane distribution factor (LDF) represents the distribution of truck traffic between lanes in one direction. For highways with one lane in each direction, this factor is 1.0 because all trucks in either direction must use the same lane. For roadways with multiple lanes in one direction, the LDF depends on the AADTT and site-specific conditions. The default MEPDG LDF values are 1.00 for roadways with one lane per direction, 0.90 for roadways with two lanes per direction, 0.60 for roadways with three lanes per direction, and 0.45 for roadways with four lanes per direction.

2.3.2.2 Vehicle (Truck) Class Distribution

Each state has its own method of classifying truck traffic. The most common method is the FHWA standard classification scheme that classifies vehicles into thirteen different classes (Figure 1 and Table 1). Based on this classification, vehicle class 1 is motorcycles, vehicle class 2 is passenger cars, vehicle class 3 is pickup trucks, vehicle class 4 is busses, and vehicle classes 5 through 13 are trucks. For pavement design, vehicle classes 1 through 3 are ignored from the analysis due to their light weight and relatively low impact on the performance of the pavement structure. Meanwhile, vehicle classes 4 through 13 (referred to thereafter as truck classes 4 through 13) are considered in the analysis and are accounted for using the truck class distribution. The latter is calculated by dividing the annual average daily truck traffic for each truck class ($AADTT_c$) by the AADTT for all trucks. The $AADTT_c$ values for truck classes 4 through 13 are calculated using the same approach described in Equation 1. The truck class distribution values are input into the MEPDG in a percent format, and the summation of these values must be equal to 100.

Early work by the MEPDG research team attempted to establish traffic patterns using information from the Long Term Pavement Performance (LTPP) database. It was suggested to categorize highways based on truck class distribution. Seventeen truck traffic classification (TTC) groups were established representing the range of commonly encountered vehicle distributions (Table 2). A reduction in variability was observed using these TTC groups. As a result, this grouping system was incorporated in the MEPDG software.

The MEPDG suggests using Table 3 in order to match a site with known truck class distribution to one of the seventeen TTC groups. As can be noticed from this table, special attention was given to the percentages of Class 4, 5, 9, and 13 trucks in developing these TTC groups. According to this classification system, if a site is determined to have more than 25% Class 4 (buses), it is classified as TTC group 17. If it has been determined that the TTC group is not 17, the main distinction between the TTC groups is the percentage of multi-trailer (Class 13 in particular). Sites with low percentage of multi-trailers (< 2%) are classified as TTC groups 1, 2, 4, 6, 9, 12, and 14; while sites with moderate to high percentage of multi-trailers (≥ 2%) are classified as TTC groups 3, 5, 7, 8, 10, 11, 13, and 15. The primary difference between the TTC groups for the previous two categories is the distribution of Class 5 and Class 9 trucks.

2.3.2.3 Monthly Adjustment Factors

The MEPDG uses the monthly adjustment factors (MAF) to account for the seasonal variations in traffic. These adjustment factors are influenced by many factors including the land use and functional classification (urban or rural) of the roadway. The following equation is used to calculate the MAF for each truck class:

$$MAF_{ic}=\frac{AMDTT_{ic}}{\sum_{i=1}^{12} AMDTT_{ic}}\times 12 \tag{2}$$

where MAF_{ic} is the monthly adjustment factor for truck class c and month i and $AMDTT_{ic}$ is the average monthly daily truck traffic for truck class c and month i. The calculation of the $AMDTT_{ic}$ is similar to that of AADTT in Equation 1. Additionally, the sum of the MAF values of all months must be equal to 12. When traffic data is not available to calculate the MAF or when there is little seasonal variation in truck traffic, the default value of 1.0 can be used for all months.

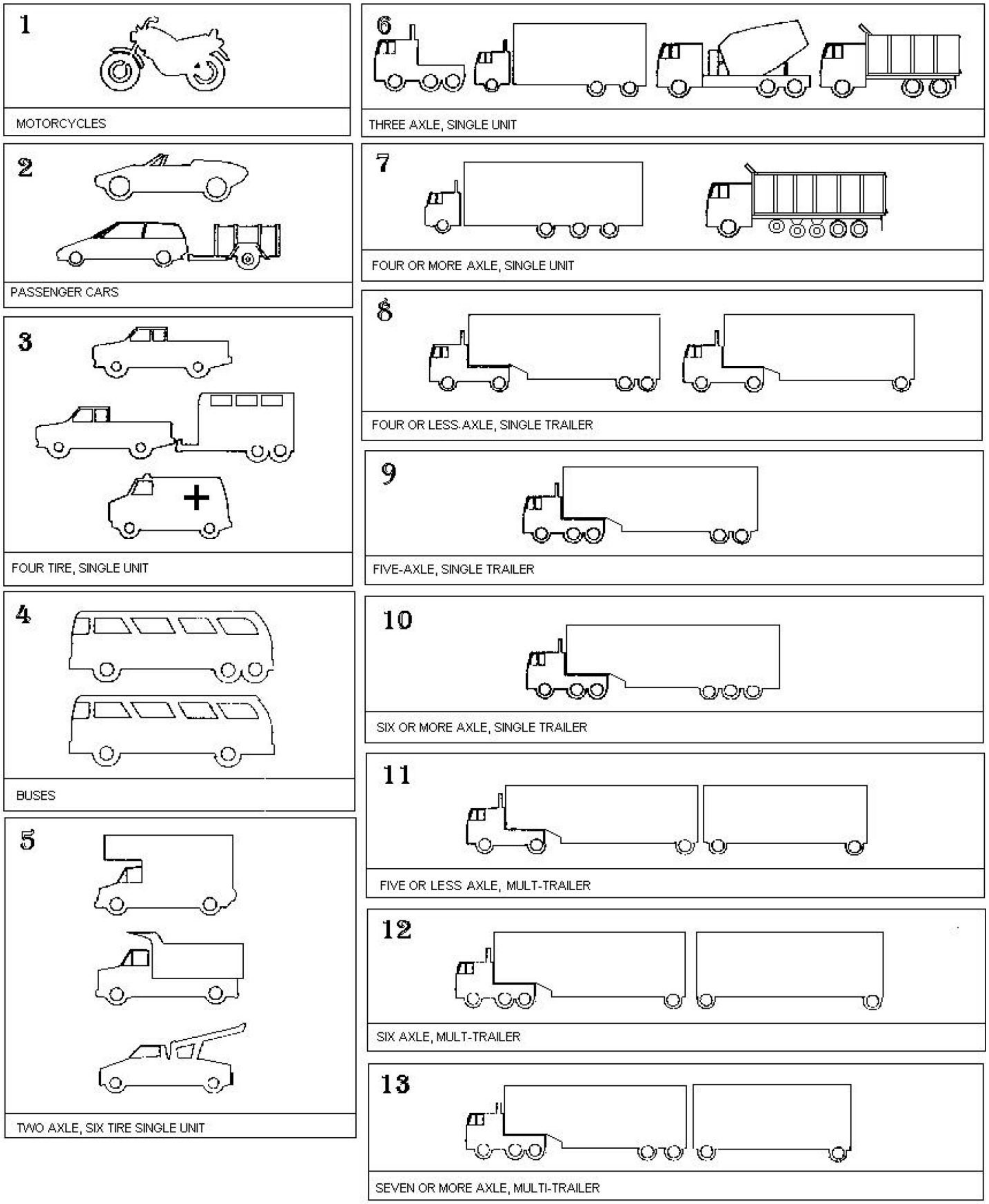


Figure 1: FHWA Vehicle Classification

Table 1: Vehicle Class Description

Class	Description
1	**Motorcycles:** All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheeled motorcycles.
2	**Passenger Cars:** All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.
3	**Other Two-Axle, Four-Tire, Single Unit Vehicles:** All two-axle, four-tire, vehicles other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.
4	**Buses:** All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be trucks and be appropriately classified.
5	**Two-Axle, Six-Tire, Single Unit Trucks:** All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.
6	**Three-axle Single unit Trucks:** All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.
7	**Four or More Axle Single Unit Trucks:** All trucks on a single frame with four or more axles.
8	**Four or Less Axle Single Trailer Trucks:** All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.
9	**Five-Axle Single Trailer Trucks:** All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.
10	**Six or More Axle Single Trailer Trucks:** All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
11	**Five or Less Axle Multi-Trailer Trucks:** All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.
12	**Six-Axle Multi-Trailer Trucks:** All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
13	**Seven or More Axle Multi-Trailer Trucks:** All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Table 2: Default Truck Traffic Classification (TTC) Groups in the MEPDG (*2*)

TTC Group	TTC Description	Vehicle/Truck Class Distribution (Percent)									
		4	5	6	7	8	9	10	11	12	13
1	Major single-trailer truck route (Type I)	1.3	8.5	2.8	0.3	7.6	74	1.2	3.4	0.6	0.3
2	Major single-trailer truck route (Type II)	2.4	14.1	4.5	0.7	7.9	66.3	1.4	2.2	0.3	0.2
3	Major single- and multi- trailer truck route (Type I)	0.9	11.6	3.6	0.2	6.7	62	4.8	2.6	1.4	6.2
4	Major single-trailer truck route (Type III)	2.4	22.7	5.7	1.4	8.1	55.2	1.7	2.2	0.2	0.4
5	Major single- and multi- trailer truck route (Type II)	0.9	14.2	3.5	0.6	6.9	54	5	2.7	1.2	11
6	Intermediate light and single-trailer truck route (I)	2.8	31	7.3	0.8	9.3	44.8	2.3	1	0.4	0.3
7	Major mixed truck route (Type I)	1	23.8	4.2	0.5	10.2	42.2	5.8	2.6	1.3	8.4
8	Major multi-trailer truck route (Type I)	1.7	19.3	4.6	0.9	6.7	44.8	6	2.6	1.6	11.8
9	Intermediate light and single-trailer truck route (II)	3.3	34	11.7	1.6	9.9	36.2	1	1.8	0.2	0.3
10	Major mixed truck route (Type II)	0.8	30.8	6.9	0.1	7.8	37.5	3.7	1.2	4.5	6.7
11	Major multi-trailer truck route (Type II)	1.8	24.6	7.6	0.5	5	31.3	9.8	0.8	3.3	15.3
12	Intermediate light and single-trailer truck route (III)	3.9	40.8	11.7	1.5	12.2	25	2.7	0.6	0.3	1.3
13	Major mixed truck route (Type III)	0.8	33.6	6.2	0.1	7.9	26	10.5	1.4	3.2	10.3
14	Major light truck route (Type I)	2.9	56.9	10.4	3.7	9.2	15.3	0.6	0.3	0.4	0.3
15	Major light truck route (Type II)	1.8	56.5	8.5	1.8	6.2	14.1	5.4	0	0	5.7
16	Major light and multi-trailer truck route	1.3	48.4	10.8	1.9	6.7	13.4	4.3	0.5	0.1	12.6
17	Major bus route	36.2	14.6	13.4	0.5	14.6	17.8	0.5	0.8	0.1	1.5

Table 3: Definitions and Descriptions of the MEPDG TTC Groups (*2*)

Buses in Traffic Stream	Commodities being Transported by Type of Truck		TTC Group No.
	Multi-Trailer	**Single-Trailers and Single-Units**	
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
Major bus route (> 25%)	Low to none (< 2%)	Mixed truck traffic with about equal single unit and single-trailer trucks	17

2.3.2.4 Hourly Distribution Factors

The MEPDG uses the hourly distribution factors (HDF) to account for traffic variations within the day. These factors are calculated by dividing the annual average hourly truck traffic ($AAHTT_i$) for hour i by the AADTT for the whole day. The calculation of the $AAHTT_i$ is similar to that of the AADTT in Equation 1. The summation of the $AAHTT_i$ values for all hours must be equal to the AADTT. The MEPDG assumes the same hourly distribution factors for all truck classes. Therefore, these factors are calculated based on the total volume of trucks rather than the volume of an individual truck class. The HDFs are input into the MEPDG as a percent. Therefore, the summation of the twenty-four hourly distribution factors must be equal to 100. Table 4 presents the default hourly truck distribution factors in the MEPDG obtained by analyzing the LTPP data.

Table 4: Default Hourly Truck Distribution Factors Based on LTPP Traffic Data (*2*)

Time Period	Distribution (%)	Time Period	Distribution (%)
12:00 a.m. - 1:00 a.m.	2.3	12:00 p.m. - 1:00 p.m.	5.9
1:00 a.m. - 2:00 a.m.	2.3	1:00 p.m. - 2:00 p.m.	5.9
2:00 a.m. - 3:00 a.m.	2.3	2:00 p.m. - 3:00 p.m.	5.9
3:00 a.m. - 4:00 a.m.	2.3	3:00 p.m. - 4:00 p.m.	5.9
4:00 a.m. - 5:00 a.m.	2.3	4:00 p.m. - 5:00 p.m.	4.6
5:00 a.m. - 6:00 a.m.	2.3	5:00 p.m. - 6:00 p.m.	4.6
6:00 a.m. - 7:00 a.m.	5	6:00 p.m. - 7:00 p.m.	4.6
7:00 a.m. - 8:00 a.m.	5	7:00 p.m. - 8:00 p.m.	4.6
8:00 a.m. - 9:00 a.m.	5	8:00 p.m. - 9:00 p.m.	3.1
9:00 a.m. - 10:00 a.m.	5	9:00 p.m. - 10:00 p.m.	3.1
10:00 a.m. - 11:00 a.m.	5.9	10:00 p.m. - 11:00 p.m.	3.1
11:00 a.m. - 12:00 p.m.	5.9	11:00 p.m. - 12:00 a.m.	3.1

2.3.2.5 Traffic Growth Factors

The MEPDG uses traffic growth factors to estimate the anticipated truck volumes over the entire design period. The MEPDG allows the pavement designer to use the same growth function for all trucks or assign different growth functions for different truck classes.

Traffic growth is typically determined from historical traffic data obtained over a relatively long period of time. This is commonly accomplished through the use of regression analysis whereby a mathematical relationship is used to describe traffic growth or decay over time. Three functions are available in the MEPDG to estimate future truck traffic. They include:

No growth $$AADTT_t = AADTT_{BY} \tag{3}$$

Linear growth $$AADTT_t = GR \times AGE + AADTT_{BY} \tag{4}$$

Compound growth $$AADTT_t = AADTT_{BY} \times (GR)^{AGE} \tag{5}$$

where $AADTT_t$ is the annual average daily truck traffic at age t, $AADTT_{BY}$ is the annual average daily truck traffic at the base year, and GR is the growth rate. The default in the MEPDG is a 4% compound growth model.

In performing the regression analysis, the historical data shall be examined to ensure a steady growth over time and to identify any outliers that may significantly alter the outcome of the analysis (*4*). Furthermore, it is desirable to fit the previous functions to traffic data obtained over a relatively long period of time to obtain a representative traffic growth rate. In a recent paper by Lu et al. (*5*) focusing on the characterization of truck traffic growth patterns in the State of California, the authors reported large variations in the estimated growth rate when using less than six years of traffic data, leading to significant errors in pavement response prediction. As a result, the authors concluded that at least six years of traffic data should be used in order to accurately estimate the traffic growth rate. However, it should be determined whether this recommendation is applicable to other states like the State of Ohio.

2.3.3 Axle Load Distribution Factors

The MEPDG uses the axle load distribution factors (also called axle load spectra) to represent the load distribution for each axle type (single, tandem, tridem and quad) and truck class (4 through 13). The axle load distribution factors are defined according to the following load intervals: Single axles are 3,000 to 40,000 lbs at 1,000-lb intervals (13.3 to 177.9 kN at 4.4-kN intervals), tandem axles are 6,000 to 80,000 lbs at 2,000-lb intervals (26.7 to 355.9 kN at 8.9-kN intervals), and both tridem and quad axles are 12,000 to 102,000 lbs at 3,000-lb intervals (53.4 to 453.7 kN at 13.3-kN intervals). These distributions factors are defined for each month during the year (January through December) to account for the seasonal variations in truck loading. The MEPDG uses the same axle load distribution factors for the entire analysis period and do not account for changes in loading over time.

The previous axle load distribution factors can be obtained by analyzing individual axle weight and spacing data collected using WIM systems. Individual axles are grouped into singles, tandems, tridems, and quads according to their spacing. State highway agencies vary in their definition of these axle groups. The FHWA defines tandem axles as a group of two or more axles spanning more than 3.28 ft (1 m) but no more than 8 ft (2.44 m); tridem axles as a group of three or more axles spanning more than 8 ft (2.44 m) but no more than 9.84 ft (3 m); and quad axle as a group of four or more axles spanning more than 9.84 ft (3 m) but no more than 12.47 ft (3.8 m); (*6*). ODOT uses an axle spacing of 6 ft (1.82 m) to differentiate between these axle groups. Accordingly, tandem axles can be defined as a group of two axles spanning no more than 6 ft (1.83 m); tridem axles can be defined as a group of three axles spanning no more than 12 ft (3.66 m), with no more than 6 ft (1.83 m) spacing between any two successive axles; and quad axles can be defined as a group of four axles spanning no more than 18 ft (5.49 m), with no more than 6 ft (1.83 m) spacing between any two successive axles.

Once the axle groups are identified, the axle group weight can be calculated by adding the weight of the individual axles within that group. This process is repeated for a sufficiently large number of trucks over an extended period of time in order to obtain representative axle load distributions for each axle group. Figure 2 shows the default single, tandem, tridem, and quad axle load distributions in the MEPDG. As can be seen from this figure, the MEPDG uses the same axle load distributions for tridem and quad axle groups. This suggests the need for an improved method to identify tridem and quad axle groups and obtain their axle load distributions. It can also be noticed from this figure that the MEPDG assumes axle load distributions for Class 5 tandem, tridem, and quad axles. Class 5 trucks are single unit trucks that consist of two single axles. Therefore, there is no need to define their tandem, tridem, and quad axle load distributions.

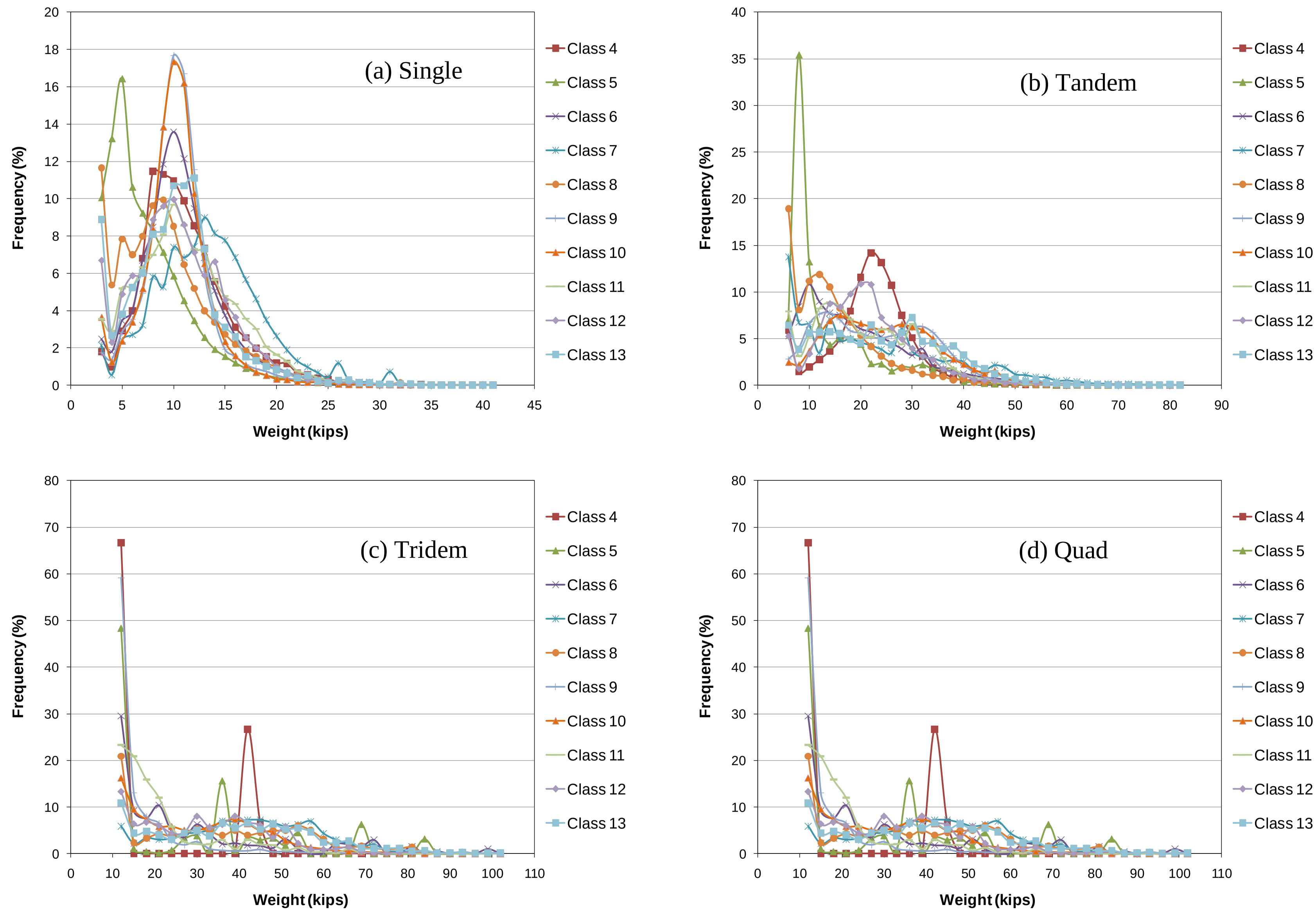


Figure 2: Default (a) Single, (b) Tandem, (c) Tridem, and (d) Quad Axle Load Distributions in the MEPDG

2.3.4 General Traffic Inputs

The MEPDG uses a number of general traffic inputs that are used in predicting the pavement response. These inputs include the lateral traffic wander, number of axles per truck, axle configuration and wheelbase distributions, and tire characteristics and inflation pressure.

2.3.4.1 Lateral Traffic Wander

The MEPDG defines the lateral traffic wander using the mean wheel location and standard deviation as well as the design lane width. The mean wheel location is the average distance from the outer edge of the wheel to the pavement marking. The default mean wheel location in the MEPDG is 18 inches (0.46 m). The traffic wander standard deviation is the standard deviation of the lateral movement of traffic flow. The default traffic wander standard deviation in the MEPDG is 10 inches (0.25 m). Finally, the design lane width is the actual traffic lane width defined by the distance between the pavement markings on both sides of the design lane, which is different than the slab width for concrete pavements. The default design lane width in the MEPDG is 12 ft (3.7 m).

2.3.4.2 Number of Axles per Truck

The number of axles per truck is the number of axles by type (single, tandem, tridem and quad) for each truck class (4 through 13). The default number of axles per truck used in the MEPDG can be seen in Table 5.

Table 5: Default Number of Axles Per Truck in the MEPDG (*2*)

	Axle Configuration			
Class	Single	Tandem	Tridem	Quad
4	1.62	0.39	0.00	0.00
5	2.00	0.00	0.00	0.00
6	1.02	0.99	0.00	0.00
7	1.00	0.26	0.83	0.00
8	2.38	0.67	0.00	0.00
9	1.13	1.93	0.00	0.00
10	1.19	1.09	0.89	0.00
11	4.29	0.26	0.06	0.00
12	3.52	1.14	0.06	0.00
13	2.15	2.13	0.35	0.00

2.3.4.3 Axle Configuration and Tire Inflation Pressure

Pavement structures are sensitive to the distance between tires and axles within a truck as well as the tire inflation pressure. As a result, these parameters are important in describing the loads applied to the pavement. The MEPDG provides default values for when it is not feasible to determine site specific values for these inputs. These values can be seen in Table 6.

Table 6: Default Axle Configuration Values in the MEPDG

Input	Description	Default Value
Average Axle Width	Distance between Outside Edges of an Axle	8.5 ft
Dual Tire Spacing	Distance between Center of Dual Tires	12 inch
Tire Pressure	Hot Inflation Pressure (Typically 10 to 15% Greater than Cold Inflation Pressure)	120 psi
Axle Spacing	Distance between Consecutive Axles	Tandem – 51.6 inch Tridem – 49.2 inch Quad – 49.2 inch

2.3.4.4 Wheelbase

The MEPDG uses the wheelbase distribution in predicting the top-down cracking in jointed plain concrete pavements (JPCP). The wheelbase refers to the distance between the steering axle and the first axle of the truck tractor. This input is only applicable to truck classes 8 through 13.This information can be obtained directly from the manufacturer specifications or measured in the field. The MEPDG classifies the wheelbase length into three categories: short, medium and long, with a default axle spacing of 12, 15 and 18 ft (3.7, 4.6, and 5.5 m), respectively. The MEPDG uses a default wheelbase distribution of 33% for short, 33% for medium, and 34% for long axle spacings.

Chapter 3
Traffic Characterization for Current Pavement Design

3.1 Introduction

The current pavement design procedure in the State of Ohio is based on the 1993 AASHTO design guide (*7*). As mentioned earlier, this design procedure uses the ESAL concept to account for traffic during the pavement design period. To calculate the accumulated ESAL's, ODOT relies on truck equivalency factors for multiple and single unit trucks rather than load equivalency factors for individual truck axles. This chapter outlines the general approach and variables used by ODOT in determining the total accumulated ESAL's.

3.2 Total Daily ESAL's

In order to calculate the total accumulated ESAL's, ODOT first calculates the total daily ESAL's. The equations used to determine the total daily ESAL's are presented in Equations 6 through 8. As can be noticed from these equations, the total daily ESAL's is the sum of the multiple and single unit truck ESAL's (B and C-ESAL's, respectively). The B trucks include multiple unit trucks with single or multi-trailers, and the C trucks include single unit trucks and buses. The B and C-ESAL's are the product of a number of factors, including the average daily traffic (ADT), 24-hour truck percentage of ADT (%T24), directional distribution (%D), lane factor (%LF), percentage of multiple unit trucks (%B), percentage of single unit trucks (%C), and a truck conversion factor (CF).

$$\text{B-ESAL's} = ADT \times \%T24 \times \%D \times \%LF \times \%B \times CF \qquad (6)$$

$$\text{C-ESAL's} = ADT \times \%T24 \times \%D \times \%LF \times \%C \times CF \qquad (7)$$

$$\text{Total Daily ESAL's} = \text{B-ESAL's} + \text{C-ESAL's} \qquad (8)$$

To calculate the B and C-ESAL's, ODOT uses the predicted ADT at the middle of the design period, assuming linear traffic growth. The growth rate is determined based on historical traffic data and more sophisticated travel demand models. Furthermore, it is assumed that the percentage of trucks will remain constant over the entire pavement design period.

ODOT uses the function classification system to group sites and obtain average traffic characteristics (Table 7). According to this classification system, roadways are categorized into urban or rural, interstate, freeway, arterial, collector or local roads. Based on these classifications, assumptions can be made about the traffic content traveling on that roadway. For instance, an urban interstate is expected to have a higher traffic volume when compared to a rural interstate. Likewise, an arterial road is expected to have a higher traffic volume than a local road.

ODOT also uses the functional classification to determine the ratio of multiple to single unit trucks (B:C ratio), which is used to describe the distribution of trucks by type, and calculate the percentage of multiple and single unit trucks of the total truck volume (%B and %C, respectively). Table 8 displays the B:C ratios used by ODOT for different functional classifications. As can be seen from this table, the B:C ratio is higher for rural roadways than urban roadways. Additionally, interstate highways have higher B:C ratios than non-interstate highways such as arterial and local roads.

Table 7: Highway Functional Classification (*7*)

Functional Classification	Description
1	Rural Interstate
2	Rural Principal Arterial
6	Rural Minor Arterial
7	Rural Major Collector
8	Rural Minor Arterial
9	Rural Local
11	Urban Interstate
12	Urban Freeway
14	Urban Principal Arterial
16	Urban Minor Arterial
17	Urban Collector
19	Urban Local

Table 8: B:C Ratio for Different Functional Classifications (*7*)

Functional Classification	B:C Ratio
Rural Interstate (01)	7:1
Rural Principal Arterial (02)	5:1
All Other Rural (06,07,08,09)	2:1
Urban Interstate (11)	4:1
Urban Freeway & Expressway (12)	3:1
Urban Principal Arterial (14)	2:1
All Other Urban (16,17,19)	1:1

To describe the damage caused to the pavement by B and C trucks, ODOT uses the ESAL conversion factor (CF). Table 9 shows the ESAL conversion factors used by ODOT for rigid and flexible pavements and the various functional classifications. These factors were determined by averaging ten years of truck weight data obtained throughout the State of Ohio. As can be noticed from this table, the ESAL CF for is greater for multiple unit trucks for both rigid and flexible pavements. This indicates that damage caused by B trucks is greater than that of C trucks.

Table 9: ESAL Conversion Factors (*7*)

Functional Classification	Rigid		Flexible	
	B	C	B	C
Rural Interstate (01)	1.86	0.66	1.23	0.51
Rural Principal Arterial (02)	2.42	0.95	1.45	0.58
All Other Rural (06, 07, 08, 09)	1.55	1.40	0.89	0.75
Urban Interstate (11)	1.92	0.84	1.21	0.62
Urban Expressway & Freeway (12)	1.80	0.86	1.22	0.50
All Other Urban (14, 16, 17, 19)	1.72	0.80	1.03	0.55

Finally, to describe the proportion of the ADT that is traveling in the design lane, ODOT uses the directional distribution (%D) and lane factor (%LF). In general, ODOT uses a 50% directional distribution unless one direction of travel has a significantly higher traffic volume. In addition, ODOT uses a lane factor equal to 100% for roadways with one lane per direction, which decreases with the increase in the number of lanes. Table 10 shows the directional and lane distribution factors for highways with different number of lanes.

Table 10: Directional and Lane Distribution Factors (*7*)

Number of Lanes	Lane Factor, LF (%)	Directional Distribution, D (%)
2 – Lane	100	50
4 – Lane	90	50
6 (or more) – Lane	80	50

3.3 Total Accumulated ESAL's

The calculation of the total accumulated ESAL's is presented in Equation 9. As can be noticed from this equation, the total accumulated ESAL's is determined by multiplying the total daily ESAL's by 365.25 days per year and by the number of years in the design period.

$$\text{Total Accumulated ESAL's} = \text{Total Daily ESAL's} \times 365.25\ \text{days/year} \times \text{Design Period} \quad (9)$$

Once the total accumulated ESAL's has been calculated using Equation 9, this value is used in the appropriate rigid or flexible pavement design equations to determine the pavement layer thicknesses. While this approach is common to pavement design, it is limited by the inherent limitations of the 1993 AASHTO design guide. Furthermore, the assumptions made in this approach may lead to inaccurate pavement design. Therefore, there is a need to evaluate the assumptions and factors used in this procedure to determine their applicability for mechanistic-empirical pavement design.

Chapter 4
Traffic Monitoring Practices in Ohio

4.1 Introduction

Traffic monitoring is used to acquire information about vehicles traveling along a roadway. This information can be used in a variety of applications including highway and pavement design, transportation planning and analysis, and economic and environmental studies. The collection of the traffic data can be accomplished using a variety of methods including the AASHTO Guidelines for Traffic Data Programs and the FHWA TMG. The AASHTO guidelines are the basis for many of the recommendations and formulas used in the TMG. ODOT uses the TMG for guidance on traffic data collection and the AASHTO guidelines for analyzing the traffic data. This chapter provides an overview of ODOT's traffic monitoring practices.

4.2 Traffic Monitoring in Ohio

ODOT has an extensive traffic monitoring program that includes more than two hundred continuous (permanent) monitoring sites supplemented with a large number of short-term counts conducted by ODOT personnel on a periodic basis. The continuous traffic data are used to obtain seasonal adjustment factors and overall traffic trends, while the short term counts are used to obtain site-specific traffic data at locations where no continuous data is available.

When considering a new site for traffic monitoring, ODOT avoids locations such as curves, crests and valleys, driveways, intersections and schools. These physical and geometrical characteristics can yield data that is not representative of the actual traffic traveling along the roadway. Additional factors that can influence the data include the absence or presence of multiple lanes, medians, turning lanes and shoulders.

The traffic monitoring equipment used in permanent and short term counts defines the data that can be obtained. Permanent traffic counts collect data continually and are therefore capable of representing fluctuations in traffic with the time of day, day of week or season. Short term counts require a minimum duration in order to avoid inaccurate traffic volumes once adjustment factors are applied. The following sections detail ODOT's continuous and short-term monitoring programs. It also covers the equipment used in traffic monitoring and their capabilities.

4.2.1 Continuous Traffic Monitoring

ODOT uses a combination of automated traffic recorders (ATR), automatic vehicle classifiers (AVC), and weigh-in-motion (WIM) systems distributed throughout the state to obtain continuous traffic data. The data acquired by each system is presented in Table 11. As can be noticed from this table, ATRs are limited in their data collection capabilities and are primarily used to gather information on the number of vehicles. The most common technology used for ATRs is the inductive loop. Inductive loops are a series of wires inserted into the pavement surface that carry an electrical current. The loops act as a conductor and when a vehicle passes over the loop, the inductance decreases, indicating the presence of a vehicle. While ATRs are the least expensive method of collecting continuous traffic data, they may reduce the pavement life and may be damaged under variable loading and temperature conditions.

AVCs expand on the information collected by ATRs by providing information on the vehicle classification, which is determined from the number of axles and axle configuration. The most common configuration for AVCs includes two inductive loops and an axle sensor. One inductive loop is placed on each side of the axle sensor. The inductive loops are used to determine the vehicle speed and length. The axle sensor determines the axles spacing by calculating the time difference between changes in electrical current caused by the presence of an axle.

WIM systems are the most versatile method of measuring traffic data. They provide information about vehicle counts, vehicle classification, and individual axle weight and spacing. WIM systems typically consist of a combination of inductive loops and axle load sensors. The three most common technologies to measure axle load are hydraulic load cells, bending plates, and piezoelectric cables. The load cell sensors consist of two metal plates installed in each wheel path with load cells placed on the underside of each plate to measure the vertical load resulting from a vehicle axle as it passes over the sensor. Similarly, the bending plate sensors consist of two metal plates installed in each wheel path. However, they utilize strain gauges mounted on the bottom of the plates to measure the vertical axle load. Piezoelectric cables are placed into the pavement so that the top of the cable is flush with the pavement surface. As truck tires pass over the sensor, the deformation caused by the tires changes the electrical resistance of the cable, which is transmitted to a receiver. These changes are converted into the load applied to the pavement. The time lapse between deflections allows for the determination of the axle spacing. WIM systems are relatively expensive and difficult to maintain. Therefore, they are typically installed along major highways like interstates, and supplemented with information from other traffic monitoring systems.

Table 11: Data Provided by Traffic Monitoring Systems

<table>
<tr><td colspan="2"></td><th colspan="3">Type of Sensor</th></tr>
<tr><td colspan="2"></td><td>Volume Counter</td><td>Vehicle Classifier</td><td>WIM Scale</td></tr>
<tr><th rowspan="3">Data Provided</th><td>Volume
of Vehicles</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Volumes By
Type of Vehicle</td><td></td><td>X</td><td>X</td></tr>
<tr><td>Axle and/or Gross
Vehicle Weight</td><td></td><td></td><td>X</td></tr>
</table>

4.2.2 Short-Term Counts

Due to the expense and difficulty of installing and maintaining continuous traffic monitoring sites, ODOT utilizes short-term counts to obtain site-specific traffic monitoring data. ODOT conducts 15,000 short-term counts every three years, 4,400 Highway Performance Monitoring System (HPMS) counts every six years, and 4,000 counts for safety purposes every six years. The short term counts provide up-to-date traffic data and geographic information about the roadway. In order to account for traffic variation in the data collection, ODOT specifies that rural traffic counts should be collected for a minimum of 48 continuous hours in 15 minute intervals, while urban roadways should have a minimum data collection period of 24 continuous hours in 15 minute variables. The difference in data collection duration is due to the variation of traffic flow along rural roadways that can only be represented through longer traffic counts. Furthermore, ODOT performs the data collection during the weekdays (Monday to Thursday) throughout the year as weather permits (typically between April and October), and avoids data collection immediately before, after or during a holiday when it is expected that there will be significant variation in traffic.

4.3 Traffic Data Formats

Traffic monitoring data is recorded according to a standard format as documented in the FHWA TMG. Over the years, ODOT has used several types of data formats. Of relevance to this study are the vehicle classification records (C Records or C-Cards) and the vehicle weight records (W Records or W-Cards). As discussed in the following subsections, C-Cards contain hourly traffic counts for vehicle classes 1 through 15 (vehicle classes 14 and 15 are optional), while W-Cards contain axle load and spacing information for individual vehicles. The purpose of these records is to organize the data into a consistent format that allows for later traffic data analysis. It is noted that vehicles that cannot be classified using ODOT's vehicle classification system are recorded into vehicle class 15 for WIM systems and into vehicle class 13 for AVC systems. Therefore, it may not be possible to separate these unclassifiable vehicles from actual truck class 13 in AVC data.

4.3.1 C-Cards

C-Cards contain an hourly traffic count record of vehicle classes 1 through 15 in each lane and direction. The data format of the C-Cards can be seen in Table 12. As can be noticed from this table, each C-Card contains 99 characters (letters and/or numbers) divided among 25 fields. The first field, the record type, refers to the type of data being collected, in which C indicates a vehicle classification record. The federal information processing standards (FIPS) code is the second field, which organizes the states into alphabetical order and assigns a number to each state. In this organization system, 01 refers to Alabama and 56 refers to Wyoming. The FIPS code for Ohio is 39. The third field is the station identification where the data was collected. The direction of travel is the fourth field, where 1 is used for North, 2 for Northeast, 3 for East, 4 for Southeast, 5 for South, 6 for Southwest, 7 for West, 8 for Northwest, 9 for North-South or Northeast-Southwest combined (ATR stations only), and 0 for East-West or Southeast-Northwest combined (ATR stations only). The lane of travel is the fifth field, where 0 is used for combined lanes, 1 for the outer most (right) lane, and 2 to 9 for the other lanes. The sixth field is the year of data collection, in which the last two numbers of the year are used to identify the year of record. The month of data is the seventh field where 01 is January, 02 is February, 03 is March, 04 is April, 05 is May, 06 is June, 07 is July, 08 is August, 09 is September, 10 is October, 11 is November, 12 is December. The eighth field is the day of the month, 01 through

31. The ninth field is the hour the data was recorded where 00 is 0:01 to 1:00 am, 01 is 1:01 to 2:00 am continuing through 23 which represents 11:01 to midnight. The total traffic volume collected during the hour of data collection is the tenth field. Finally, fields 11 through 25 are the volume for each vehicle class of traffic based on the states vehicle classification code.

Table 12: C-Cards Data Format

Field	Column	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	4	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
24 (optional)	90-94	5	Class 14 Count
25 (optional)	95-99	5	Class 15 Count

4.3.2 W-Cards

W-Cards contain axle load and spacing information for individual vehicles in each lane and direction. The data format of the W-Cards can be seen in Table 13. As can be noticed from this table, each W-Card contains up to 105 characters divided among 38 fields. In each W-Card, the first field, the record type, refers to type of data being collected, in which W indicates a truck weight record. The definition of fields 2 through 9 is the same as that in the C-Cards. The tenth field is the vehicle class. However; vehicle classes 1 through 3 are generally omitted because W-Cards primarily focus on weights of trucks and buses. The eleventh field is generally left open to allow data to be collected about additional factors like vehicle speed or pavement temperature. The twelfth field is the total vehicle weight recorded to the nearest 100 kilograms without a decimal point. This field is equal to the sum of all axle weights without rounding. Field thirteen is the total number of axles including any trailers. The spacing and weight of the axles is determined by the axle number. The remaining fields, 14 through 38 represent the axle spacing and weight for each subsequent axle. The number of axles determines the number of axle weight and spacing fields.

Table 13: W-Cards Data Format

Field	Column	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
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

Table 13: W-Cards Data Format (Cont.)

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

4.4 Traffic Data Analysis

Once short and long-term traffic monitoring data has been obtained, ODOT processes this data to produce information that can be used for several purposes including pavement design. One of the most critical pieces of information determined from the traffic data is the average annual daily traffic (AADT). This quantity provides an indication of the total number of vehicles traveling along a roadway in a given day in units of vehicles per day. ODOT uses the AASHTO equation to calculate the AADT from continuous data. This equation averages the traffic volumes based on the day of the week for all twelve months before it calculates the annual average daily value. To calculate the AADT from short-term counts, ODOT uses a series of seasonal and annual adjustment factors. The seasonal adjustment factors are used to account for variations in traffic throughout the year. This value is calculated by taking the three year average traffic volume for each day of the week and dividing it by the three year AADT. All sites within the same functional classification are combined to determine the adjustment factor for each day of the week for a given month. The annual adjustment factors are used to account for variations in traffic from one year to another. These factors are also obtained based on functional classification. ODOT recommends that these factors are used with caution since there are a number of variables that influence traffic volume including the economy and changes in land use. Additionally, ODOT notes that these values may not be applicable in locations with atypical traffic patterns such as theme parks, stadiums and recreational areas.

In addition to the AADT, ODOT determines the average annual daily truck traffic (AADTT) from both short and long-term counts for use in applications that require truck data. ODOT uses the AASHTO equation to calculate the AADTT from long-term counts. Although ODOT did not apply any seasonal adjustment factors to truck data in the past, it has recently implemented truck factoring to estimate AADTT from short-term counts.

Chapter 5

Traffic Monitoring Dataset

5.1 Introduction

This chapter discusses the traffic monitoring dataset that was analyzed to obtain the MEPDG traffic inputs for the various hierarchical levels. The traffic data was collected using permanent traffic monitoring sites distributed throughout the State of Ohio from 2006 to 2011. The total number of sites was 143, with 93 AVC and 50 WIM systems. Figure 3 displays the locations and identification numbers of these sites. Additional information about these sites in terms of location (route, district, county), functional classification, direction, and number of lanes is provided in Tables 14 and 15 for AVC and WIM sites, respectively. As can be noticed from Figure 3, the traffic monitoring sites were primarily located on or near major roadways in both urban and rural locations. As discussed in Chapter 4, AVCs provide information on vehicle count and classification, while WIM systems provide information on vehicle count and classification as well as axle loads and spacings. The AVC data is summarized in the C-Card format and the WIM data is summarized in both C-Card and W-Card formats. The C-Card and W-Card data availability is presented in the following sections.

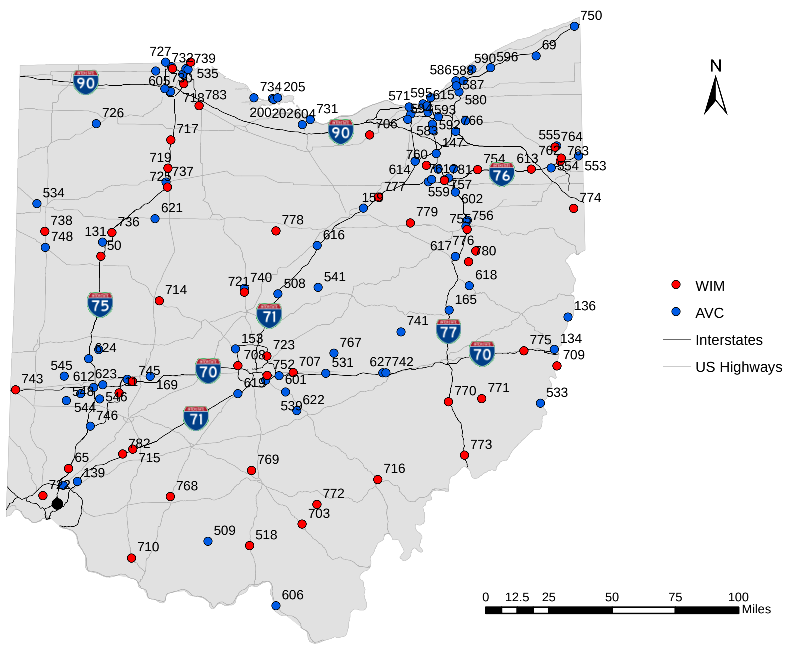


Figure 3: Locations of AVC and WIM Sites in Ohio

Table 14: AVC Sites

Site ID	District	County	FC	Route	Direction	No. of Lanes
69	4	ATB	6	45	NS	2
124	4	STA	11	77	NS	6
131	1	ALL	16	142	EW	2
134	11	BEL	16	40	EW	2
136	11	JEF	12	7	NS	4
139	8	WAR	11	71	NS	8
147	4	SUM	11	77	NS	4
153	6	FRA	11	270	NS	6
158	2	LUC	11	75	NS	8
159	3	ASD	1	71	NS	6
165	11	TUS	6	36	EW	2
169	7	CLA	16	41	NS	2
171	7	CLA	7	316	EW	2
200	2	OTT	14	163	EW	2
202	2	OTT	14	53	NS	2
205	2	OTT	7	269	EW	2
502	6	FRA	12	33	EW	4
508	6	MRW	1	71	N	4
509	9	ADA	2	32	EW	4
531	5	LIC	1	70	EW	6
533	10	MOE	2	7	NS	4
534	1	VAN	2	30	EW	4
538	2	LUC	14	51	NS	4
539	5	FAI	2	33	EW	4
541	5	KNO	2	13	NS	2
544	7	MOT	14	49	NS	4
545	7	MOT	2	49	NS	2
546	7	MOT	12	4	NS	4
548	7	MOT	8	36	EW	2
549	7	MIA	8	193	EW	2
551	4	SUM	11	77	NS	6

Table 14: AVC Sites (Cont.)

Site ID	District	County	FC	Route	Direction	No. of Lanes
553	4	TRU	1	80	W	4
554	4	MAH	12	11	NS	4
555	4	TRU	2	11	S	4
558	4	SUM	11	76	EW	4
559	4	SUM	11	76	W	8
564	4	SUM	12	8	NS	6
568	12	CUY	11	71	NS	8
569	12	CUY	11	77	N	6
571	12	CUY	11	90	E	8
573	12	CUY	11	90	EW	4
575	12	CUY	11	90	EW	9
580	12	CUY	11	271	NS	10
583	12	CUY	11	480	EW	8
586	12	LAK	12	2	EW	6
587	12	LAK	11	90	EW	6
588	12	LAK	11	90	EW	6
590	12	LAK	12	2	EW	4
591	12	CUY	12	422	EW	4
592	12	CUY	11	77	NS	4
593	12	CUY	12	176	NS	6
594	12	CUY	14	237	NS	6
595	12	CUY	12	6	EW	6
596	12	LAK	11	90	EW	4
601	6	FRA	11	70	WB	6
602	4	SUM	11	77	N	6
603	2	LUC	2	20	EW	2
604	3	ERI	2	250	EW	4
605	2	WOO	14	20	EW	4
606	9	SCI	2	52	EW	4
609	3	MED	11	71	NS	6
612	7	MOT	11	75	S	5

Table 14: AVC Sites (Cont.)

Site ID	District	County	FC	Route	Direction	No. of Lanes
614	3	MED	11	271	NS	4
615	12	CUY	11	71	NS	5
616	3	RIC	1	71	NS	6
617	11	TUS	1	77	NS	4
618	11	TUS	12	250	EW	4
619	6	FRA	11	71	NS	4
621	1	HAN	2	30	EW	4
622	5	FAI	12	33	E	4
623	7	MOT	11	70	EW	6
624	7	MIA	11	75	S	6
626	8	HAM	11	275	EW	6
627	5	MUS	1	70	EW	4
726	2	HEN	2	24	EW	2
727	2	LUC	12	23	N	4
729	2	LUC	11	75	NS	4
730	2	LUC	11	475	NS	4
731	3	ERI	12	6	EW	6
734	2	OTT	2	2	EW	4
737	1	HAN	11	75	NS	4
739	2	LUC	11	280	NS	7
740	6	DEL	8	202	S	1
741	5	COS	2	16	EW	2
742	5	MUS	11	70	EW	4
746	7	MOT	11	675	NS	4
748	7	MER	2	33	EW	2
750	4	ATB	11	90	EW	4
756	4	STA	12	30	EW	6
757	4	SUM	11	76	EW	4
761	4	SUM	12	21	NS	4
766	4	SUM	11	480	EW	4
767	5	LIC	12	16	EW	4

Table 15: WIM Sites

Site ID	District	County	FC	Route	Direction	No. of Lanes
50	7	AUG	1	75	NS	4
65	8	BUT	11	75	NS	6
518	9	SCI	2	23	NS	4
535	2	LUC	11	75	N	6
613	4	MAH	1	76	E	4
703	9	JAC	2	35	EW	4
706	3	LOR	12	20	E	4
707	5	LIC	11	70	EW	4
708	6	FRA	11	270	NS	6
709	11	BEL	12	7	NS	4
710	9	BRO	6	68	NS	2
711	8	GRE	11	675	N	4
714	7	LOG	2	33	E	4
715	8	CLI	1	71	NS	4
716	10	ATH	12	33	EW	4
717	2	WOO	1	75	N	4
718	2	WOO	11	75	NS	6
719	1	HAN	1	75	S	4
721	6	DEL	2	23	NS	4
722	8	HAM	12	126	W	4
723	6	FRA	11	270	S	7
725	1	HAN	14	68	NS	4
732	2	LUC	11	475	NS	4
736	1	ALL	11	75	NS	4
738	1	VAN	6	127	NS	2
743	8	PRE	1	70	EW	4
745	7	CLA	1	70	EW	4
752	6	FRA	11	70	EW	6
754	4	POR	1	76	EW	4
755	4	STA	11	77	N	4
760	4	MED	14	18	EW	4

Table 15: WIM Sites (Cont.)

Site ID	District	County	FC	Route	Direction	No. of Lanes
762	4	TRU	11	80	EW	4
763	4	TRU	12	11	NS	4
764	4	TRU	14	82	EW	4
768	9	HIG	14	62	EW	2
769	9	ROS	7	104	NS	4
770	10	NOB	1	77	S	4
771	10	MOE	6	78	EW	2
772	10	VIN	8	683	NS	2
773	10	WAS	7	821	NS	2
774	11	COL	8	14	EW	2
775	11	BEL	1	70	EW	4
776	11	TUS	7	183	EW	2
777	3	WAY	1	71	NS	6
778	3	CRA	2	30	E	4
779	3	WAY	2	30	EW	4
780	11	TUS	6	212	EW	2
781	4	SUM	11	76	EW	4
782	8	CLI	1	71	NS	4
783	2	WOO	2	20	EW	4

5.2 C-Cards Data Availability

Figure 4 provides the number of sites with twelve months of continuous classification data. From this figure, it can be seen that the majority of sites had less than three continuous years of data and only a small number of sites had six continuous years of classification data. This lack of data availability can be attributed to a number of factors including equipment maintenance, equipment failure, and installation of new equipment within the data collection period.

Figure 5 presents the availability of classification data by functional classification. As can be seen from this figure, classification data was available for all functional classifications except 9 (rural local), 17 (urban collector), and 19 (urban local). It can also be noticed that more data is available for functional classifications 1 (rural interstate), 2 (rural principal arterial), 11 (urban interstate), and 12 (urban freeway). This distribution of data will allow for the analysis of traffic trends and generation of statewide averages.

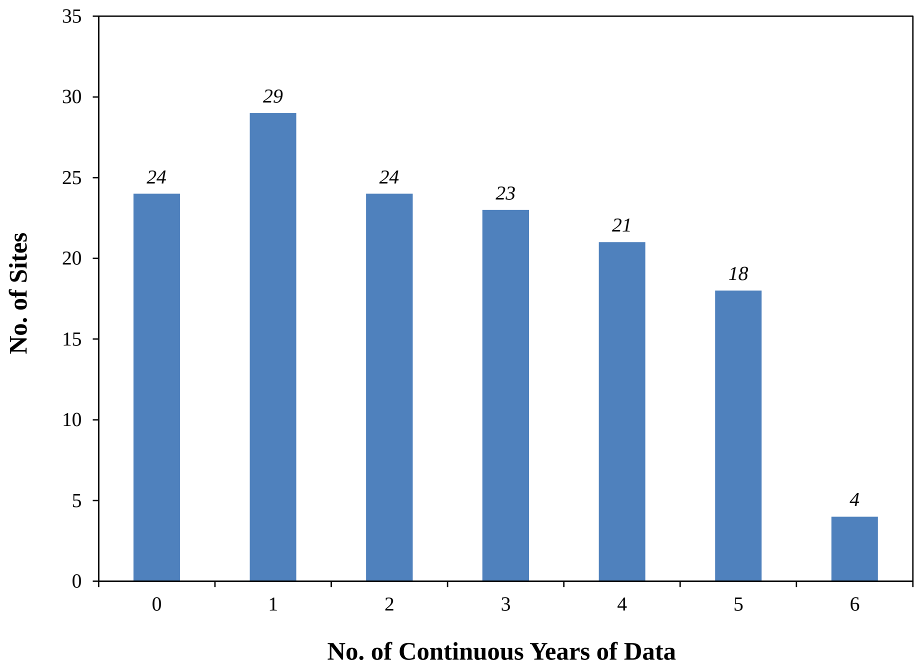


Figure 4: Availability of Classification Data

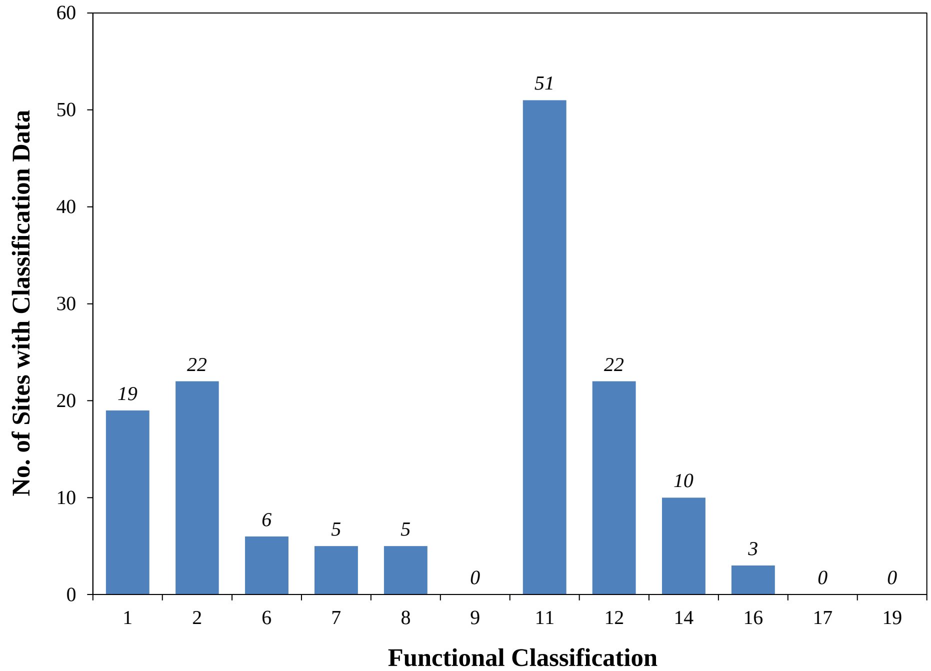


Figure 5: Availability of Classification Data by Functional Classification

5.3 W-Cards Data Availability

Figure 6 provides the number of sites with twelve months of continuous weight data. As can be seen from this figure, all sites had less than six continuous years of data with the majority having less than two continuous years of weight data. As previously noted, traffic weight data can only be obtained from WIM systems, whereas classification data can be obtained from both AVC and WIM systems. Therefore, less data is available for vehicle weight than classification.

Figure 7 presents the availability of weight data by functional classification. As can be seen from this figure, weight data was available for all functional classifications except 9 (rural local), 16 (urban minor arterial), 17 (urban collector), and 19 (urban local). It can also be noticed that more data is available for functional classifications 1 (rural interstate), 2 (rural principal arterial), 11 (urban interstate), and 12 (urban freeway). This distribution of data will allow for the generation of statewide axle load spectra that can be extrapolated to nearby roadways.

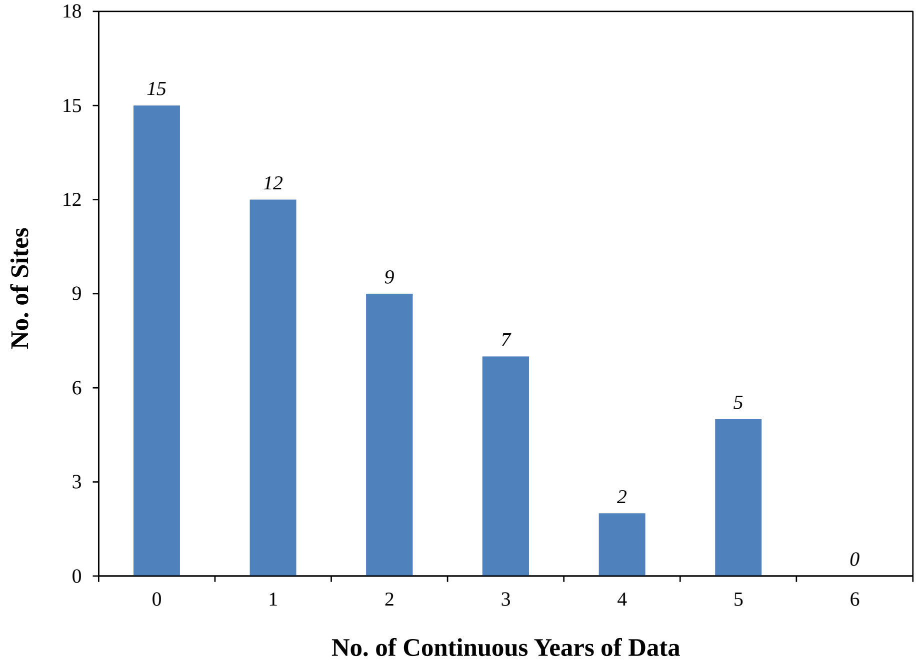


Figure 6: Availability of Weight Data

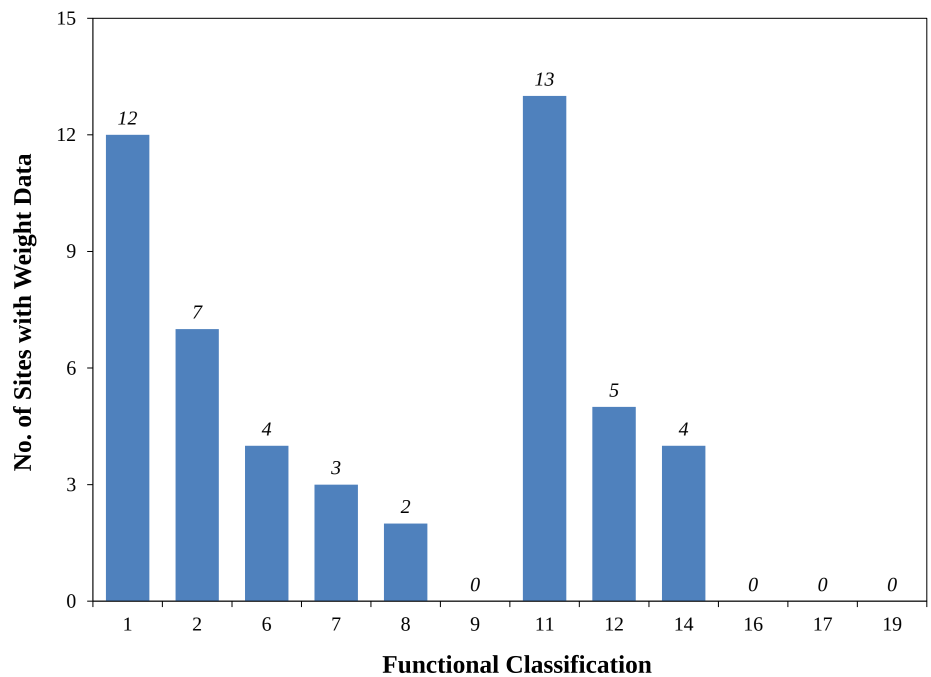


Figure 7: Availability of Weight Data by Functional Classification

Chapter 6
Quality Control of Traffic Monitoring Data

6.1 Introduction

The traffic monitoring data used for this project was provided by ODOT in the form of C-Cards and W-Cards as discussed in Chapter 5. This data was collected by permanent AVC and WIM systems distributed throughout the State of Ohio from 2006 to 2011. Since the C-Cards and W-Cards provided were in their original text format, considerable efforts were made to identify and exclude any erroneous data prior to obtaining the required MEPDG traffic inputs. This quality control process was used to detect invalid data entries, outliers, and trends that would otherwise be unrecognizable due to the amount of data and the variations that occur over the collection period. This process was critical in ensuring that the generated traffic inputs accurately portrayed the traffic characteristics at each AVC and WIM location.

6.2 Types of Error

Long term traffic monitoring systems are subjected to significant wear from traffic and weather. As a result, these devices will occasionally fail to obtain accurate data or require maintenance to maintain their performance. When this occurs, errors are encountered in the recorded data. Additionally, the data retrieved from these devices may contain invalid data entries resulting from the conversion of binary information into a standard text format. In general, this type of error includes empty lines and empty spaces in the data, but can be more subtle like an inaccurate total volume or inaccurate gross weight error. Such errors can cause inaccurate results or prevent the analysis due to inconsistencies in the data format. Another source of error is inconsistent vehicle count or classification due to intermittent malfunction with the traffic monitoring equipment. Furthermore, WIM systems can be affected by temperature, which may cause a shift in the axle load data. In some instances, these shifts may be difficult to identify without examining the axle load spectra over an extended period of time.

6.2.1 Invalid Data Entries

There are many types of invalid data entry that can occur in the recording of traffic data. The traffic monitoring data was examined for the following invalid data entries: empty lines and empty spaces, invalid field values, duplicate data, total volume error, and gross weight error. Empty lines do not contain any relevant information, empty spaces are data records with one or more fields without information, and invalid field values are data entries that do not fall within the expected range (e.g., month $\neq$ 1 to 12 or hour $\neq$ 0 to 23). In all cases, the line containing the error in the C-Card or W-Card was ignored from the analysis.

Duplicate data errors are ones in which two data entries have identical year, month, day, hour, travel direction, and lane number. Once these entries were identified, one of the entries was removed from the analysis. Duplicate data entries would skew the results and reduce the accuracy of the analysis.

The total volume errors are ones in which the sum of each vehicle class volume did not add up to the total volume. These errors are specific to the C-Cards and indicate an equipment malfunction. The gross weight errors are ones in which the sum of each vehicle axle load is not equal to the total gross weight. These errors are specific to the W-Cards and also indicate a potential equipment malfunction. Entries containing total volume or gross weight errors were removed from the analysis to prevent the need to identify which part of the data was incorrect.

6.2.2 Inconsistent Truck Volumes

Truck traffic generally follows a trend in which weekends have relatively low truck volumes and weekdays have higher truck volumes with the peak occurring between Tuesday and Thursday. Additionally, there is little variation in truck volumes between consecutive days of week from one week to another. Any data that does not reflect this trend could be due to equipment malfunction or atypical traffic patterns. Such occurrences may distort the actual traffic trends and lead to inaccurate traffic characterization.

An outlier detection method was developed to identify inconsistent truck volumes and exclude them from the analysis. Outliers are data points that vary significantly from the rest of the data. These data points can affect the analysis and the ability to obtain accurate trends in the data. As a result, it is imperative to identify these outliers in order to ensure a successful analysis. The presence of non-stationary or noisy data makes identifying outliers a difficult process. A stationary dataset is one in which there is little fluctuation, while the amount of "noise" refers to the number of misleading or outlying data points. When data fluctuates, it is more challenging to identify outliers because a trend that represents a portion of the data may not be applicable to the entire dataset.

Several outlier detection techniques have been investigated to determine their suitability for identifying inconsistent truck volumes. These techniques included the Z-score method, the modified Z-score method, the Grubbs' test, the two-sided median-based method, and the one-sided median-based method (*8*). The following paragraphs offer a summary of these techniques and highlight their advantages and limitations.

The Z-Score method screens data for outliers using the sample mean and standard deviation. The Z-score is calculated using the following equation:

$$Z_i = \frac{y_i - \bar{y}}{\sigma} \geq 3 \text{ or } \frac{n-1}{\sqrt{n}} \quad (10)$$

where y_i is an observation, $\bar{y}$ is the sample mean, σ is the sample standard deviation, and n is the number of data points in the sample. As can be seen from the previous equation, the Z-score calculates the difference between each observation and the sample mean and then divides that value by the sample standard deviation. The result is then compared to a critical value to determine if the observation is an outlier. Generally, a Z-score equal to or greater than three indicates the presence of an outlier.

The Z-score method assumes that the dataset follows a standard normal distribution. Therefore, if the data is not normally distributed, the critical value calculation will be incorrect. This method is also based on the sample mean, which may be influenced by outlying data points resulting in an under-detection of outliers. Another limitation of this method is that the standard deviation may be inflated by a single data point with an extreme value, which may prevent the detection of less extreme outliers.

The modified Z-score method utilizes the sample median and the median of the absolute deviation from the sample median to detect outliers. The following equation is used to calculate the modified Z-score:

$$M_i = \frac{0.6745|y_i - \tilde{y}|}{\text{median}\{|y_i - \tilde{y}|\}} \geq 3.5 \quad (11)$$

where M_i is the modified Z-score, y_i is an individual data observation, and $\tilde{y}$ is the median of the data sample. As can be seen from the previous equation, the modified Z-score method calculates the deviation between each data point and the sample median. This value is then multiplied by 0.6745 and divided by the median of the absolute deviation of each observation from the sample median. If the modified Z-score is found to be greater than or equal to 3.5, the data point is considered to be an outlier.

As discussed previously, the sample mean may be influenced by outlying data points resulting in an under-detection of outliers. The modified Z-Score method addresses this issue by using the sample median instead of mean in detecting outliers. As a result, the masking that occurs when using the Z-score method can be avoided and more outliers can be identified.

The Grubbs' test utilizes the maximum deviation from the mean and the standard deviation to identify outliers:

$$G_i = \frac{\max(y_i - \bar{y})}{\sigma} \geq \frac{n-1}{\sqrt{n}} \sqrt{\frac{t^2_{\alpha/(2n),n-2}}{n-2+t^2_{\alpha/(2n),n-2}}} \tag{12}$$

where y_i is the individual data observation, $\bar{y}$ is the sample mean, σ is the standard deviation, n is the number of data points in the sample, and $t^2_{\alpha/(2n),n-2}$ is a t-statistic used for a two sided test. As can be seen from the previous equation, the maximum absolute value of the deviation of each data point is calculated by subtracting the sample mean from each observation. This value is then divided by the sample standard deviation. The result is then compared to a critical value calculated using the above-mentioned t-statistic and the number of data points.

The Grubbs' test is an iterative procedure where one outlier is identified per iteration. As a result, the number of observations, sample mean and sample standard deviation must be recalculated every iteration. Additionally, the Grubbs' test uses the sample mean and standard deviation in detecting outliers, which may be biased by the presence of extreme values in the observation data as discussed previously.

The main limitation of the previous outlier detection methods is that the entire dataset must be considered when determining the presence of outliers. This limitation can be addressed using the two-sided and one-sided median-based methods. The two-sided median-based outlier detection method is graphically displayed in Figure 8. As can be seen from this figure, this method uses a neighborhood of data points to identify outliers in a data series. The neighborhood consists of a number of data points ($\eta_t^{(\kappa)} = \{y_{t-\kappa}, \ldots, y_{t-1}, y_{t+1}, \ldots, y_{t+\kappa}\}$) defined by 2κ within a window starting at $t - \kappa$ and ending at $t + \kappa$. The data is ranked to determine the median, $m_t^{(k)}$, of the neighborhood. Once the median is calculated, the difference between the data point and the median is compared to a threshold, τ, to determine if that data point is an outlier. If the absolute value of the difference is greater than or equal to the threshold, $|y_t - m_t^{(k)}| \geq \tau$, the data point is an outlier.

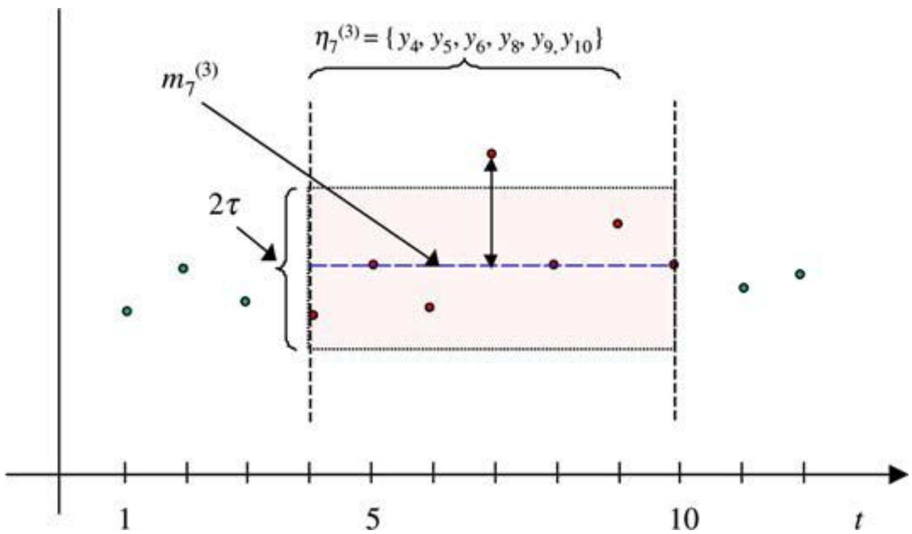


Figure 8: Graphical Representation of the Two-Sided Outlier Detection Method (*9*)

The one-sided median-based outlier detection method is a modified version of the two-sided median-based method. The primary difference between the two methods is in the comparison with the threshold value. To determine whether a data point is an outlier, the one-sided median-based method compares the difference rather than the absolute difference between the data point and its neighborhood median, m_t, to the threshold, τ. As a result, the one-sided median-based method can be used to identify sudden jumps in the data where the outlier is greater than the median of the neighborhood ($y_t - m_t^{(k)} \geq \tau$) or sudden drops in the data where the outlier is less than the median ($m_t^{(k)} - y_t \geq \tau$). The threshold value used in the two-sided and one-sided median-based methods is determined using judgment and actual trends in the data. Additionally, these methods provide the ability to adjust the threshold value and the neighborhood window for different parts of the data.

The most common factor leading to inconsistent truck volumes is equipment malfunctioning in one of the two directions. Given that daily truck volumes are calculated for both directions, this will result in a sudden drop in the ADTT value obtained for these days, which would reduce the estimation of the AADTT. The one-sided median-based outlier detection method was used to identify these sudden drops and remove them from the analysis. In order to obtain a more stationary data and allow for the implementation of the one-sided median-based outlier detection method, the truck volume data was separated based on the day of week. Figure 9 presents twelve consecutive months of daily truck volumes collected at a continuous traffic monitoring site. Figure 10 shows the trucks volumes from Figure 9 separated based on the day of week. As can be seen from these figures, the day of week truck volumes are relatively constant throughout this period with slight variations due to seasonality. Additionally, once the daily truck volumes are separated based on the day of week, it becomes more apparent which values are outliers. Through visual inspection of numerous traffic monitoring sites, a threshold function equal to $\tau = 2 \times (\text{Median DOW ADTT})^{3/4}$ was found to provide satisfactory outlier detection results using a neighborhood window of nine data points ($\kappa = 4$). Using this threshold function and the comparison previously described, the outliers were detected and are highlighted in red in Figure 11. With the outliers identified, the daily truck volumes were reassembled for the twelve month period as seen in Figure 12.

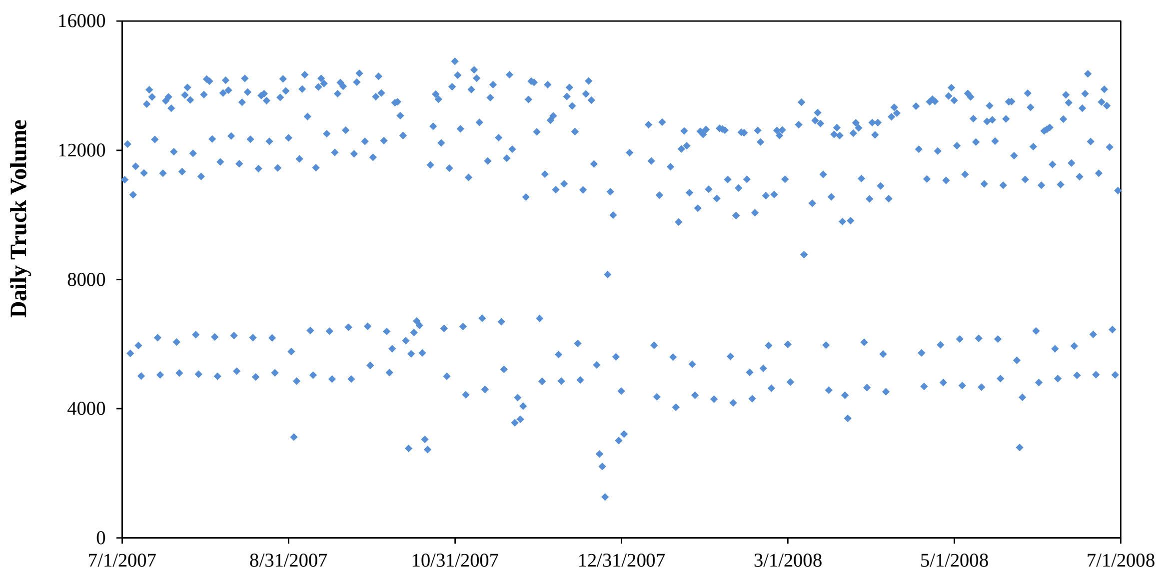


Figure 9: Daily Truck Volumes for Twelve Consecutive Months

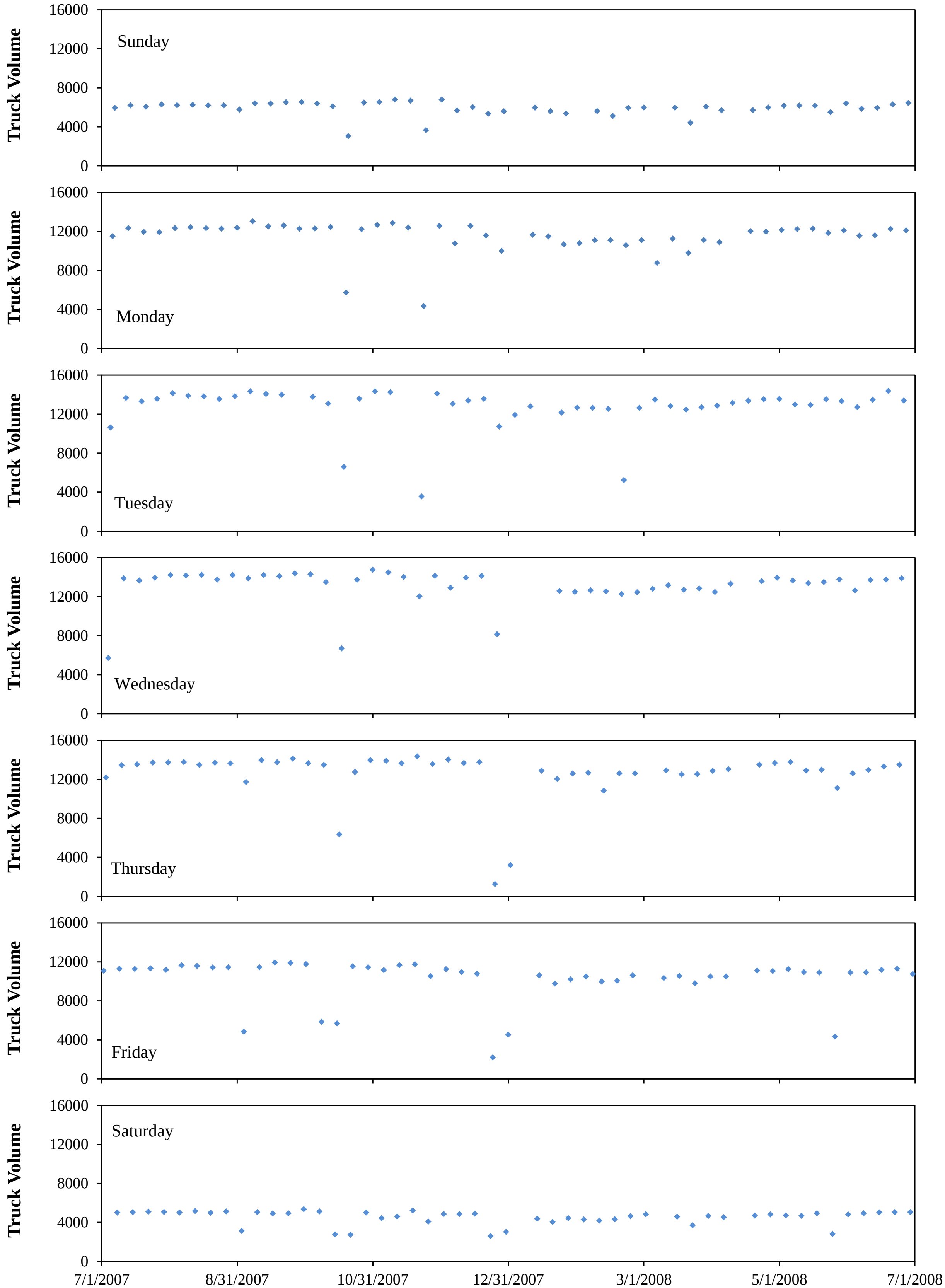


Figure 10: Day of Week Truck Volumes

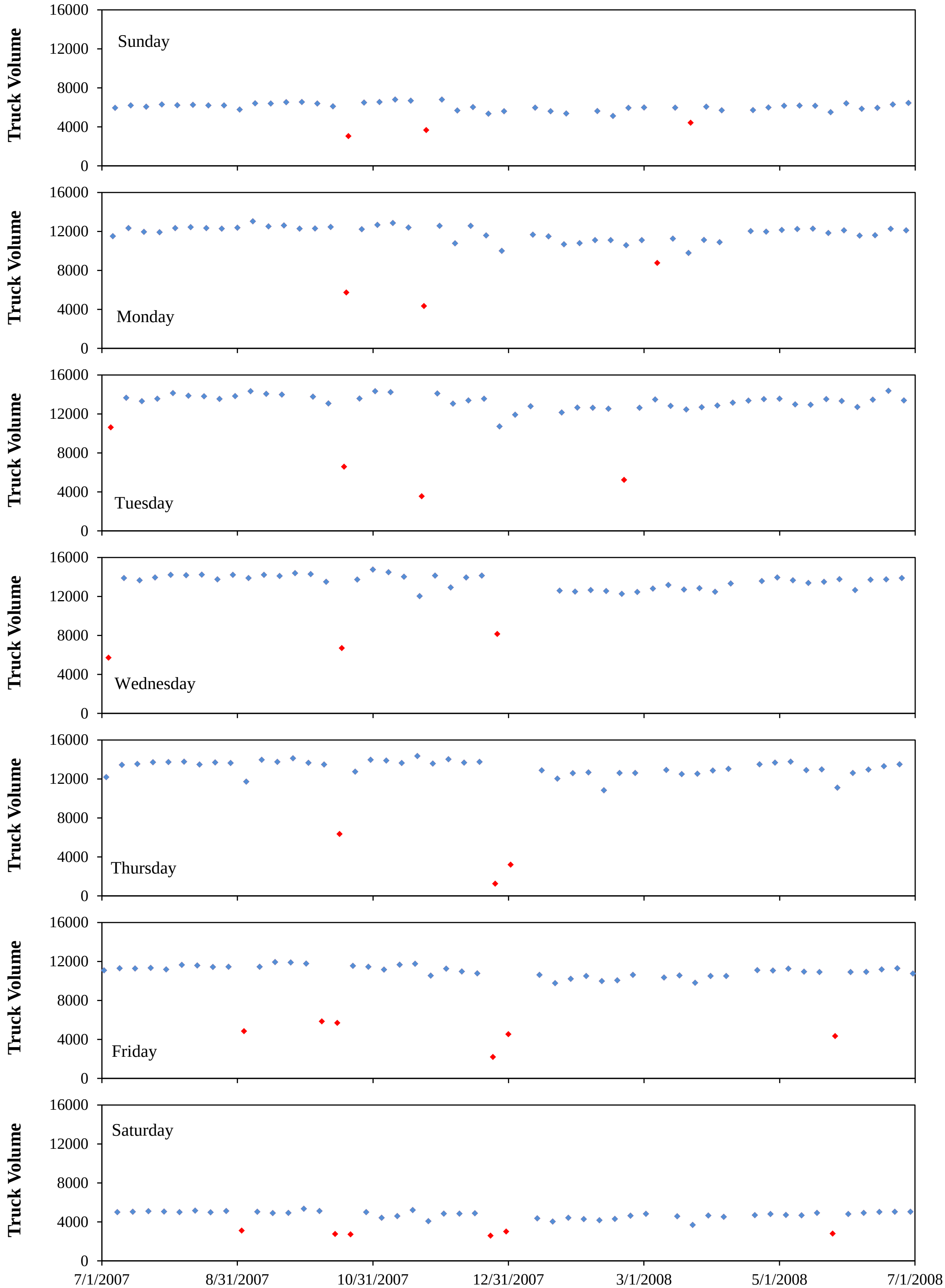


Figure 11: Day of Week Truck Volumes (Outliers in Red)

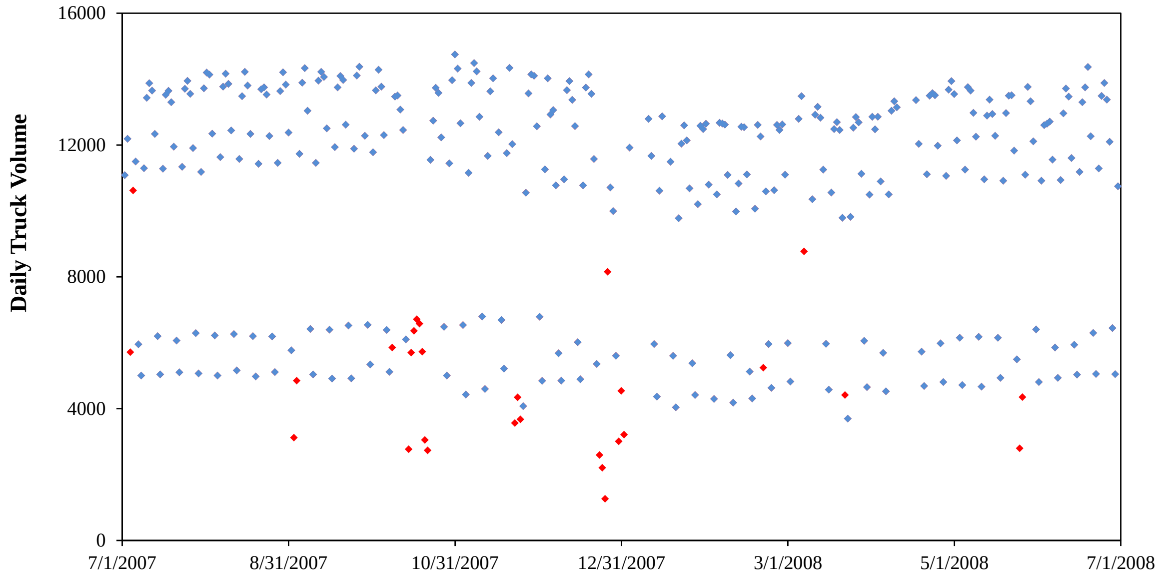


Figure 12: Daily Truck Volumes for the Twelve Month Period (Outliers in Red)

6.2.3 Gross Weight and Axle Load Spectra Errors

As previously mentioned, WIM systems can be affected by temperature and weather conditions, which may cause a shift in the axle load spectra. Also, these devices require annual calibration to provide accurate axle load data. To validate the performance of WIM systems, typical weight ranges have been established by the LTPP for the front steering and drive tandem axles as well as the gross vehicle weight of Class 9 trucks. According to the LTPP, the front axle should be in the range of 8,000 to 12,000 lbs (35.6 to 53.4 kN) regardless of whether the truck is loaded or empty, while the drive tandem of a fully loaded truck should be between 30,000 to 36,000 lbs (133.4 to 160.1 kN). Furthermore, when the gross vehicle weight of Class 9 trucks is plotted in a histogram, there should be two peaks: one peak between 28,000 and 36,000 lbs (124.6 to 160.1 kN) and another peak between 72,000 and 80,000 lbs (320.3 to 355.9 kN). If a plot shows both peaks shifted from their expected range, the scale probably needs to be calibrated. For histograms with one shifted peak, the site data should be reviewed for other potential errors such as a high number of classified but not weighed vehicles. This could be an indication of an equipment error or a large number of vehicles exceeding the legal weight limit. Finally, the number of vehicles with weights greater than 80,000 lbs (355.9 kN) should be inspected. If there is a high percent of vehicles that fall in that category it may be an indication that the WIM device needs to be calibrated. It is noted that some states like Michigan have vehicle weight limits that are greater than 80,000 lbs (355.9 kN), which is also the case for northwest Ohio. Therefore, special considerations should be given to sites in these regions.

By analyzing the gross weight and axle load distributions at all WIM sites in Ohio, modified weight ranges of those recommended by the LTPP were implemented in this study to validate the weigh in motion data. An empty weight of 28,000 to 36,000 lbs (124.6 to 160.1 kN) and a full weight of 70,000 to 80,000 lbs (311.4 to 355.9 kN) were used for the gross vehicle weight of Class 9 trucks. In addition, a front axle load and a full drive tandem load of 8,000 to 12,000 lbs (35.6 to 53.4 kN) and 28,000 to 36,000 lbs (124.6 to 160.1 kN) were used, respectively. The two main differences are the reduction in the lower limits for the full gross weight from 72,000 lbs (320.3 kN) to 70,000 lbs (311.4 kN) and the full drive tandem load from 30,000 lbs (133.4 kN) to 28,000 lbs (124.6 kN). These limits were reduced to accommodate the large number of Class 9 trucks that were observed just below the recommended LTPP limits. If any of the monthly gross weights or axle loads were found to be outside these modified ranges, they were excluded from the analysis and the remaining gross weight and axle load data was used in the calculation of the annual averages.

An example of the influence of erroneous monthly gross vehicle weights on the annual gross vehicle weight can be seen in Figures 13 through 16 for Site 518, which is located in southern Ohio along US Highway 23. As can be noticed from Figure 13, there are many months in 2008 with peak weights outside the previously described empty and full weight ranges, which results in an annual gross vehicle weight deviating from the expected ranges. In Figures 15 and 16, it can be seen that when the erroneous monthly gross vehicle weights are removed, the peaks of the annual gross vehicle weight are more consistent with the expected ranges.

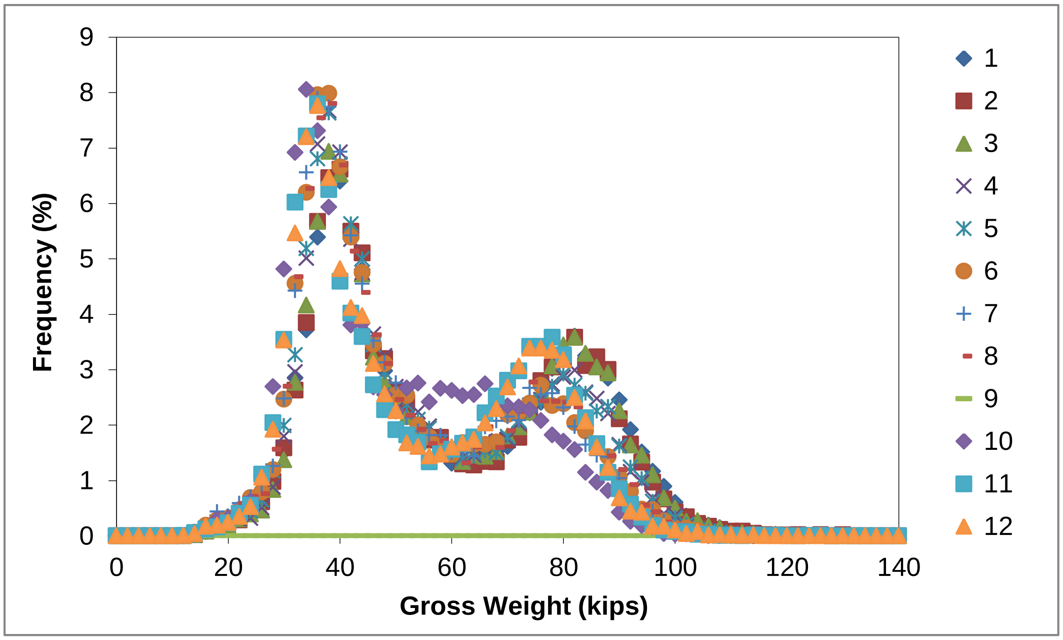


Figure 13: Unadjusted Monthly Class 9 Gross Vehicle Weight for Site 518 and Year 2008

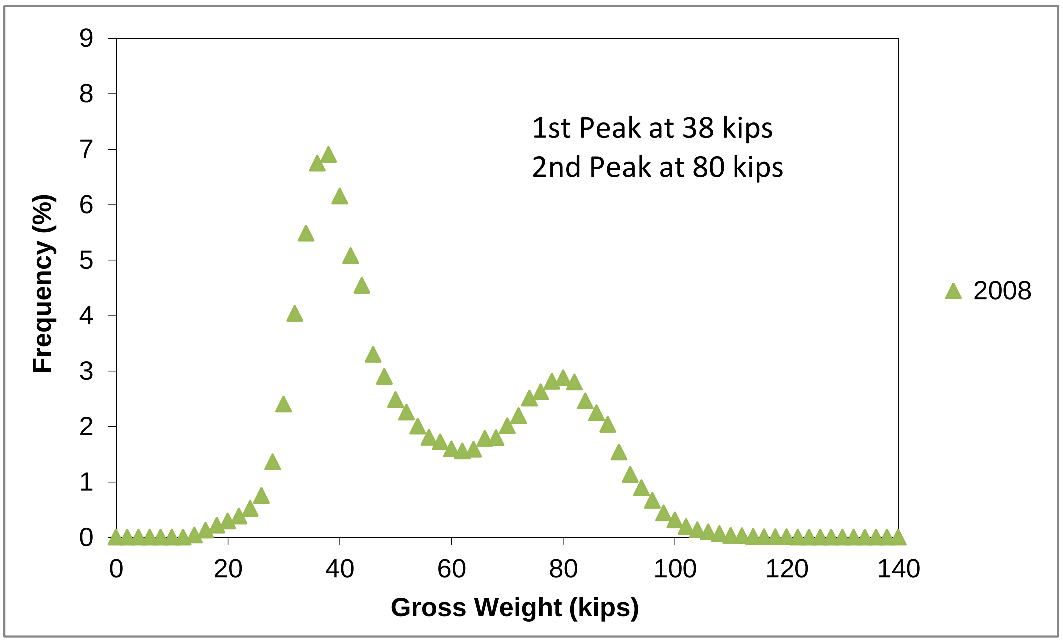


Figure 14: Unadjusted Annual Class 9 Gross Vehicle Weight for Site 518 and Year 2008

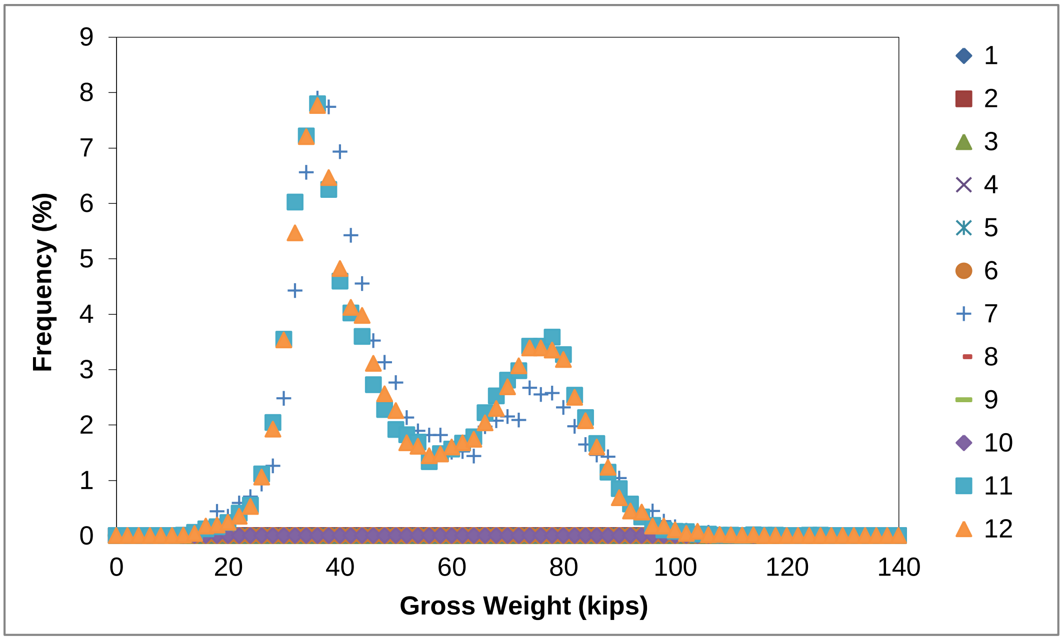


Figure 15: Adjusted Monthly Class 9 Gross Vehicle Weight for Site 518 and Year 2008

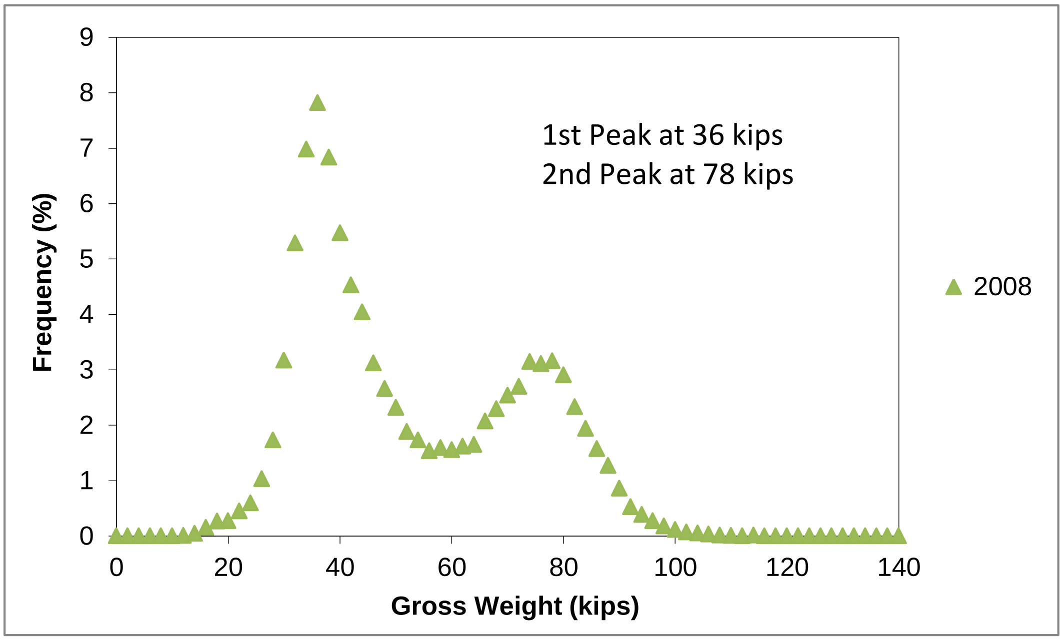


Figure 16: Adjusted Annual Class 9 Gross Vehicle Weight for Site 518 and Year 2008

6.3 Conflicting Trends Between Adjacent Sites

Traffic data from adjacent sites and sites along the same roadway were used to determine if the data obtained was accurate and representative of the traffic characteristics. These sites were examined for conflicting trends in truck class count, truck class distribution, and gross vehicle weight and axle load spectra. Figures 17 to 26 show the six-year average daily truck count by class across the State of Ohio. Sites with truck counts less than ten were not included to facilitate the visual comparison between the sites. The advantage of these figures is that they associate the truck count data, obtained from continuous traffic monitoring sites, to their respective location, which allows for a more direct comparison between neighboring sites. In doing so, it should be noted that since these figures show the six-year averages, the variability among adjacent sites could in part be due to annual variations in truck traffic. An example of conflicting trends in truck count can be seen by comparing site 708 west of Columbus on interstate 270 to other adjacent sites. For this site, it can be noticed that the truck counts for Classes 4, 5, 6, 8, and 10 are significantly higher than the truck counts recorded by adjacent sites for these classes. While it is expected to have some variability between neighboring sites, the increases and decreases can in general be tracked by the counts recorded at nearby sites. From these figures, it can be observed that the truck counts recorded at neighboring sites does not support such high truck counts obtained at site 708 for the above-mentioned truck classes.

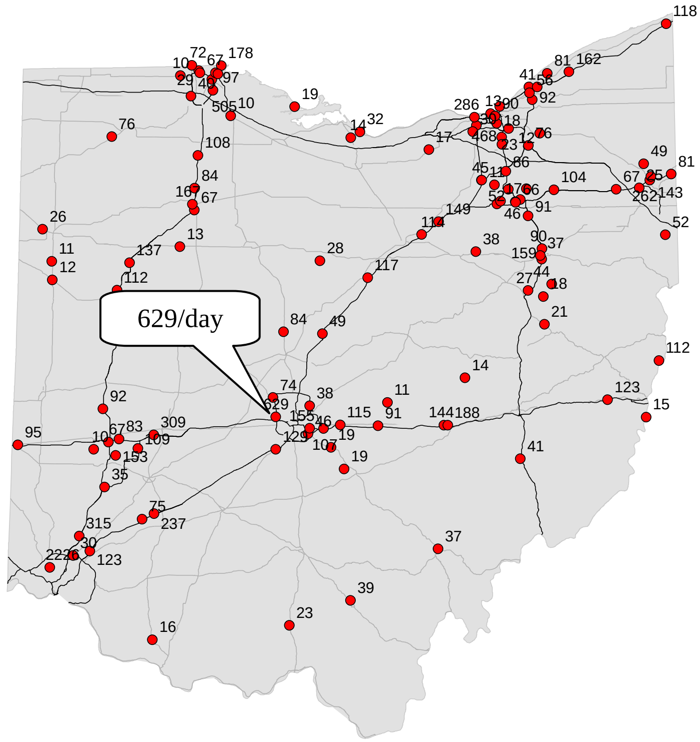


Figure 17: Six-Year Average Daily Class 4 Truck Count

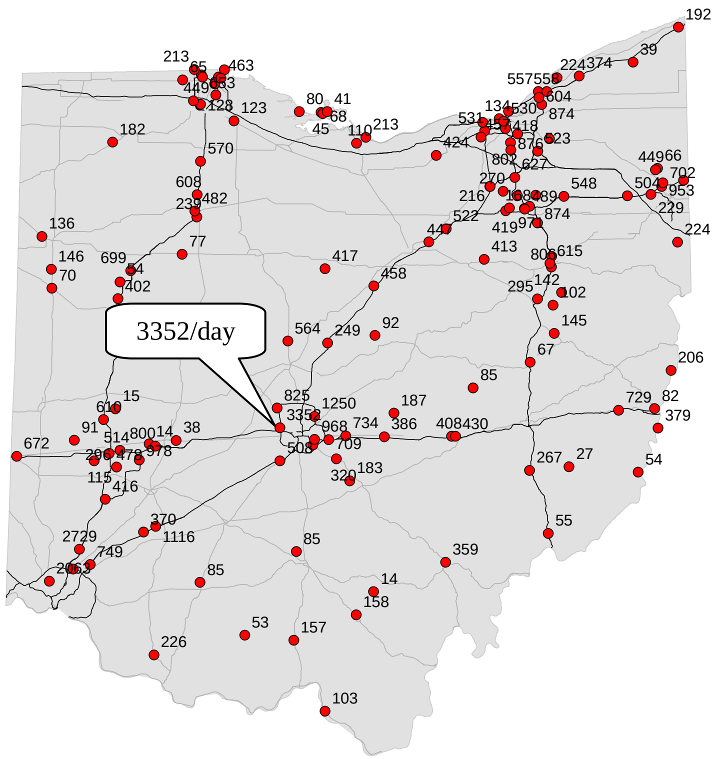


Figure 18: Six-Year Average Daily Class 5 Truck Count

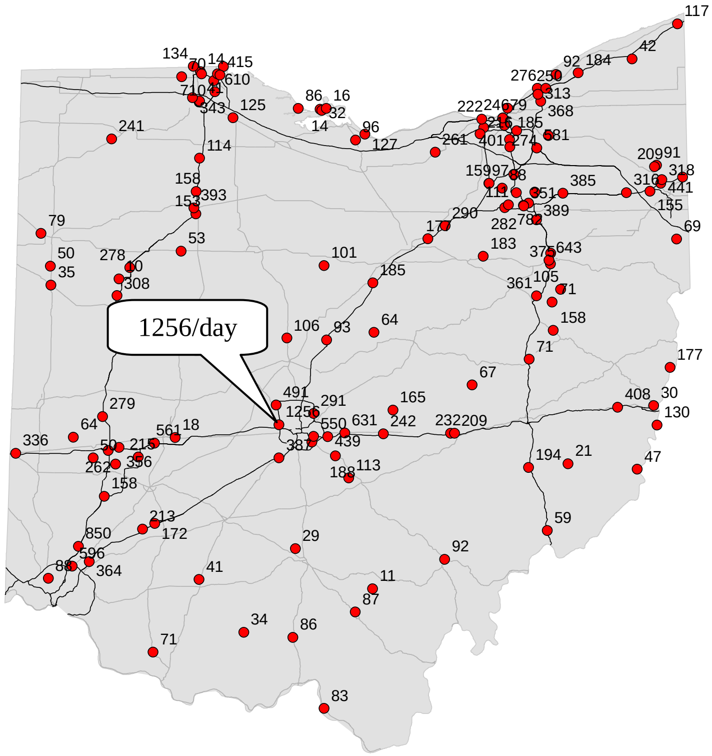


Figure 19: Six-Year Average Daily Class 6 Truck Count

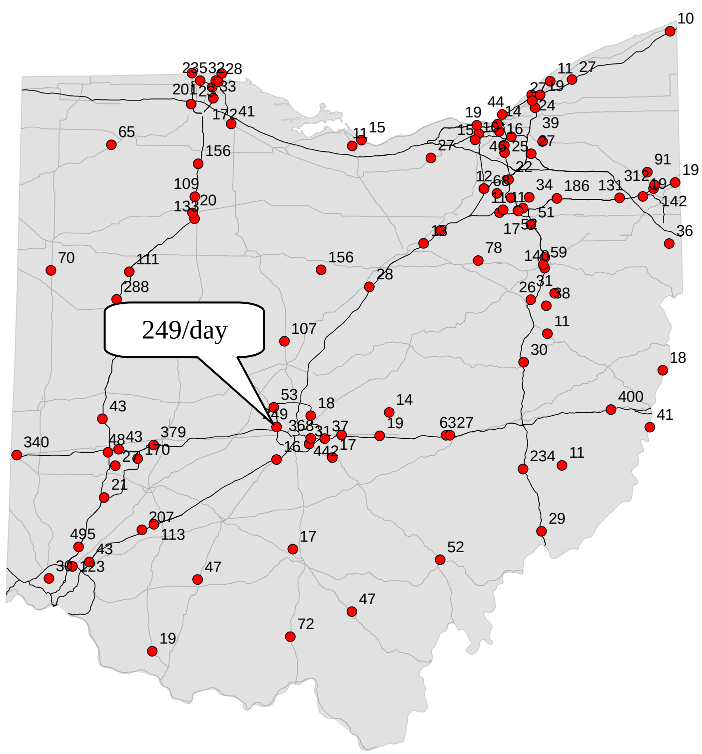


Figure 20: Six-Year Average Daily Class 7 Truck Count

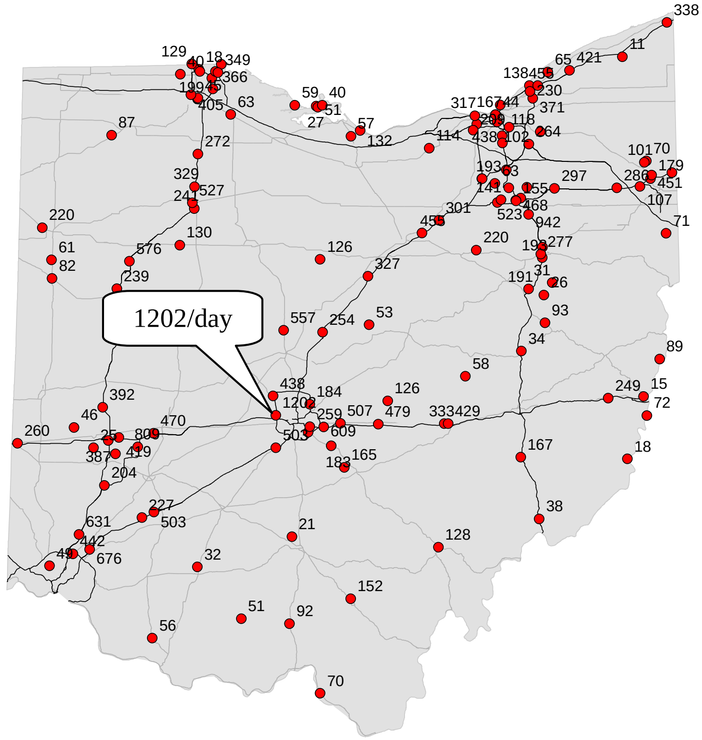


Figure 21: Six-Year Average Daily Class 8 Truck Count

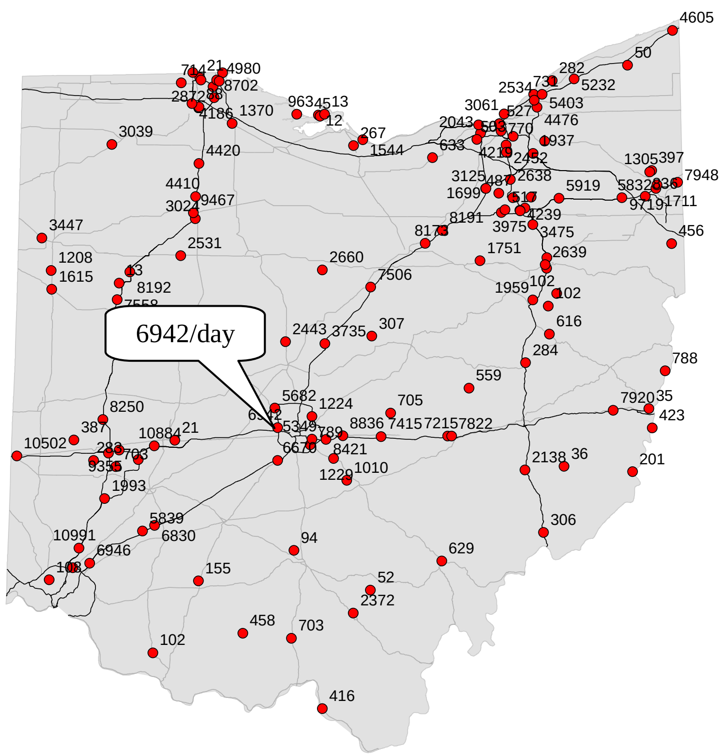


Figure 22: Six-Year Average Daily Class 9 Truck Count

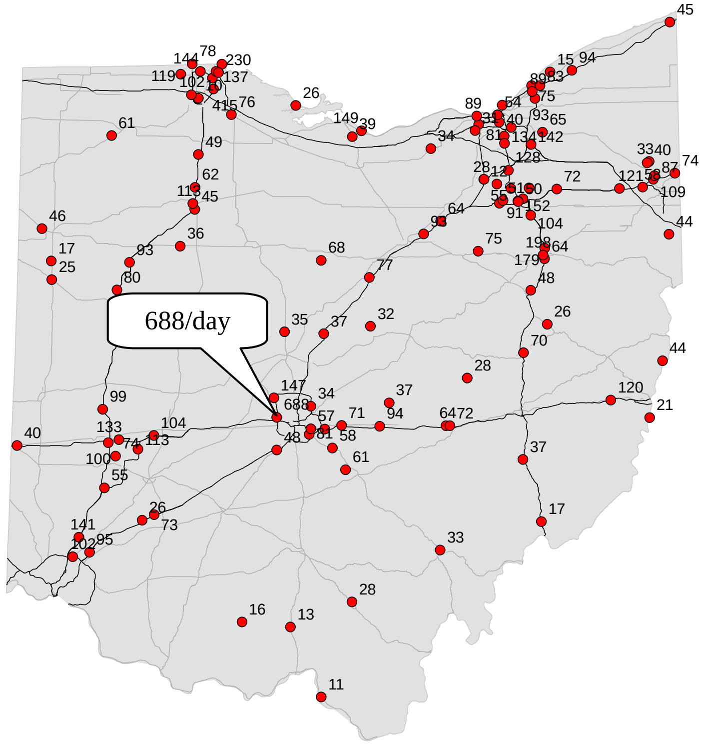


Figure 23: Six-Year Average Daily Class 10 Truck Count

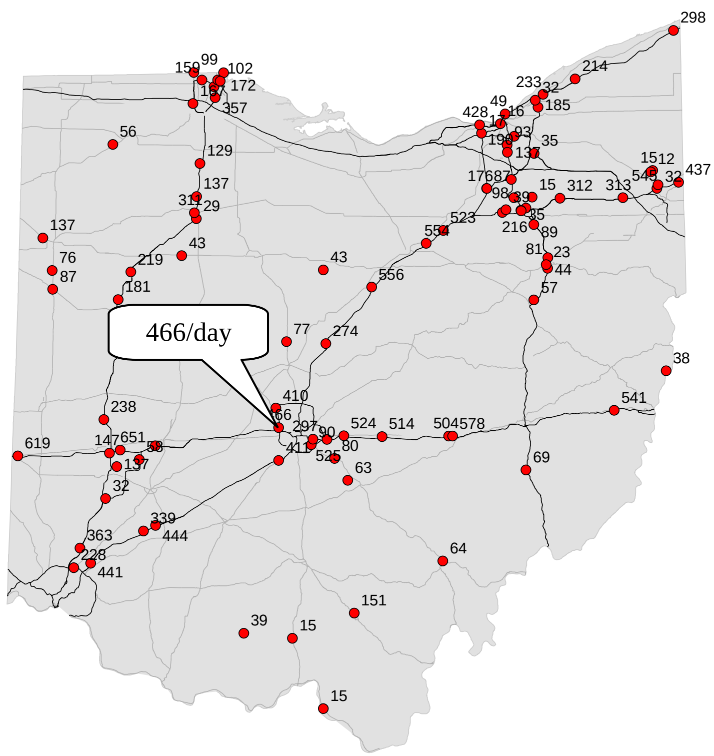


Figure 24: Six-Year Average Daily Class 11 Truck Count

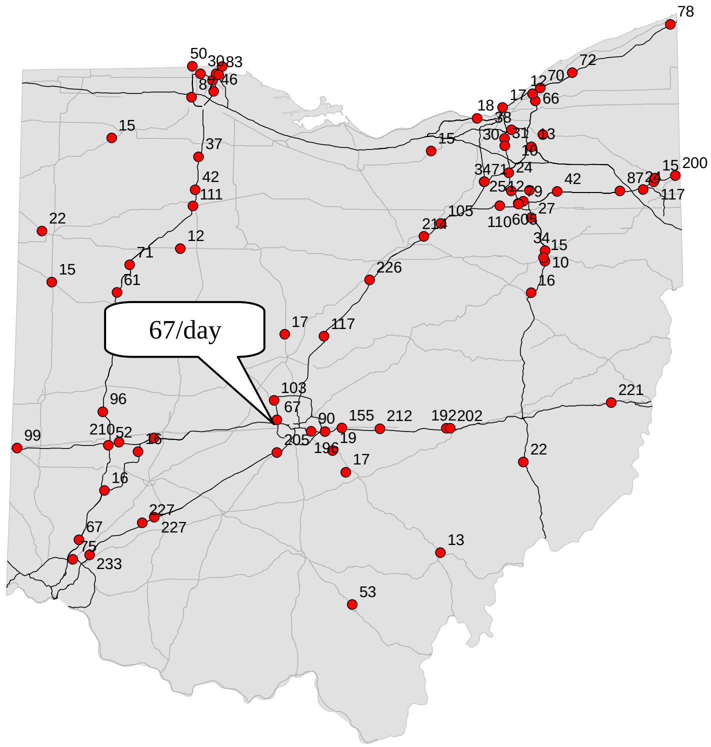


Figure 25: Six-Year Average Daily Class 12 Truck Count

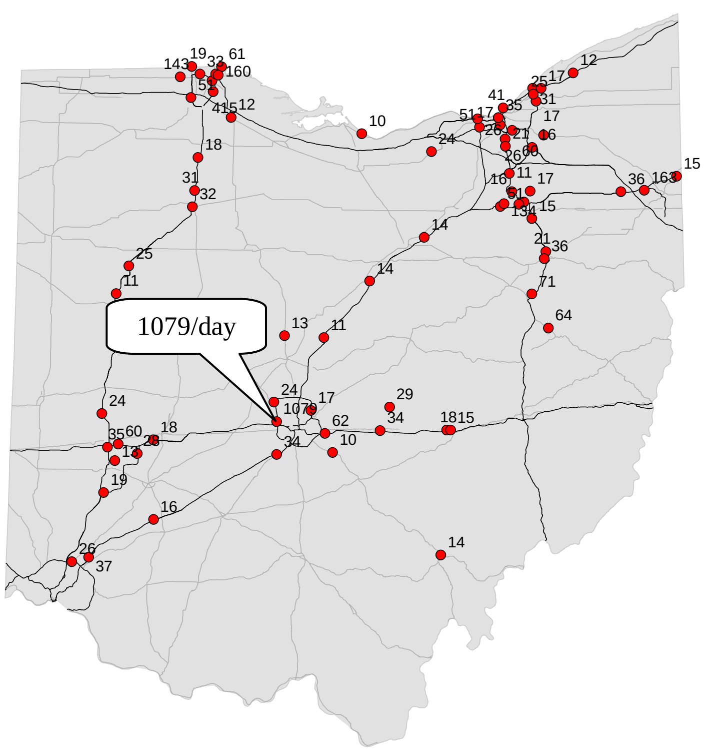


Figure 26: Six-Year Average Daily Class 13 Truck Count

In addition to comparing adjacent sites based on truck counts, the sites were compared according to their truck class distribution. It is expected that the truck class distribution will vary outside and within major cities; however, these changes are generally gradual and should not contain large fluctuations. An example of an inconsistent truck class distribution along interstates 71, 76, 271, and 90 (from Cincinnati in southwestern Ohio to Cleveland and Akron in northeastern Ohio) is shown in Figure 27 and Tables 16 to 18. As can be seen in Tables 16 and 17, the percentage of Class 9 trucks along interstates 71, 271, and 90 varies between 70 to 80% outside the major cities. However, this percentage reduces significantly closer to Cleveland where a noticeable increase in the percentage of Class 5, 6, 8, 10, and 13 trucks is observed. In Table 18, it can be seen that the percentage of Class 9 trucks ranged between 65 and 75% except for site 757, which shows high percentages of Class 5, 6, 7, 12, and 13 trucks. While the decrease in Class 9 and increase in Class 5 is expected in an urban environment, the relatively high percentages of truck Class 6, 7, and 12 are significantly greater than observed at neighboring sites. This indicates that this site was not properly working and when this was brought to ODOT's attention, it was revealed that the site was indeed not working properly and was replaced with site 781.

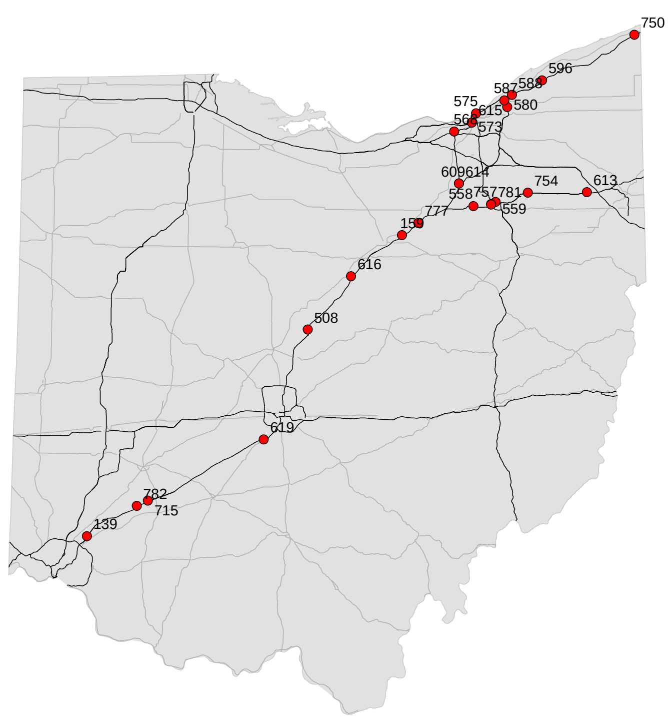


Figure 27: Continuous Traffic Monitoring Sites along Interstates 71, 76, 271, and 90

Table 16: Truck Class Distribution along Interstate 71

				Truck Class Distribution (%)									
Route	**Site**	**FC**	**City**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
71	139	11	CIN	1	8	4	0	7	72	1	5	2	0
71	782	1	--	1	5	3	3	3	78	0	5	3	0
71	715	1	--	2	11	2	1	5	70	1	5	2	0
71	619	11	COL	2	11	2	1	5	70	1	5	2	0
71	508	11	COL	1	5	2	0	5	77	1	6	2	0
71	616	1	--	1	5	2	0	3	79	1	6	2	0
71	159	1	--	1	4	2	0	4	80	1	5	2	0
71	777	1	--	1	5	3	3	3	78	1	5	1	0
71	609	11	CLE	2	14	6	0	8	63	2	3	1	0
71	568	11	CLE	5	22	16	1	7	43	3	1	0	2
71	615	11	CLE	5	33	14	1	10	31	3	1	0	2

Table 17: Truck Class Distribution along Interstates 271 and 90

				Truck Class Distribution (%)									
Route	**Site**	**FC**	**City**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
271	614	11	--	1	5	2	0	5	79	1	4	2	0
271	580	11	CLE	1	13	6	1	6	68	1	3	1	0
90	588	11	--	2	8	3	0	6	75	1	3	1	0
90	596	11	--	2	6	3	0	6	77	1	3	1	0
90	750	11	--	2	3	2	0	6	79	1	5	1	0

Table 18: Truck Class Distribution along Interstate 76

				Truck Class Distribution (%)									
Route	**Site**	**FC**	**City**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
76	558	11	--	1	7	4	0	5	75	1	5	2	1
76	781	11	AKR	1	8	6	3	3	73	1	4	1	0
76	757	11	AKR	1	15	23	11	4	36	1	0	6	2
76	559	11	AKR	1	10	8	1	6	66	2	3	1	1
76	754	1	--	1	7	5	2	4	75	1	4	1	0
76	613	1	--	1	7	4	2	4	76	2	4	1	0

The gross vehicle weight and axle load spectra were also compared between adjacent sites and sites along the same roadway. Figures 28 to 33 show the gross vehicle weight distribution for Class 9 trucks along interstate 70. As can be seen from Figures 29 through 33, all sites expect site 707 follow the same trend in which the frequency corresponding to the full gross peak is higher than the frequency corresponding to the empty gross peak, which is typical for interstate highways. This indicates that site 707 is not properly working and should not be included in the development of the statewide axle load averages. Since the gross vehicle weight of Class 9 trucks fell within the expected weight ranges, it would not have been possible to determine that this site was not working without comparing it to adjacent sites.

Figure 28: WIM Sites along Interstate 70

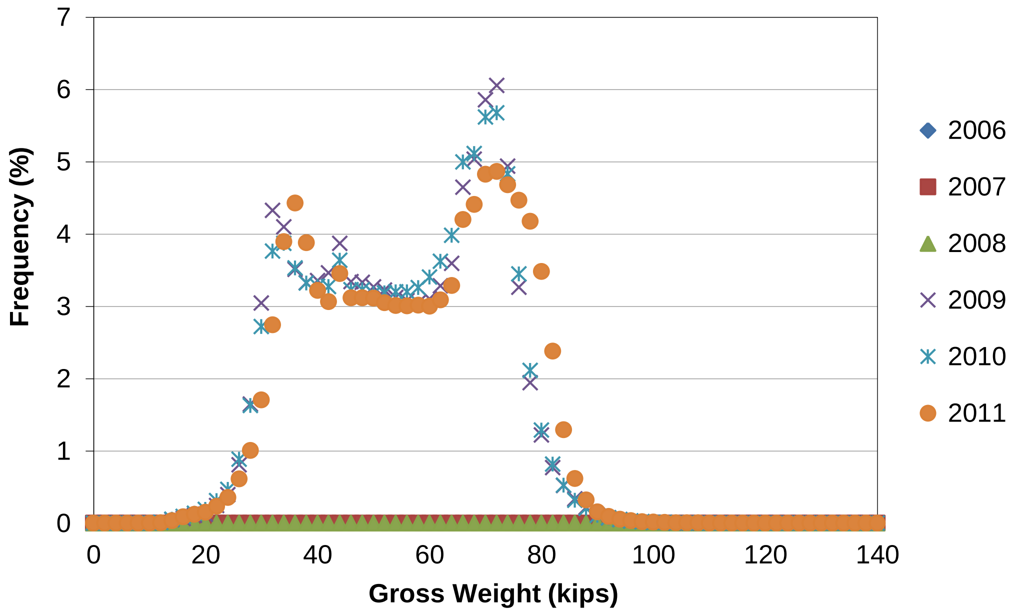


Figure 29: Annual Class 9 Gross Weight Distribution at Site 775

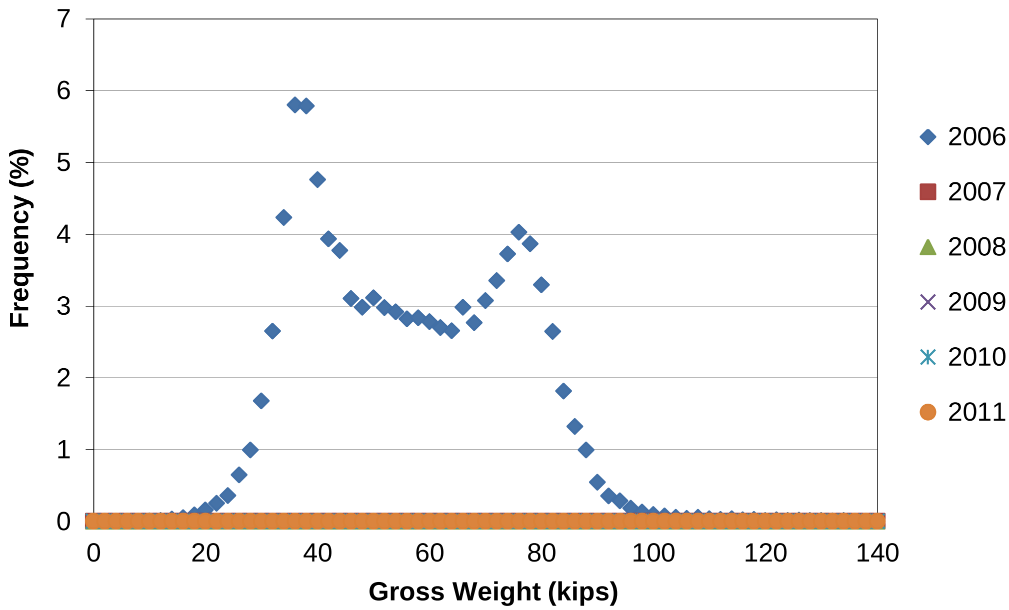


Figure 30: Annual Class 9 Gross Weight Distribution at Site 707

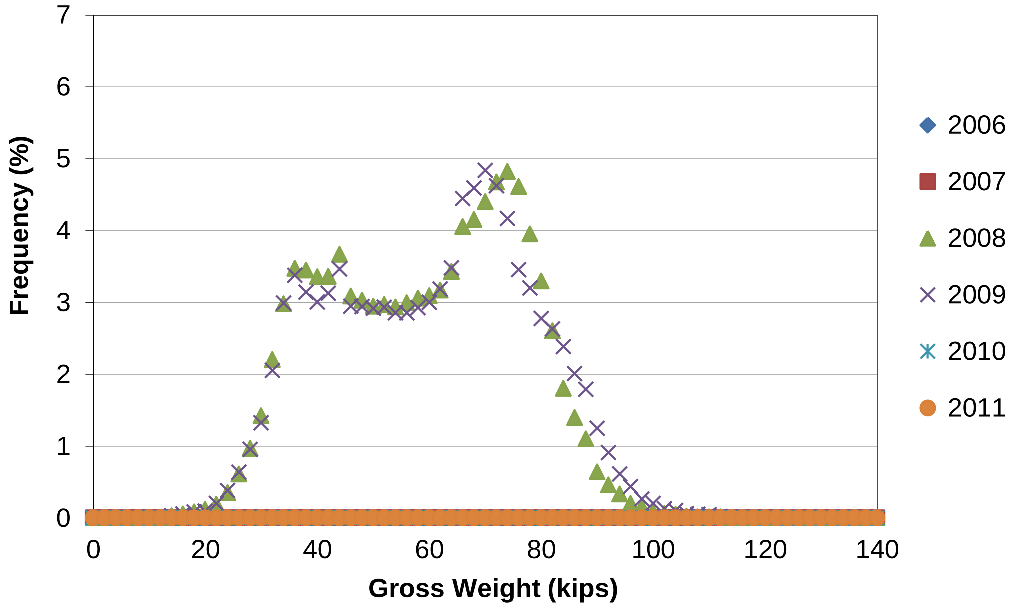


Figure 31: Annual Class 9 Gross Weight Distribution at Site 752

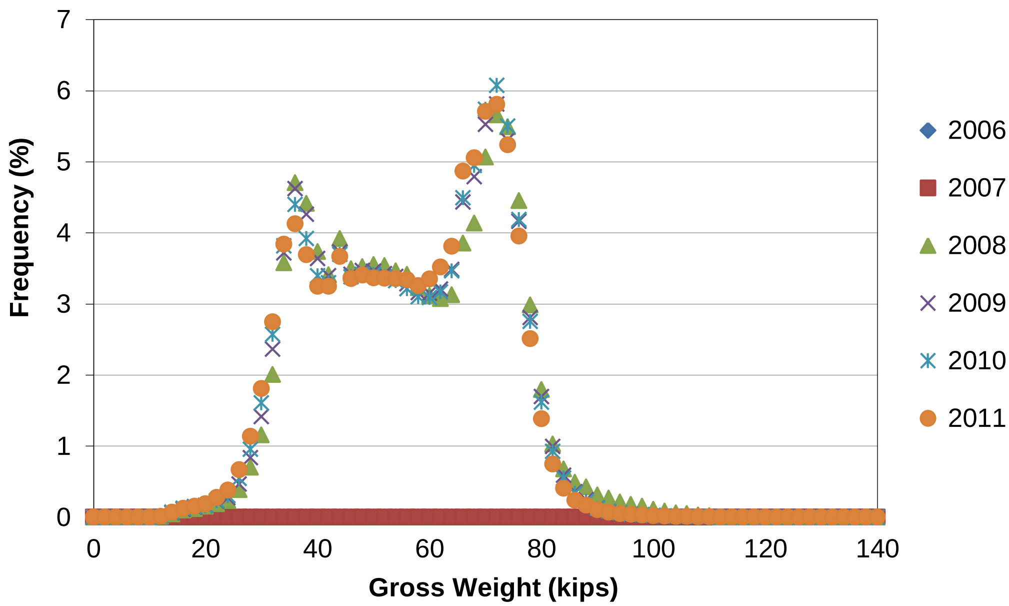


Figure 32: Annual Class 9 Gross Weight Distribution at Site 745

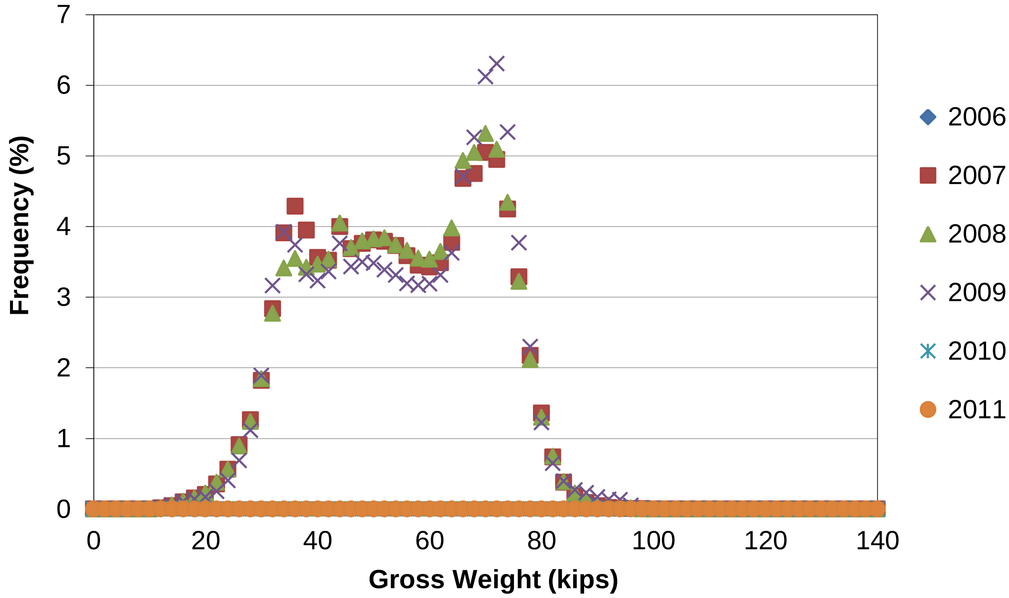


Figure 33: Annual Class 9 Gross Weight Distribution at Site 743

Chapter 7
Traffic Analysis Program

7.1 Introduction

A Visual Basic for Applications (VBA) code was utilized to analyze the continuous traffic monitoring data obtained throughout the State of Ohio. VBA is an event-driven programming language that is available in several Microsoft Office applications including Microsoft Excel. VBA provides the ability to automate processes suitable for analyzing large amounts of data similar to that used in this study. The VBA code was developed to generate Level 1, 2, and 3 MEPDG traffic inputs. As discussed earlier, Level 1 requires project-specific traffic data, Level 2 relies on regional traffic data and statewide averages, while Level 3 uses default traffic inputs. This chapter discusses the capabilities of the VBA code and outlines the information necessary for generating the MEPDG traffic inputs.

7.2 Program Description

The VBA code can be run from within Microsoft Excel by navigating to the Developer tab and selecting the appropriate macro from the dialogue box. Upon running the macro, a welcome screen is opened depicting various images of the University of Akron, surrounding the official university seal (Figure 34). The welcome screen provides the user with the ability to start a new project or exit the VBA code. Once a new project is started, the main graphical user interface opens providing three analysis options: 1) Analyze Traffic Data (C-Cards and W-Cards), 2) View Results, and 3) Generate MEPDG Traffic Inputs (Figure 35). The Analyze Traffic Data option analyzes the C-Cards and W-Cards and summarizes the results in a Microsoft Access database. The View Results option allows the user to visualize the results generated by the Analyze Traffic Data option. It can be used to view "Traffic Count and Truck Class Distribution" or "Gross and Axle Load Spectra". Finally, the Generate MEPDG Traffic Inputs option utilizes the results database to generate traffic inputs in a format that can be directly imported into the MEPDG. The following subsections provide additional information on using these analysis options and the inputs and outputs of each option.

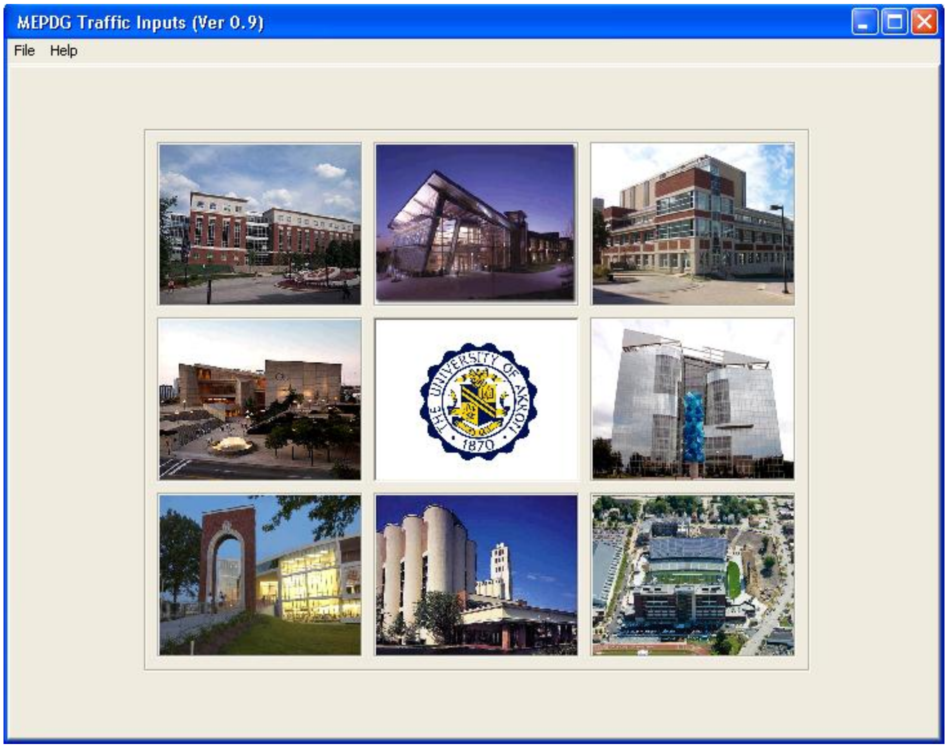


Figure 34: Welcome Screen

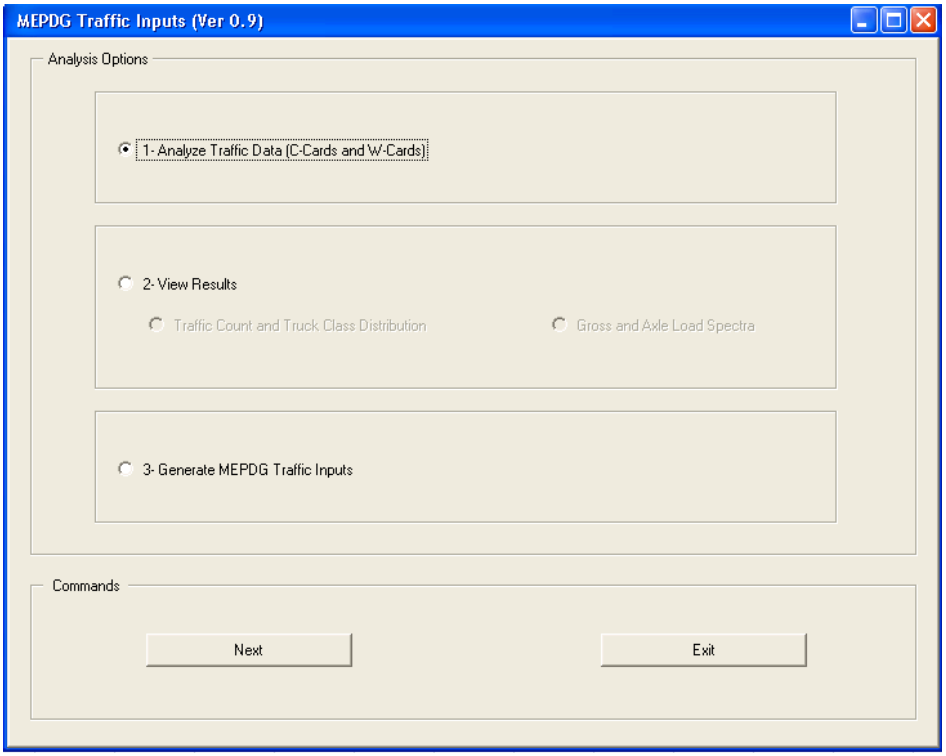


Figure 35: Analysis Options Screen

7.2.1 Analyze Traffic Data

The layout of the Analyze Traffic Data option screen can be seen in Figure 36. As can be seen from this figure, the first entry required from the user is the location of the site information file. This file contains information about each traffic monitoring site including site ID, type of equipment, direction, number of lanes, district, county, route, functional classification, and location. This information is maintained by ODOT Traffic Monitoring Section and updated upon any changes like the addition or removal of traffic monitoring sites. The user can then choose to analyze C-Cards, W-Cards, or both. In order for the program to analyze the C-Cards or W-Cards, the user must specify the location of these files using the corresponding Browse button. In addition, the location in which the results database will be stored must be selected and the analysis period must be defined indicating the beginning and end of the analysis. The results database generated by this analysis option is discussed later in this chapter. Finally, on the right hand side of the screen, under the data handling sections, the user can decide which quality control measures to apply in the analysis of the C-Cards and W-Cards. The quality control measures available to the user are detailed in Chapter 6.

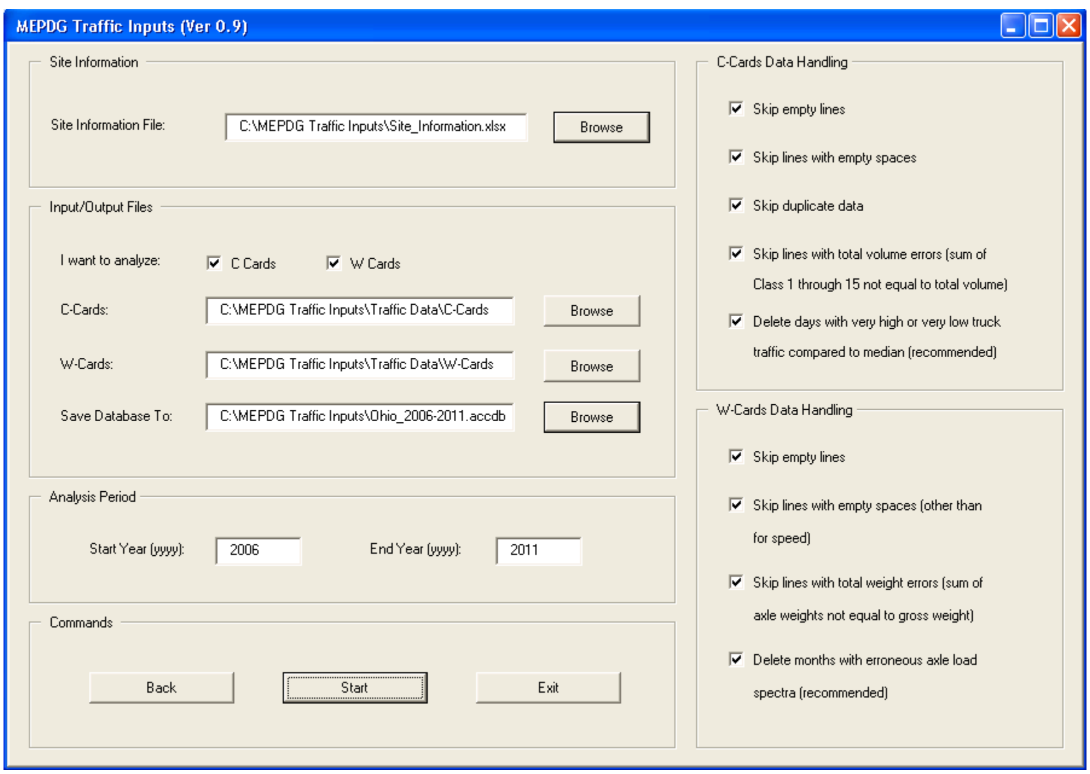


Figure 36: Analyze Traffic Data Screen

7.2.2 View Results

The View Results option can be used to visualize the “Traffic Count and Truck Class Distribution” or the “Gross and Axle Load Spectra” in the results database. This allows the user to determine if the data and trends are accurate prior to generating the MEPDG traffic inputs. By selecting the “Traffic Count and Truck Class Distribution” option, the screen shown in Figure 37 will be opened. The user must first identify the location where the results database was stored using the Browse button under the Select Database section. Once a results database is chosen, the VBA code will access the database and acquire any relevant information based on the selection in the tables below the chart area. There are four tables: Data Type, Site, Year, and Class; which provide the user with various options for viewing the data. The chart, in the center of the screen, is updated every time a change is made in the four tables. The right side of the screen provides additional supporting information about each site. This includes detailed Site Information, AADT and AADTT, Data Availability, and Historical Traffic Data. The Site Information data includes the site identification number (Site), direction (Dir), district (Dist), county (Co), route (Ro), functional classification (FC), and traffic monitoring program (Prg). The AADT and AADTT table allows the user to see these values while visualizing the other trends in the chart area such as the truck class distribution. The Data Availability table provides a list of months for which data is available. The Historical Traffic Data provides the user with the option to compare the analysis results with past traffic data for a particular site. In order to use this option, the user must specify the location of the database that contains the historic traffic data. This database was created using information provided by ODOT Traffic Monitoring Section. The use of the Historical Traffic Data is optional and would not affect the visualization of the other results.

By selecting the “Gross and Axle Load Spectra” option, the screen shown in Figure 38 will be opened. This screen is similar to that described for the “Traffic Count and Truck Class Distribution” option. The main difference is in the three tables to the right of the screen, which provide the peak loads for the gross weight, front axle, and drive tandem of Class 9 trucks. In each of these tables, the VBA code displays whether the data passed or failed the weight limits discussed in Section 6.2.3. Monthly and annual comparisons can be made based on the selection in the Data Type table below the chart area. It should be noted that the results database must be closed prior to viewing the results using the “Traffic Count and Truck Class Distribution” or “Gross and Axle Load Spectra” options.

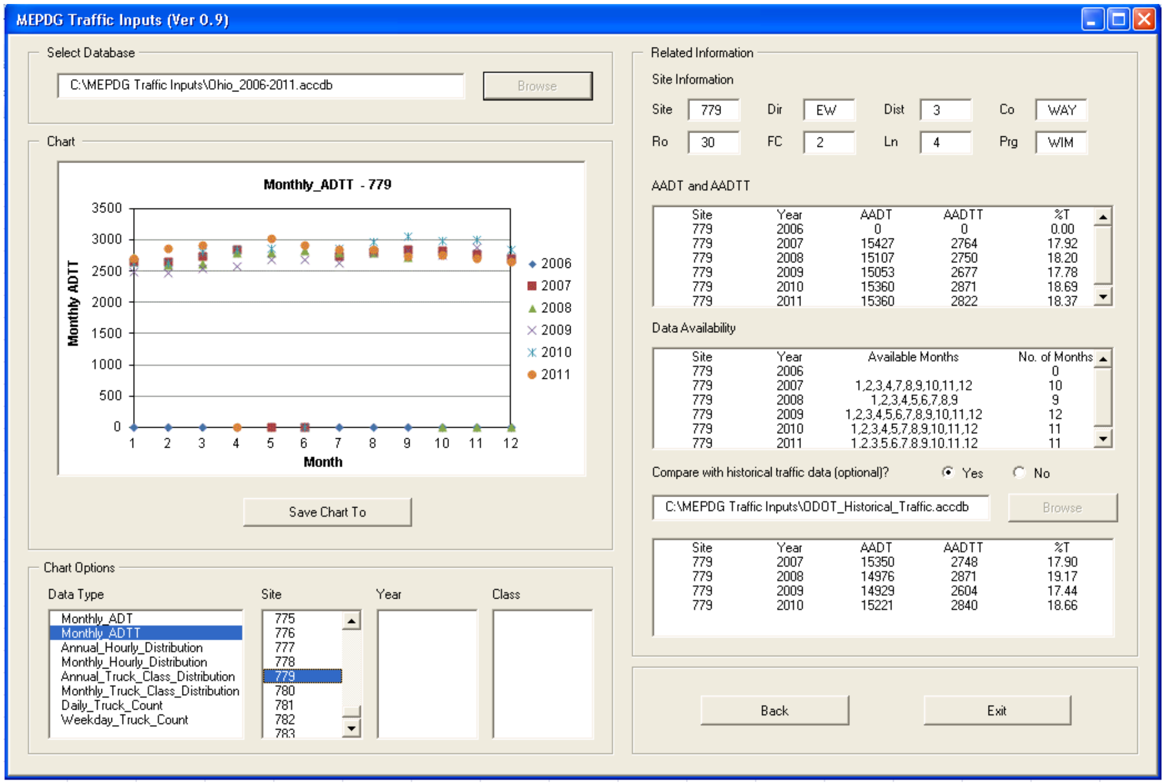


Figure 37: Traffic Count and Truck Class Distribution Screen

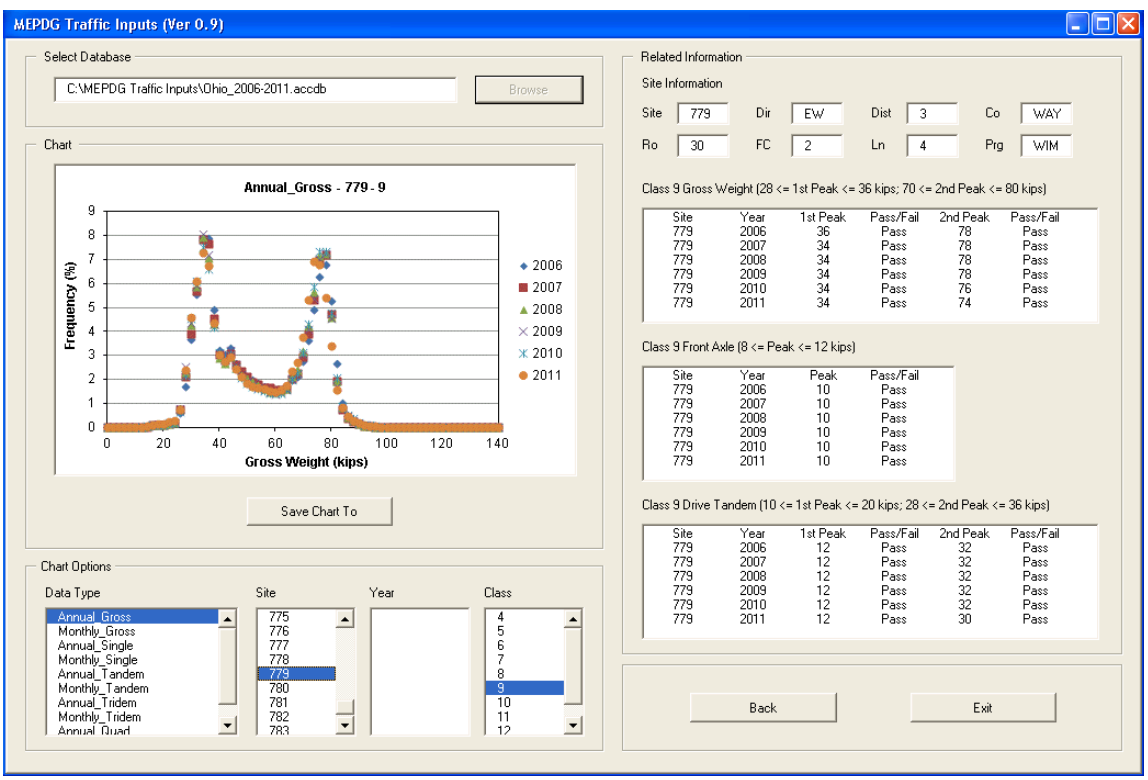


Figure 38: Gross and Axle Load Spectra Screen

7.2.3 Generate MEPDG Traffic Inputs

The main screen for the Generate MEPDG Traffic Inputs option is shown in Figure 39. As can be seen from this figure, the user must first identify the location of the results database and the location where the generated traffic inputs will be stored. The user can navigate through the screen to using a series of tabs to provide basic information about the pavement project and to select the hierarchal level for the various traffic inputs. The first tab titled Project Info. allows the user to enter basic information about the proposed pavement project including the project ID, route, start mile post, end mile post, and the functional classification of the roadway. The second tab titled Base-Year Traffic enables the user to input information for the initial two-way AADTT, number of lanes in design direction, percent of trucks in design direction, percent of trucks in design lane, and operational speed in mph (Figure 40). The third tab titled Traffic Volume Adjustment Factors contains four sections for the monthly adjustment factors, vehicle classification distribution, hourly distribution, and growth rate (Figure 41). The first three sections allow the user to select the level of design, while the growth rate section has three options: no growth, linear growth, and compound growth. The fourth tab titled Axle Load Distribution contains four sections for the single, tandem, tridem, and quad axle load distributions (Figure 42). The user has the option to choose the level of design for each of these sections. The fifth and final tab titled General Traffic Inputs provides an option to select the level of design for the number of axles per truck, axle configuration, and wheelbase (Figure 43).

To the right of the Generate MEPDG Traffic Inputs screen is a section with drop down boxes containing information needed for the various hierarchal levels. If Level 1 (project-specific continuous site) is selected for any of the sections under the Traffic Volume Adjustment Factors tab, the user must choose a continuous classification site from which the inputs will be generated. In order to facilitate the selection of a continuous classification site with sufficient traffic data, the VBA code provides the list and number of months with available data. Additionally, if Level 1 (project-specific continuous site) is selected for any of the sections under the Axle Load Distribution tab or for the number of axles per truck under the General Traffic Inputs tab, the user must choose a continuous WIM site from which the inputs will be generated. As previously stated, the VBA code provides the list and number of months with available data for the selected WIM site and year. Furthermore, if Level 1 (project-specific short-term counts) is selected for the vehicle class distribution under the Traffic Volume Adjustment Factors tab, the Short-Term Counts option screen is opened as shown in Figure 44. As can be seen from this figure, the user must first provide information about the traffic monitoring location including district, county, route, direction, number of lanes per direction, mile post, and location. The user must then provide the monitoring date (in mm/dd/yyyy format) when the short-term counts were obtained, and enter the unadjusted short-term truck counts each truck class. The data entered into this screen is adjusted using a set of seasonal adjustment factors to calculate the truck class distribution at the traffic monitoring location. Finally, if Level 3 is selected for the Vehicle Classification Distribution under the Traffic Volume Adjustment Factors tab, the user must choose a truck traffic classification (TTC) group, and if Level 2 is selected for any of the four sections under the Axle Load Distribution tab, the user must choose an axle load distribution cluster (or weight cluster). The development of the weight clusters is discussed in the following chapter.

Once the previous information is entered, the MEPDG traffic inputs can be generated using the Generate button at the bottom of the screen. The generated inputs will be summarized in a standard text format that can be directly imported into the MEPDG for used in pavement design. The main advantage of the Generate MEPDG Traffic Inputs option is that it generates traffic inputs for various design levels; thus, allowing for a more direct and efficient comparison of the influence of these design levels on pavement design.

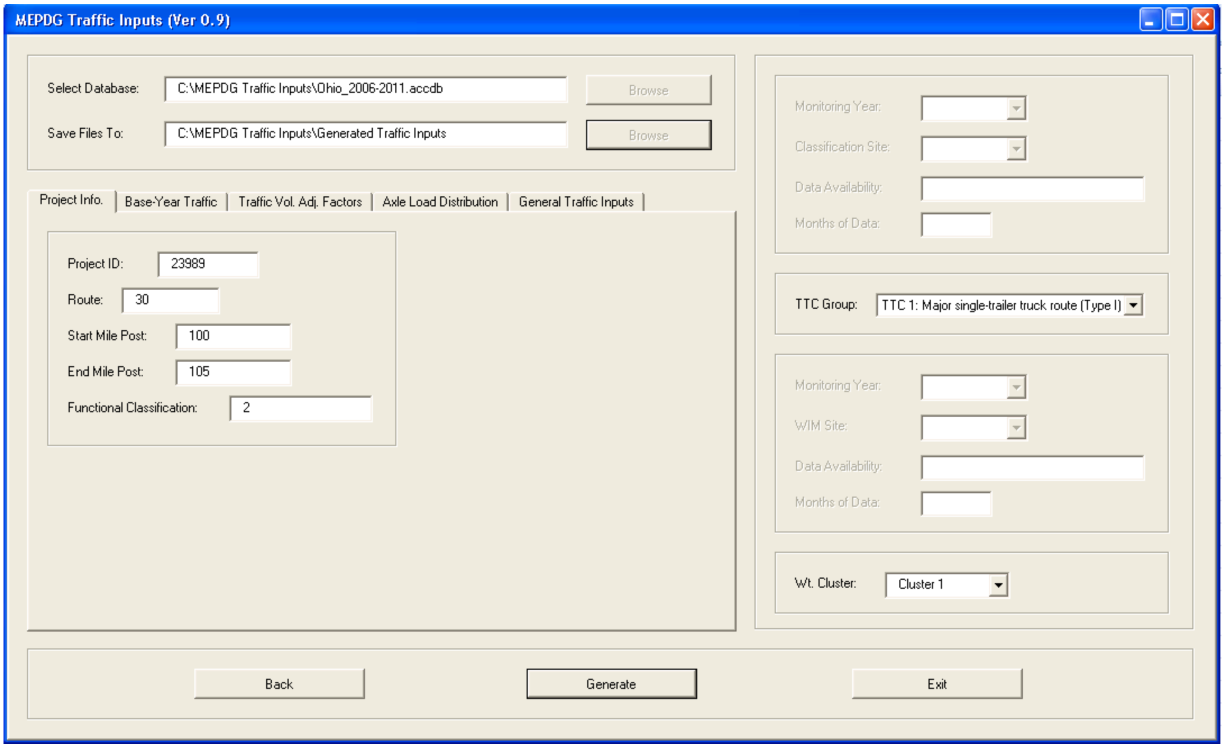


Figure 39: Generate Traffic Inputs Screen Showing Project Info Tab

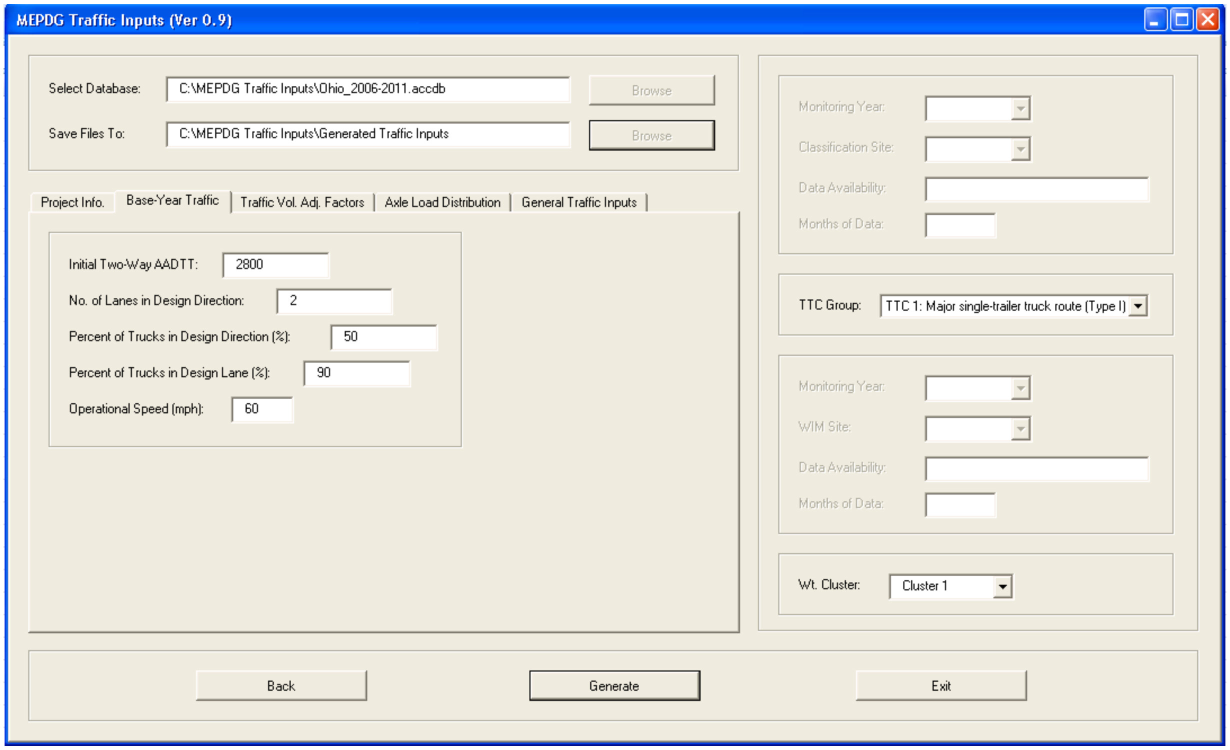


Figure 40: Base-Year Traffic Tab

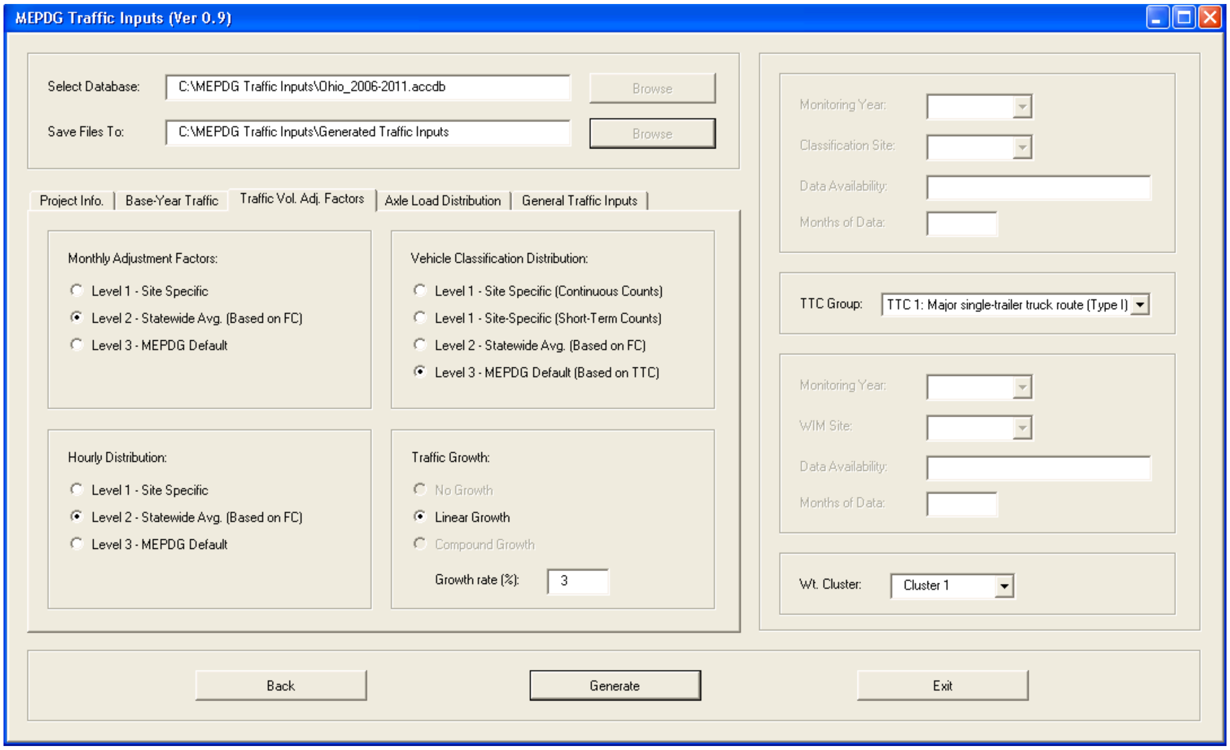


Figure 41: Traffic Volume Adjustment Factors Tab

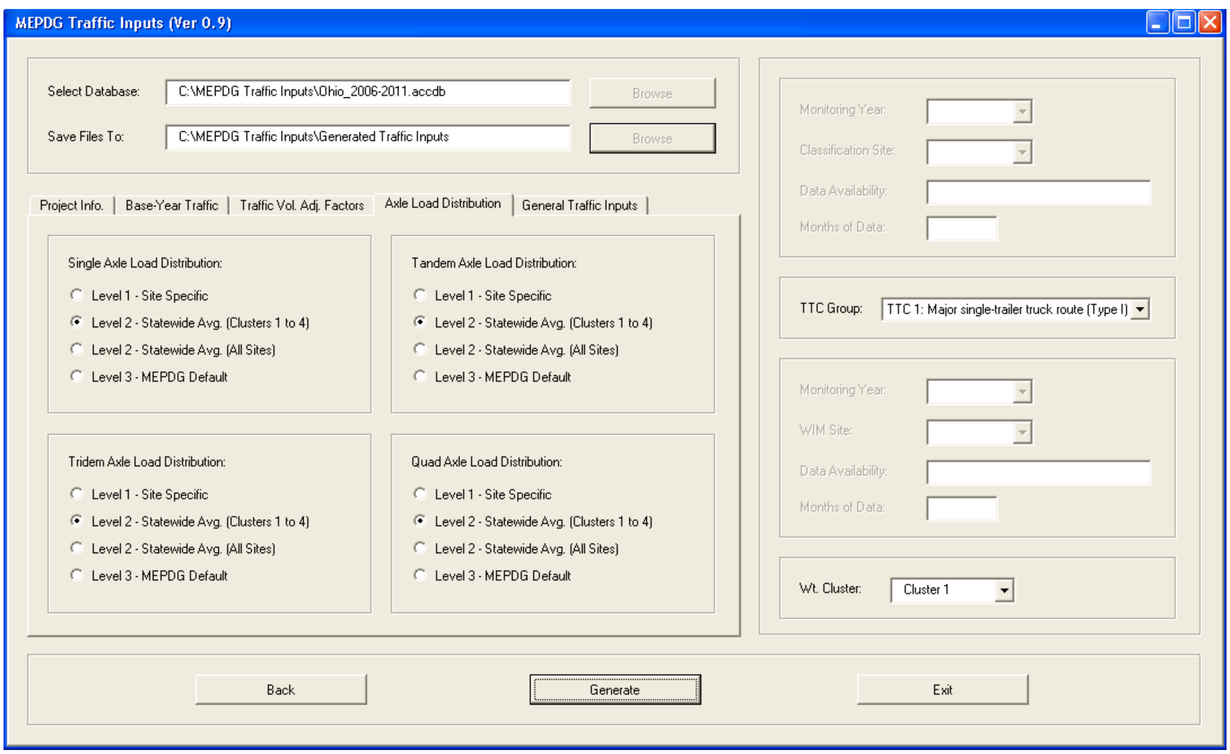


Figure 42: Axle Load Distributions Tab

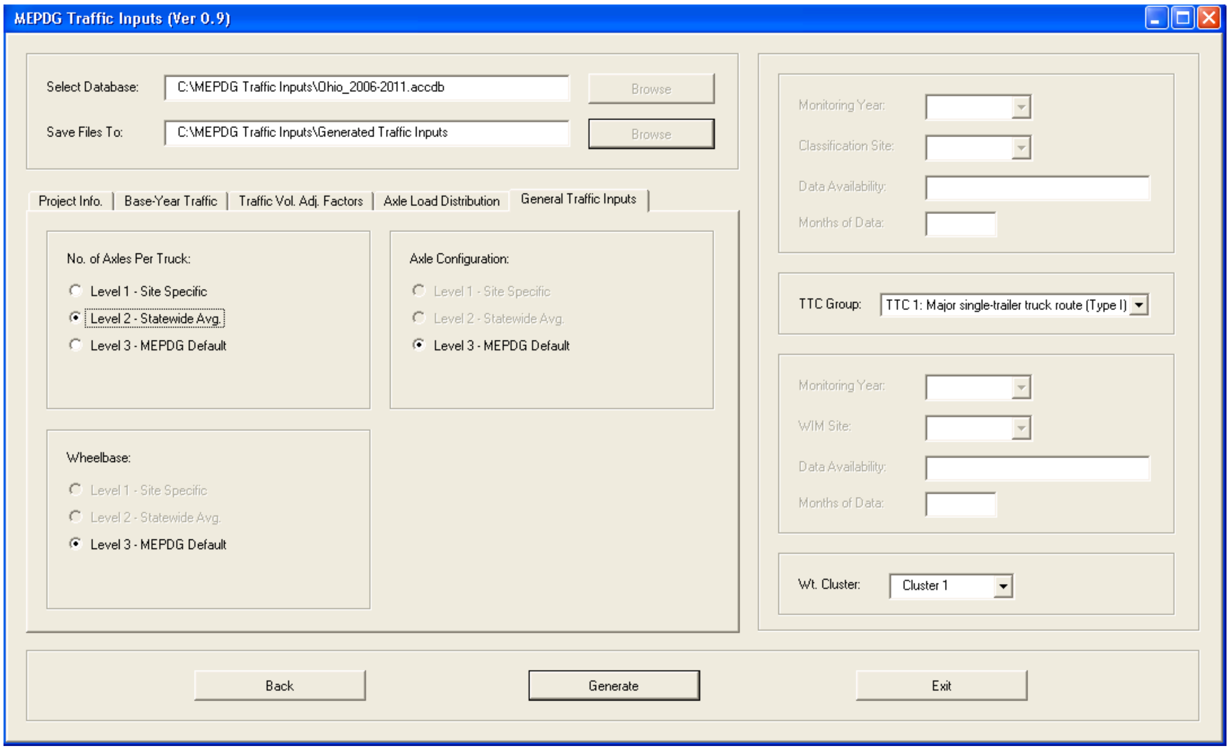


Figure 43: General Traffic Inputs Tab

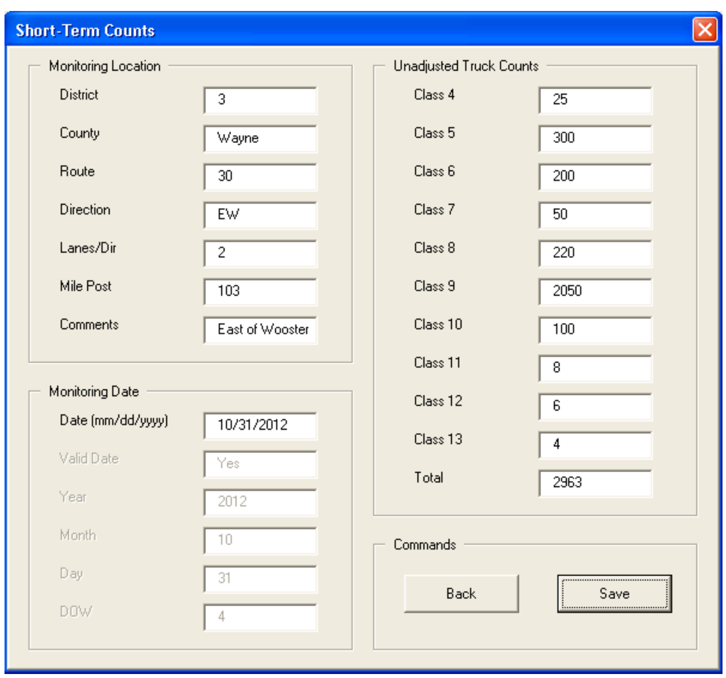


Figure 44: Short-Term Counts Option Screen

7.3 Database Format

The database created by the Analyze Traffic Data option is stored in a Microsoft Access format. The database can be accessed to view and analyze the results prior to generating the MEPDG traffic inputs. In addition, this database can be used to supplement ODOT's effort to study truck flow patterns in the State of Ohio. The database contains a series of tables organized into five main categories including: Site General, Site Traffic, Site Weight, Statewide Traffic, and Statewide Weight (Table 19). The title of each table describes the data available in that table. By grouping the tables into different categories, the user can find the appropriate information without intensive searching through the numerous tables.

The Site General category includes two tables. The Site_General_Information table contains information on the site like identification number, direction, number of lanes, district, county, route, functional classification, and longitude and latitude; while the Site_General_FC_TTC contains information on the site functional classification and TTC group by year. The latter can be used to determine the expected TTC groups for different functional classifications.

The Site Traffic category summarizes the results from the C-Cards data analysis into fifteen tables. These tables contain information on data availability; AADT, AADTT, and percent trucks; daily, monthly, and annual truck counts and truck class distributions; directional and lane distributions; hourly distribution factors; monthly adjustment factors; and seasonal adjustment factors.

The Site Weight category summarizes the results from the W-Cards data analysis into eighteen tables. These tables contain information on data availability; monthly and annual gross weight distributions; monthly and annual single, tandem, tridem, and quad axle load spectra; monthly and annual error checks for gross weight, front axle, and drive tandem axle of Class 9 trucks; and number of axles per trucks.

The Statewide Traffic and Statewide Weight categories contain statewide averages for the data results in the Site Traffic and Site Weight categories. In addition, they include the list of sites used in calculating the averages and the standard deviation from the mean. The methods for determining these statewide averages are discussed in the following chapter.

Table 19: Results Database Tables

Site General	Site_General_Information Site_General_FC_TTC
Site Traffic	Site_Traffic_Data_Availability Site_Traffic_Annual_ADT_ADTT_Percent_Truck Site_Traffic_Annual_DOW_Truck_Class_Count Site_Traffic_Annual_Hourly_Distribution Site_Traffic_Annual_Truck_Class_Distribution Site_Traffic_Directional_And_Lane_Distributions Site_Traffic_Monthly_ADT_ADTT_Percent_Truck Site_Traffic_Monthly_DOW_Truck_Class_Count Site_Traffic_Monthly_Hourly_Distribution Site_Traffic_Monthly_Truck_Class_Distribution Site_Traffic_Monthly_Adjustment_Factors Site_Traffic_Daily_Truck_Class_Distribution Site_Traffic_SeaAdjFac_Truck_Class
Site Weight	Site_Weight_Data_Availability Site_Weight_Annual_Gross Site_Weight_Annual_Single Site_Weight_Annual_Tandem Site_Weight_Annual_Tridem Site_Weight_Annual_Quad Site_Weight_Annual_Class_9_Error_Checks Site_Weight_Annual_Class_9_Front_Axle Site_Weight_Annual_Class_9_Drive_Tandem Site_Weight_Annual_AxlesPerTruck Site_Weight_Monthly_Gross Site_Weight_Monthly_Single Site_Weight_Monthly_Tandem Site_Weight_Monthly_Tridem Site_Weight_Monthly_Quad Site_Weight_Monthly_Class_9_Error_Checks Site_Weight_Monthly_Class_9_Front_Axle Site_Weight_Monthly_Class_9_Drive_Tandem

Table 19: Results Database Tables (Cont.)

Statewide Traffic	Statewide_Traffic_Hourly_Distribution_FC_Avg Statewide_Traffic_Hourly_Distribution_FC_Site_List Statewide_Traffic_Hourly_Distribution_FC_StDev Statewide_Traffic_Hourly_Distribution_TTC_Avg Statewide_Traffic_Hourly_Distribution_TTC_Site_List Statewide_Traffic_Hourly_Distribution_TTC_StDev Statewide_Traffic_MAF_FC_Avg Statewide_Traffic_MAF_FC_Cont_Site_List Statewide_Traffic_MAF_FC_StDev Statewide_Traffic_MAF_TTC_Avg Statewide_Traffic_MAF_TTC_Cont_Site_List Statewide_Traffic_MAF_TTC_StDev Statewide_Traffic_SeaAdjFac_Avg_Truck_Class Statewide_Traffic_SeaAdjFac_Cont_Site_List_Truck_Class Statewide_Traffic_SeaAdjFac_StDev_Truck_Class Statewide_Traffic_VCD_FC_Avg Statewide_Traffic_VCD_FC_Site_List Statewide_Traffic_VCD_FC_StDev
Statewide Weight	Statewide_Weight_AxlesPerTruck_Avg Statewide_Weight_AxlesPerTruck_StDev

Chapter 8
Traffic Analysis Results

8.1 Introduction

This chapter presents the traffic analysis results that were obtained using the Visual Basic for Application (VBA) code presented in the previous chapter. As mentioned earlier, this code is capable of generating traffic inputs for Levels 1, 2, and 3 in the MEPDG. Level 1 pavement design uses site-specific traffic data and is relatively straight forward, while Level 3 uses default traffic inputs. Therefore, this chapter will focus on Level 2, which involves the development of statewide averages for various traffic inputs. It should be noted that ODOT currently uses highway functional classification in pavement design. Therefore, in order to allow for a seamless transition from the current pavement design method to the MEPDG, ODOT intends to continue using the functional classification in the determination of the MEPDG traffic inputs. The following sections detail the data analysis and results obtained for each traffic input.

8.2 Base Year AADTT

The base year AADTT is probably the most critical traffic input in pavement design. Project-specific AADTT is commonly determined through short term counts or estimated from nearby traffic monitoring sites. Historical AADTT data for major roadways in Ohio is readily available and can be obtained from ODOT Traffic Monitoring Section's website. In the implementation of the MEPDG, the Traffic Monitoring Section will continue to provide this information for use in pavement design.

8.3 Directional Distribution Factor

The directional distribution factor quantifies the difference in truck volume between the two directions and is expressed as the percent of truck traffic volume that occurs in the design direction. The current directional distribution factors used by ODOT were provided in Table 10, while the findings from the VBA code are displayed in Figures 45 to 49 relative to the number of lanes. As can be seen from these figures, the majority of the sites had a directional distribution factor between 50 and 55%. By comparing the current directional distribution factors used by ODOT and the directional distribution factors determined from the VBA code, it can be observed that the actual directional distribution factors are slightly greater than 50%. Also, there are a few sites that have nearly 70% to 30% directional distribution. It is noted that these directional distribution factors were obtained over multiple years and hence are believed to be an accurate representation of the truck volume distribution. While the directional distribution factors at these sites are significantly higher than the average, there are relatively few sites with such high differences. Therefore, the current values used by ODOT should be acceptable for most roadways in Ohio, but the exact directional distribution factor may need to be determined if a noticeable variation is observed.

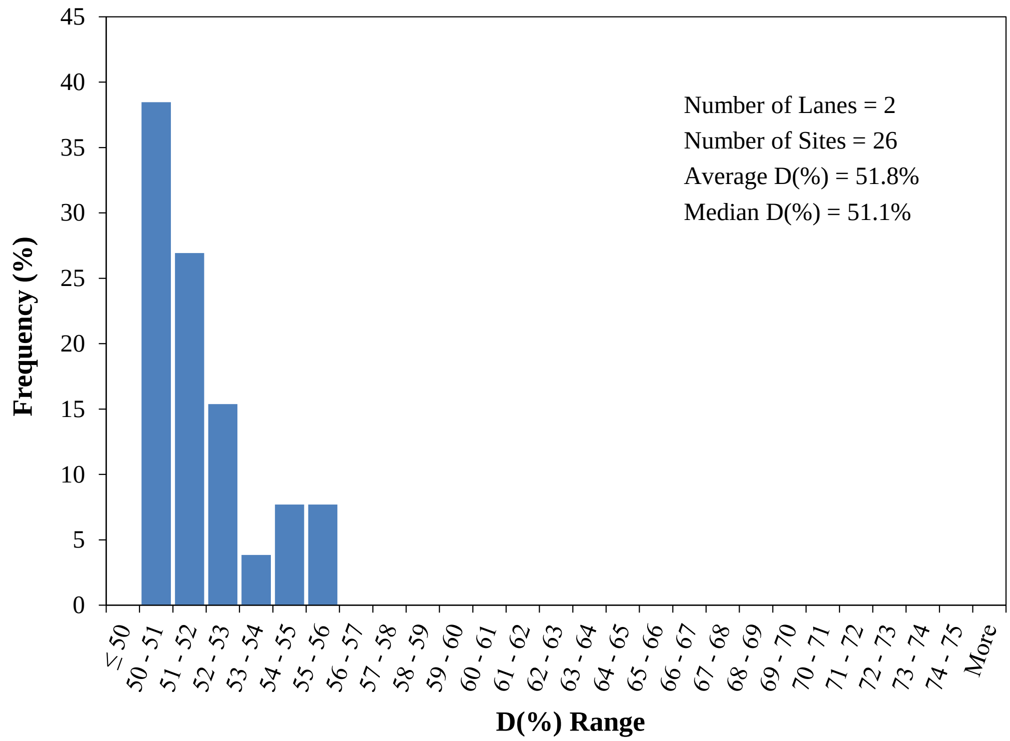


Figure 45: Directional Distribution for Two Lane Roadways

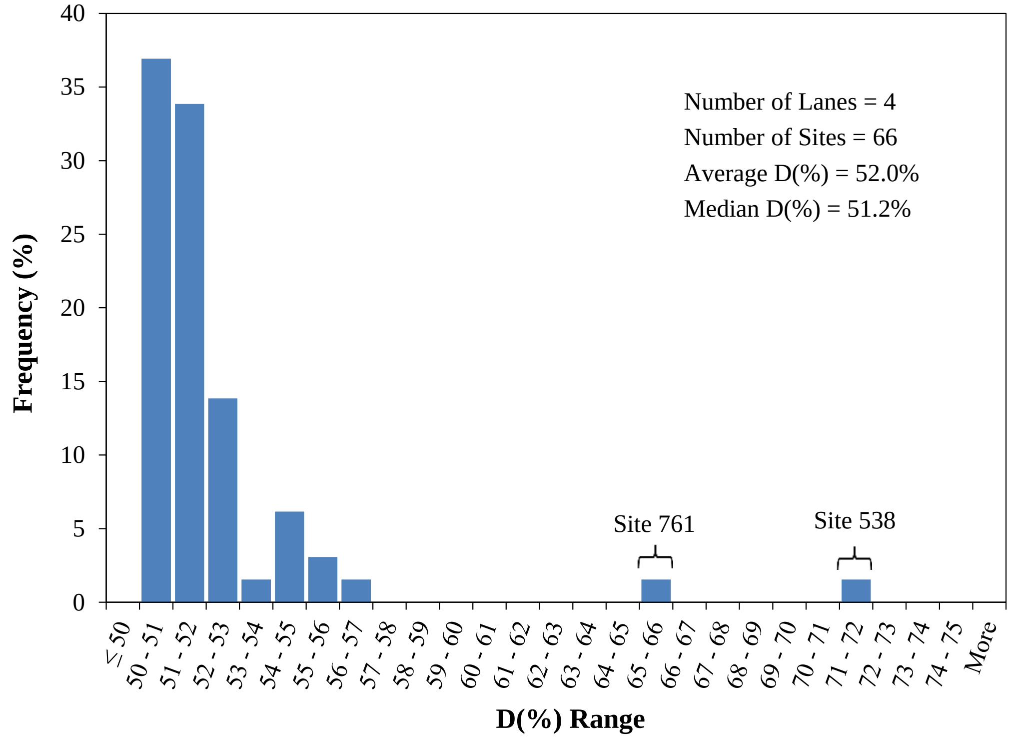


Figure 46: Directional Distribution for Four Lane Roadways

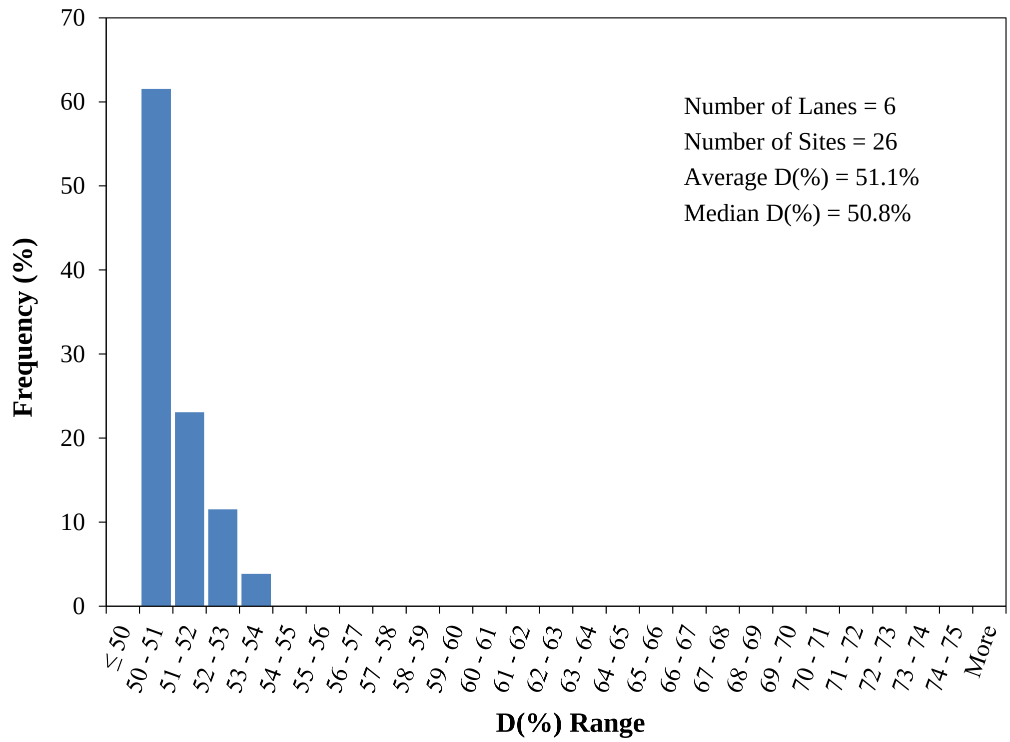


Figure 47: Directional Distribution for Six Lane Roadways

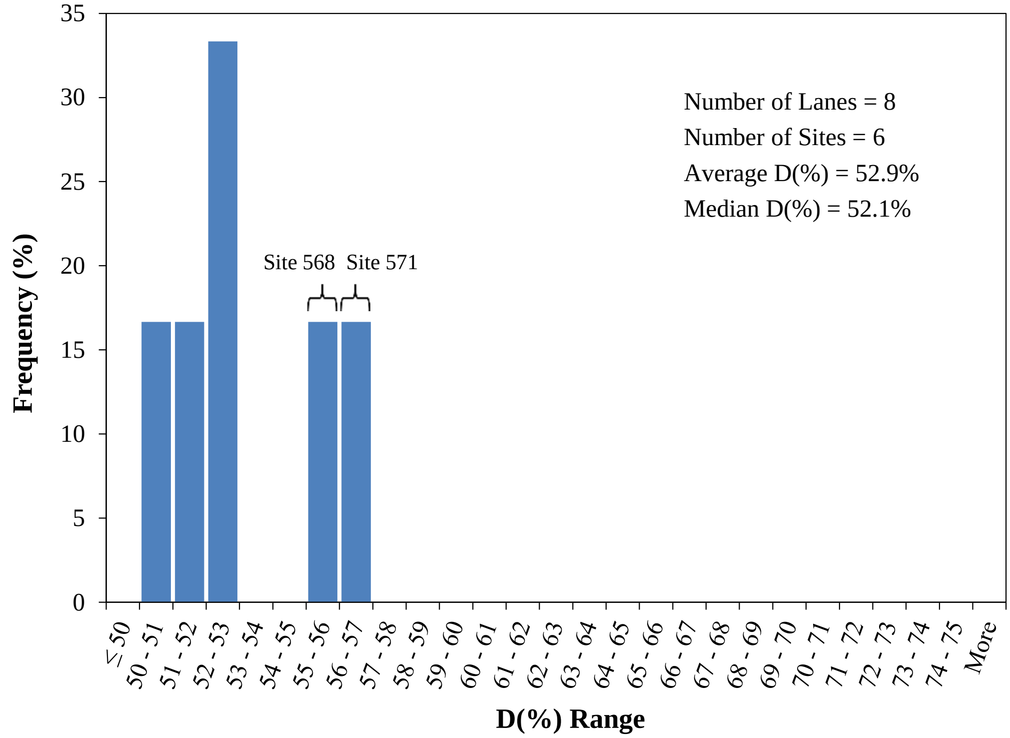


Figure 48: Directional Distribution for Eight Lane Roadways

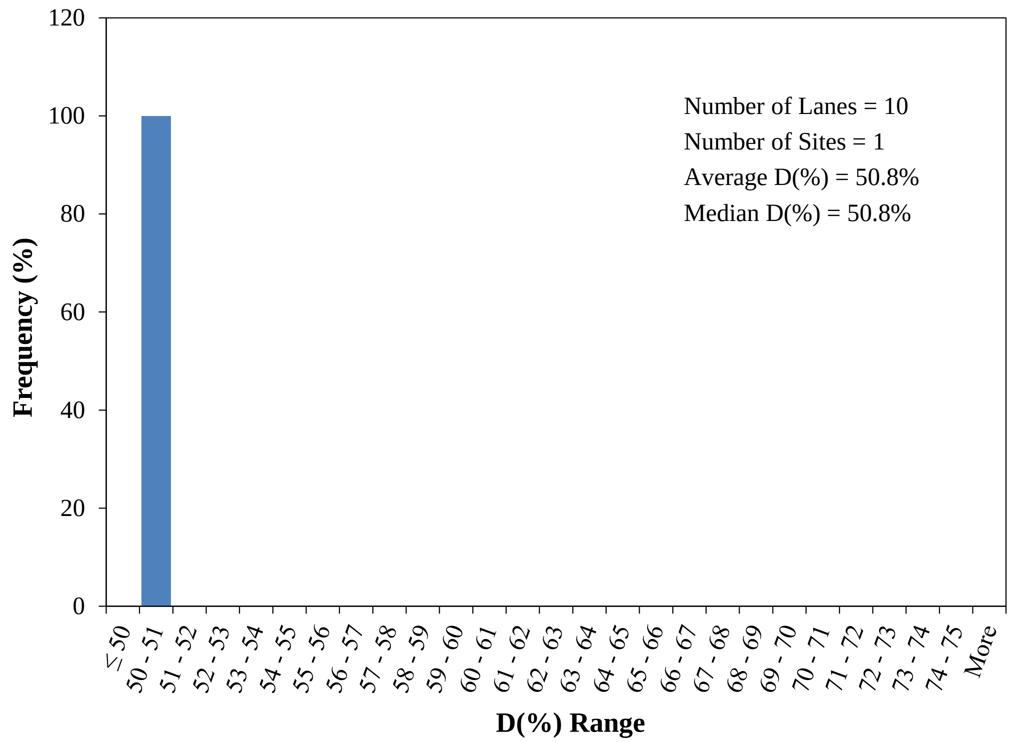


Figure 49: Directional Distribution for Ten Lane Roadways

8.4 Lane Distribution Factor

The truck lane distribution factor represents the distribution of truck traffic between lanes in one direction. The lane distribution factors currently used by ODOT were shown in Table 10, while the results from the VBA code can be seen in Figures 50 to 54 relative to the number of lanes. As can be seen from these figures, the lane distribution factor for two lane highways (one lane in each direction) is 100% and it decreases with the increase in the number of lanes. Additionally, the spread of the lane distribution factors relative to the average increases with the increase in the number of lanes except for highways with ten lanes (five lanes per direction) where data is available for only one site. By comparing the current lane distribution factors used by ODOT and the lane distribution factors determined from the VBA code, it can be seen that ODOT's lane distribution factors are conservative for highways with six or more lanes, but are close to the average for highways with four or less lanes. Therefore, to provide a more consistent pavement design, it is recommended to use the following lane distribution factors: 100% for highways with two lanes, 95% for highways with four lanes, 80% for highways with six lanes, and 70% for highways with eight or more lanes.

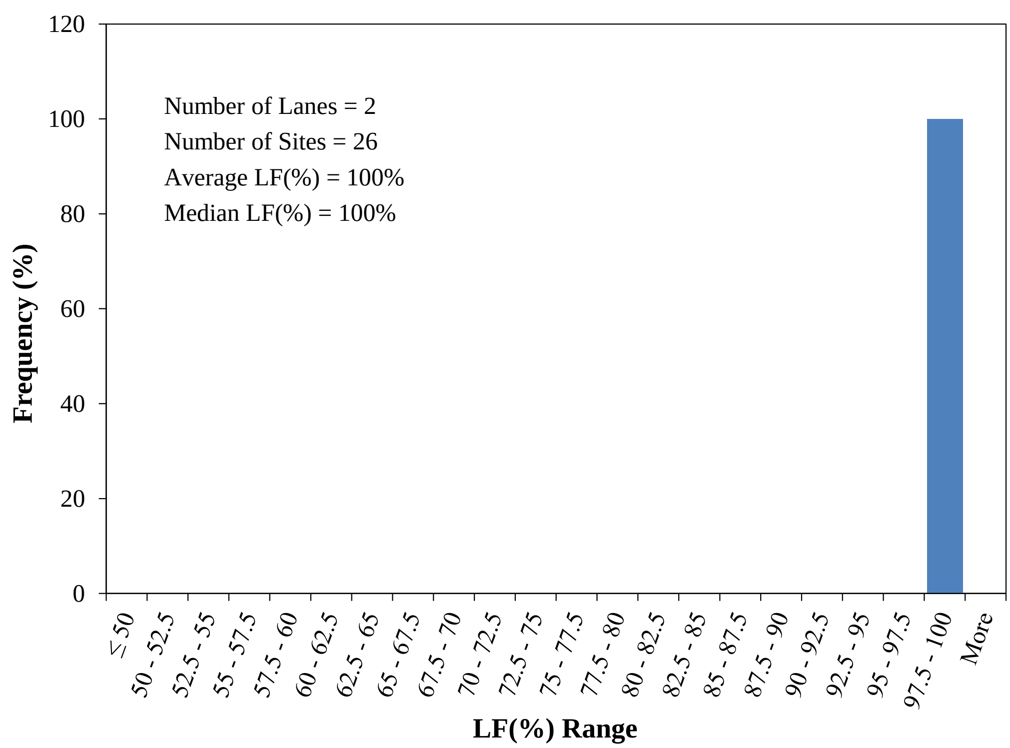


Figure 50: Lane Distribution for Two Lane Roadways

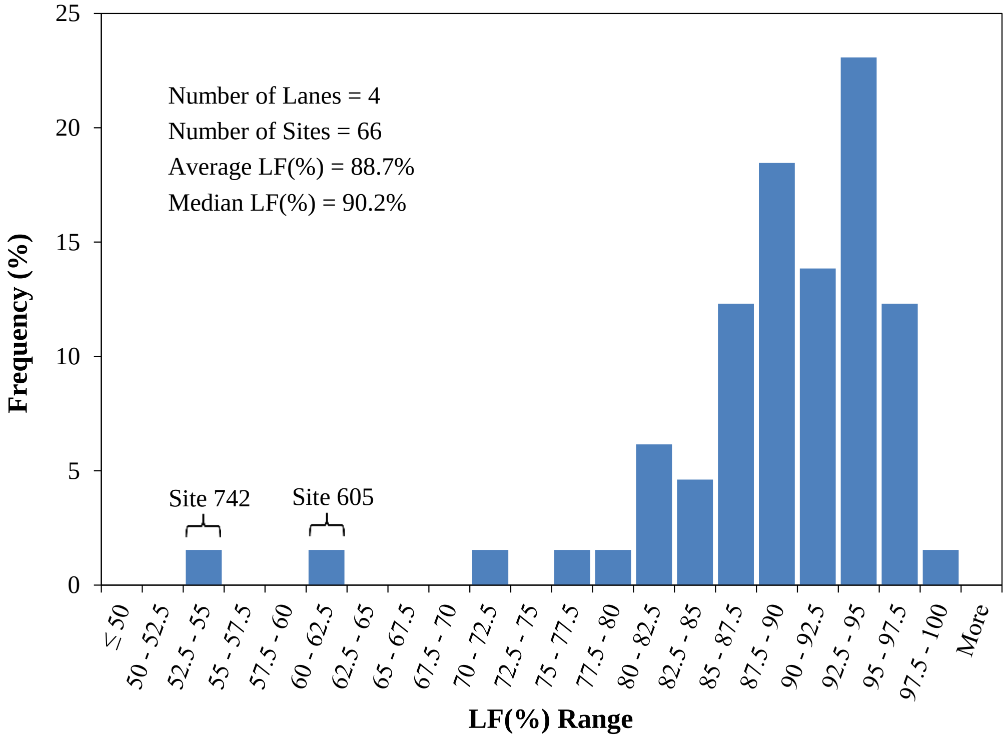


Figure 51: Lane Distribution for Four Lane Roadways

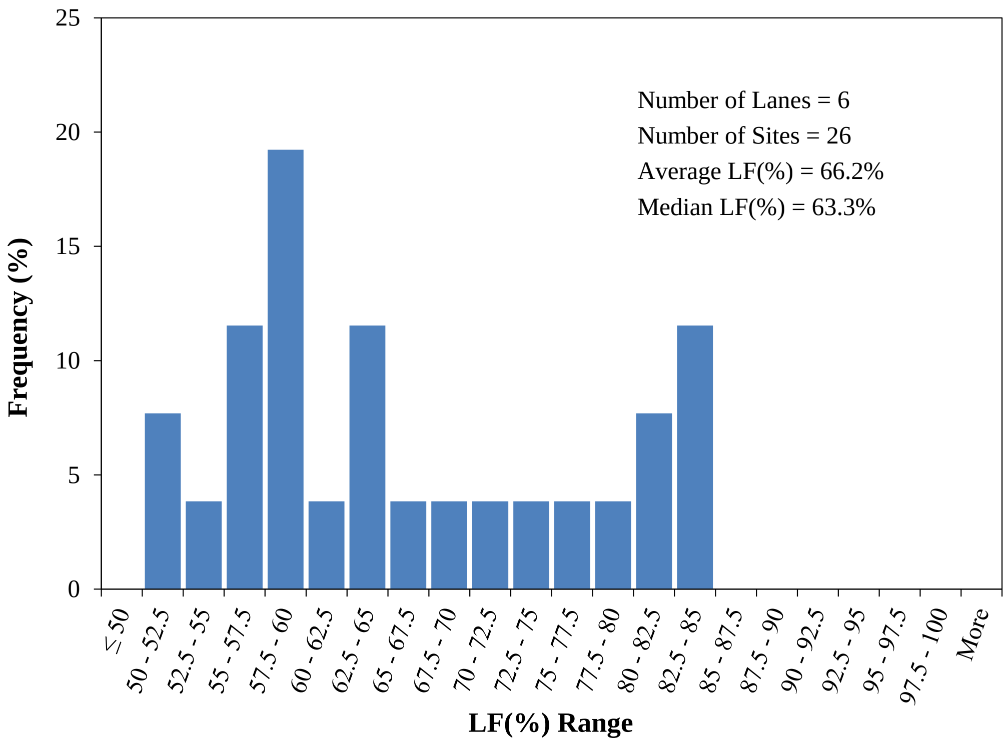


Figure 52: Lane Distribution for Six Lane Roadways

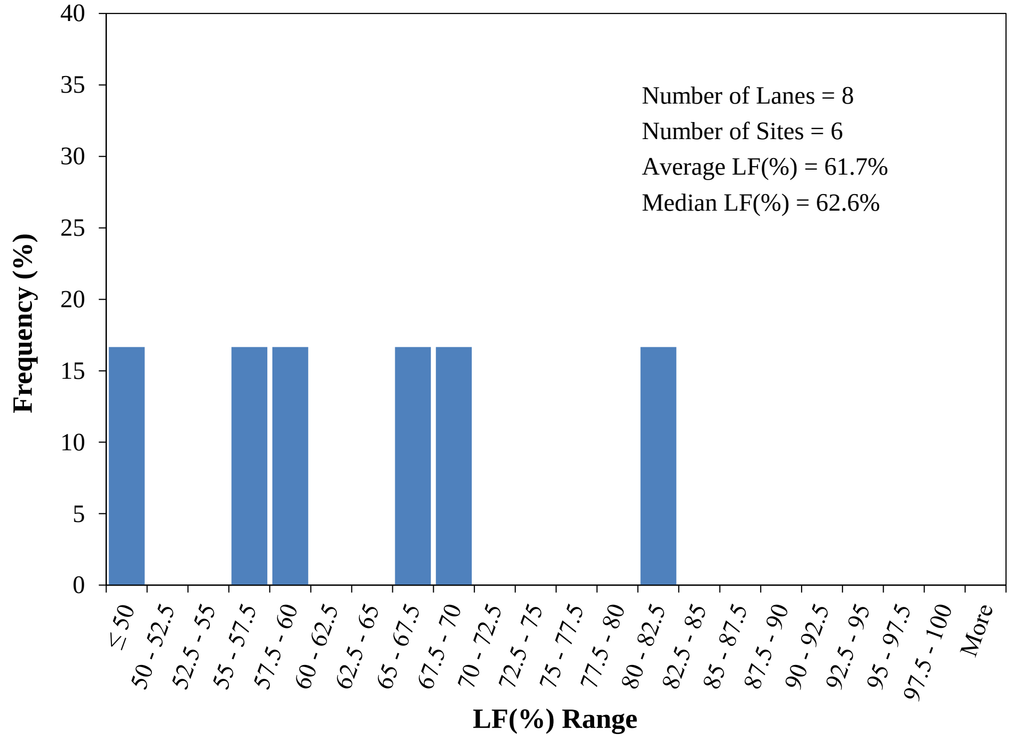


Figure 53: Lane Distribution for Eight Lane Roadways

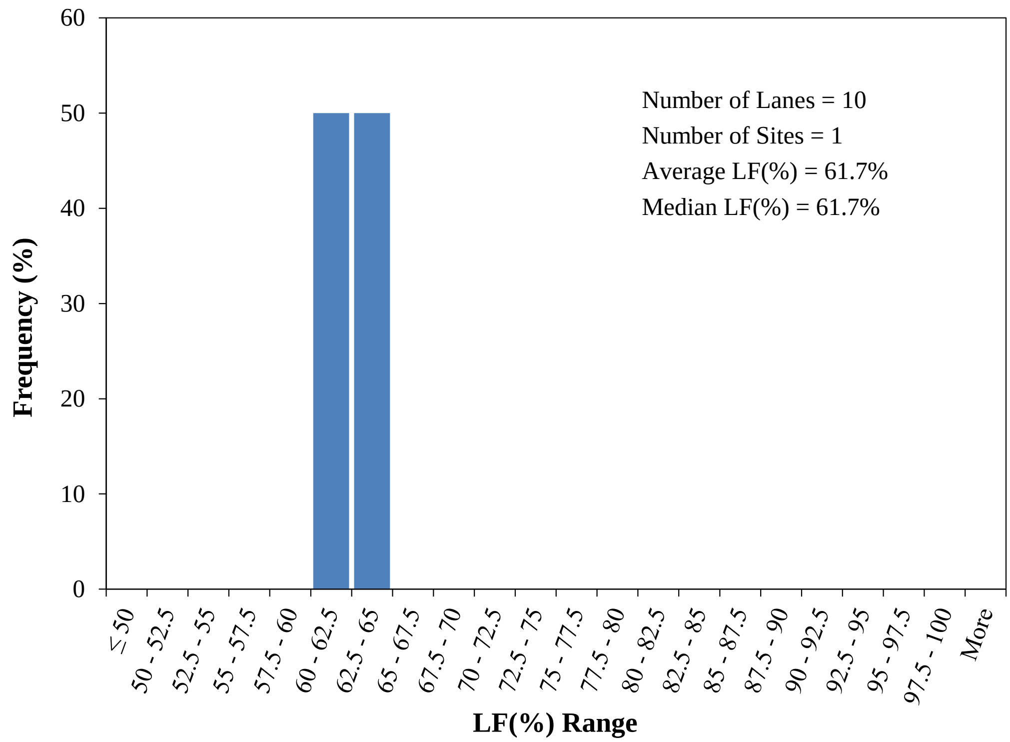


Figure 54: Lane Distribution for Ten Lane Roadways

8.5 Vehicle (Truck) Class Distribution

As discussed previously, ODOT currently uses the B:C ratio to describe the truck class distribution along a roadway based on its functional classification. This approach was investigated to determine whether it could be used in developing statewide truck class distributions for the MEPDG. Figure 55 shows the distribution of the B:C ratio for the continuous traffic monitoring sites based on FC. It can be noticed from this figure that the average B:C ratio decreases with the increase in FC value for both rural and urban sites. This implies that multiple unit trucks are more prevalent on interstate and other major highways. It can also be noticed from this figure that there is a wide range in B:C ratios especially for FCs 1 (rural interstate), 2 (rural principal arterial), and 11 (urban interstate). This suggests that it may not be reasonable to assign a B:C ratio based on FC. Therefore, there is a need for an alternative method to determine the truck class distribution.

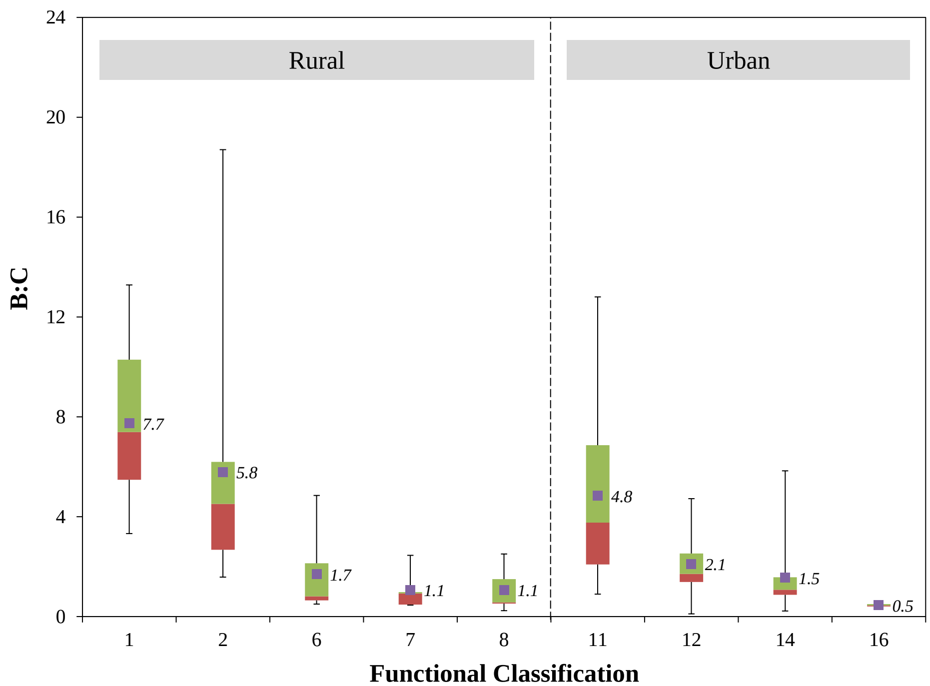


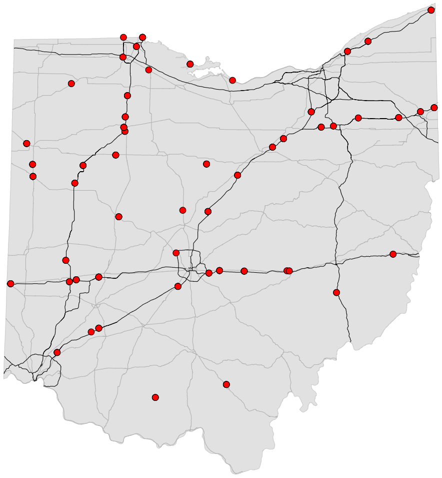
Figure 55: B:C Distribution for Different Functional Classifications

8.5.1 Vehicle (Truck) Class Distribution based on TTC

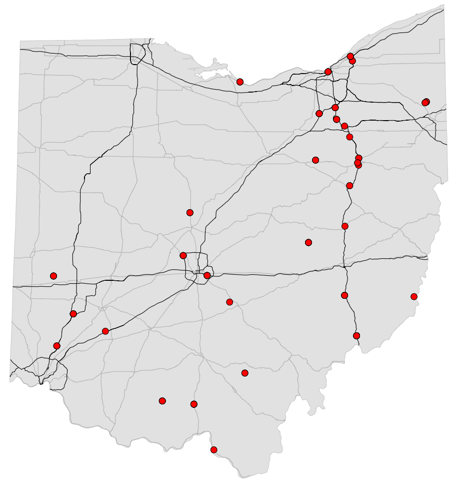
The MEPDG suggests using the TTC grouping system presented in Table 2 to define the truck class distribution, and to use Table 3 to determine the most applicable TTC group. These tables were utilized to obtain the TTC group for each traffic monitoring site and year for which data is available. Figure 56 shows the location of the traffic monitoring sites belonging to each TTC group. It can be observed from this figure that the majority of the sites were classified as TTC 1 or TTC 2, while none of these sites were classified as TTC 11 or TTC 13. It should be noted that since the analysis of the TTC groups was conducted for multiple years, a site may be represented in several TTC groups.

Several observations can also be made based on Figure 56 regarding the truck class distribution along interstate highways throughout Ohio. For instance, along I-71 and I-76, the sites away from Cleveland, Columbus and Cincinnati are classified as TTC 1, while sites closer to these cities are classified as TTC 2. This trend can also be seen along I-75, where sites away from Toledo are classified as TTC 1 and sites closer to Toledo are classified as TTC 2. The same trend can be observed along I-70 where sites away from Columbus are classified as TTC 1, whiles sites near Columbus are classified as TTC 2. As discussed previously, the primary difference between TTC 1 and TTC 2 is in the percentages of Class 5 and Class 9 trucks. Class 9 trucks constitute a significant portion of the truck traffic outside the cities, resulting in a TTC 1 classification. However, inside the cities there are other truck classes present reducing the percentage of Class 9 trucks and causing the site to be classified as another TTC group.

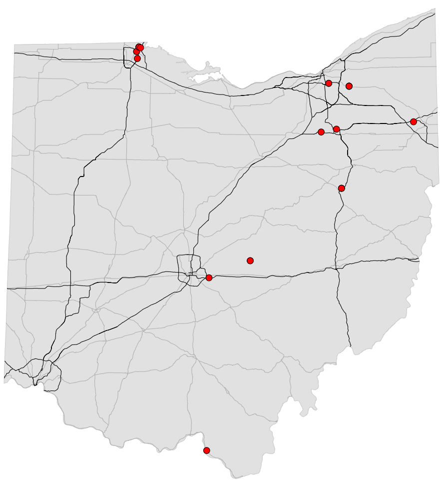
Another observation that can be made from Figure 56 is that most sites along I-77 are classified as TTC 2, which indicates that there are a smaller percent of Class 9 trucks traveling on this interstate than the other major interstates in Ohio. It can also be observed from this figure that most sites along I-75 in Northwest Ohio are classified as TTC 3. As compared to TTCs 1 and 2, TTC 3 has a smaller percent of Class 9 trucks but a significantly higher percent of Class 10 and Class 13 trucks. Furthermore, it can also be observed in this figure that most sites in the Cleveland area are classified as TTC 4, TTC 6, or TTC 9. Similar to TTC 2, these TTC groups have a small percent of Class 13 trucks. However, they progressively contain lower percentages of Class 9 trucks. Finally, only one site, located in the Cincinnati area, was classified as TTC 17 (major bus route). It is noted however that this TTC classification was only based on three months of data as compared to six years of data for some of the other sites. Therefore, this site should be reviewed to determine the accuracy of the collected traffic data.



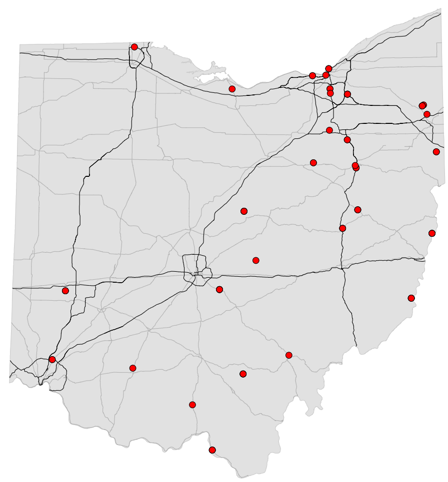
(a) TTC 1



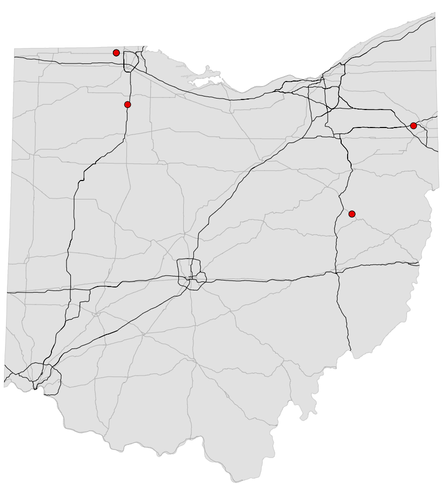
(b) TTC 2



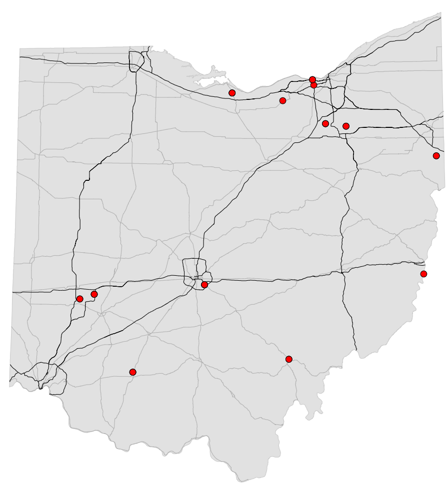
(c) TTC 3



(d) TTC 4

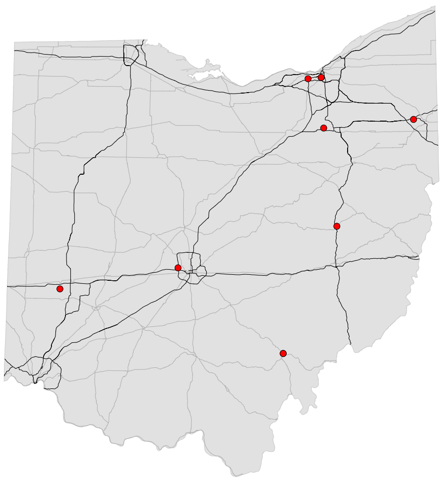


(e) TTC 5



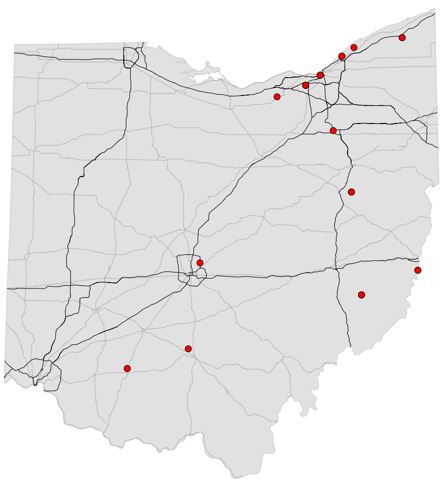
(f) TTC 6

Figure 56: Location of Sites Belonging to TTC Groups 1 through 17

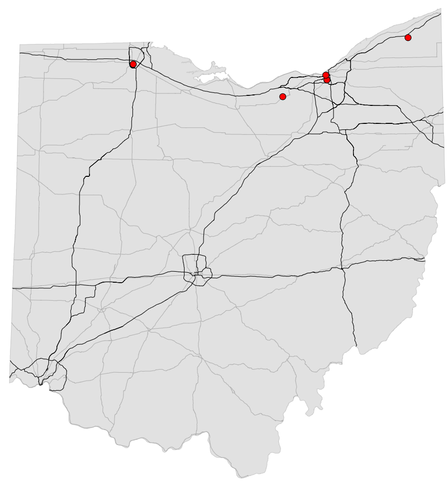


(g) TTC 7

(h) TTC 8

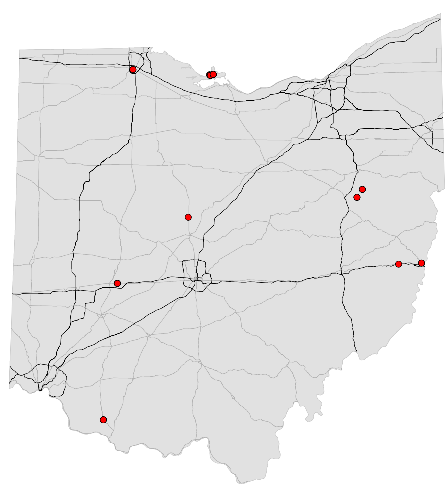


(i) TTC 9



(j) TTC 10

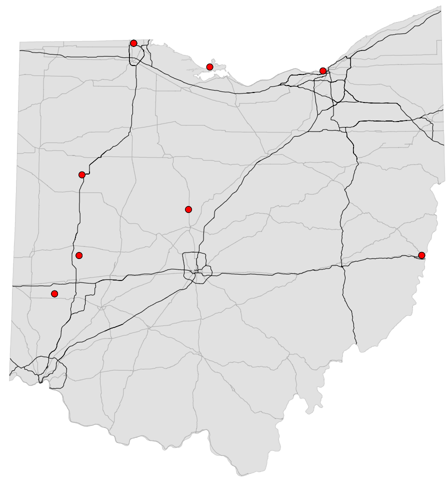
(k) TTC 11



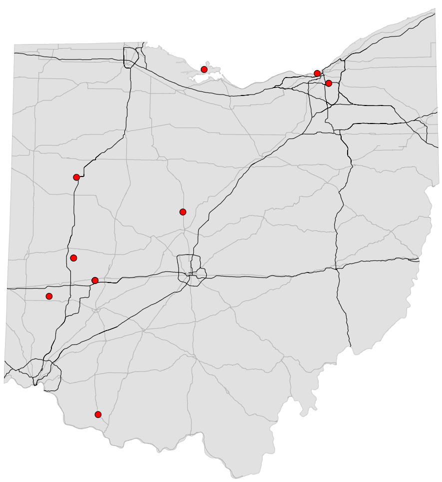
(l) TTC 12

Figure 56: Location of Sites Belonging to TTC Groups 1 through 17 (Cont.)

(m) TTC 13



(n) TTC 14



(o) TTC 15

(p) TTC 16

(q) TTC 17

Figure 56: Location of Sites Belonging to TTC Groups 1 through 17 (Cont.)

Table 20 shows the TTC groups corresponding to each functional classification. Several trends can be noticed from this table between the TTC group and functional classification. For example, rural interstates are primarily classified as TTC 1, while urban interstates are primarily classified as TTCs 1 through 4. However, a wide range of TTC groups are associated with the other functional classifications. This lack of correlation between the functional classification and the TTC groups further confirms that it may not be suitable to determine the truck class distribution based on functional classification.

Table 20: Functional Classifications and Corresponding TTC Groups

		Functional Classification											
		1	**2**	**6**	**7**	**8**	**9**	**11**	**12**	**14**	**16**	**17**	**19**
TTC Group	**1**	69	40	4				80	2	6			
	2	7	30	1	6	2		44	7	2			
	3	3	1					14	8				
	4		21	3		7		23	13	9			
	5	1	4						3				
	6		4			1		5	13	5			
	7			1				2	6	1			
	8								1				
	9			11	1			5	7	7			
	10			1				1	4	2			
	11												
	12	1		8	7	1				9	6		
	13												
	14					8			3	7	5		
	15			1	3	4		2	1	1	1		
	16					1							
	17								1				

While the previous discussion suggests that it may not be possible to assign a TTC group based on functional classification, it was also observed in this study that many of the TTC groups are not representative of the prevailing truck patterns in Ohio. Table 21 presents selected sites classified as TTC 4. As shown in this table, the percentage of Class 9 trucks is close to that used in TTC 4, but the percentage of the other truck classes varied significantly. This is especially true for Classes 6, 10, and 11. For example, the MEPDG recommends using 2.2% for Class 11 in

TTC 4, but the actual percentage varied from 0% for site 772 in year 2006 to 4.6% for site 539 in year 2007. In fact, the variations in Class 11 for all sites throughout the State of Ohio seem to be more dominant than the variations in Class 13, which is one of the primary truck classes used in defining the TTC group. Therefore, it is concluded that the TTC grouping system suggested by the MEPDG may not lead to an accurate representation of the prevailing truck patterns in Ohio.

Table 21: Truck Class Distribution of Selected Sites Classified as TTC 4

			Class (%)									
Site ID	**Year**	**FC**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
539	2007	2	0.8	14.3	9.7	0.6	8.5	57.7	2.4	4.6	1.0	0.3
539	2008	2	0.9	14.3	8.9	0.7	9.4	57.0	3.1	4.4	0.8	0.6
539	2009	2	0.9	15.1	8.7	0.7	9.7	56.8	2.7	3.4	1.0	1.1
539	2011	2	1.0	15.6	8.5	1.0	8.3	58.6	3.0	3.1	0.8	0.3
541	2007	2	1.5	16.0	10.3	1.1	9.3	54.9	5.4	0.4	0.1	1.0
541	2008	2	1.3	16.1	11.6	1.0	8.6	54.3	6.2	0.4	0.1	0.4
541	2009	2	1.4	16.4	11.6	1.3	9.9	53.0	5.8	0.1	0.1	0.4
541	2010	2	1.3	16.0	11.9	1.2	9.1	53.7	6.0	0.2	0.0	0.6
541	2011	2	1.5	16.9	10.6	1.1	9.6	54.8	4.9	0.1	0.0	0.5
544	2009	14	1.6	23.4	10.9	1.1	5.1	55.2	1.5	0.4	0.2	0.5
544	2010	14	2.5	22.1	9.7	0.9	5.0	57.9	1.0	0.2	0.2	0.5
544	2011	14	2.2	23.9	9.1	0.7	4.8	57.0	1.3	0.2	0.2	0.5
618	2007	12	2.7	13.0	14.9	0.7	7.3	56.6	2.6	0.9	0.0	1.3
618	2008	12	2.7	13.2	19.4	0.8	8.6	50.2	2.2	0.8	0.1	1.9
618	2009	12	1.7	13.2	14.9	1.0	9.7	55.8	1.5	1.1	0.0	1.2
764	2006	14	1.0	18.0	10.2	4.6	3.9	58.8	1.6	0.6	0.8	0.4
764	2007	14	2.4	16.8	10.1	4.4	4.4	58.4	1.6	0.9	0.5	0.3
764	2008	14	3.9	23.3	7.8	3.2	4.9	54.2	1.8	0.6	0.3	0.1
764	2011	14	1.6	26.9	8.8	3.9	3.9	52.3	2.1	0.2	0.3	0.1
766	2007	11	1.6	15.4	18.3	0.5	7.0	51.5	4.2	0.9	0.2	0.4
766	2008	11	2.0	14.8	13.7	0.4	7.0	57.1	3.4	1.0	0.3	0.2
766	2009	11	2.5	14.3	15.1	0.5	7.7	54.0	4.2	1.0	0.4	0.2
766	2010	11	2.3	13.3	16.9	1.6	7.5	52.1	3.9	0.9	0.6	0.9
772	2006	8	1.7	18.3	12.6	7.3	9.4	48.2	1.2	0.0	1.2	0.1
772	2007	8	1.3	15.1	11.9	3.2	12.8	51.9	3.2	0.1	0.2	0.4
772	2010	8	0.8	15.8	10.6	1.0	12.0	56.2	2.9	0.1	0.0	0.6
772	2011	8	0.8	17.0	18.3	2.5	12.0	46.1	2.7	0.1	0.0	0.5

Default TTC 4 Percentages	2.4	22.7	5.7	1.4	8.1	55.2	1.7	2.2	0.2	0.4

8.5.2 Vehicle (Truck) Class Distribution based on Short Term Counts

The previous discussion indicates the TTC grouping system suggested by the MEPDG may lead to a misrepresentation of prevailing truck class distributions in Ohio. As a result, alternative techniques have been sought to more accurately determine the truck class distribution. Some states have implemented a clustering technique in which sites with similar truck class distributions are grouped into clusters to represent the prevailing truck patterns. This allows calculating new statewide averages for the truck class distributions other than those defined in the MEPDG TTC grouping system. The main shortcoming for this technique is that it requires re-clustering the sites to incorporate new data collected each year, which may lead to the formation of different clusters than those produced in previous years. Another limitation of this method is that it is significantly affected by prevailing Class 9 percentages. As discussed in later sections, most cluster analysis techniques are based on absolute or squared difference of site attributes. Since Class 9 trucks are prevalent along major highways, variations in this truck class typically dictate the formation of the truck class distribution clusters. Hence, sites with similar Class 9 percentages might be grouped together with less consideration to the other truck classes resulting in wide variations in truck class distributions within each cluster. Finally, this method requires using site-specific short term counts to estimate the annual truck counts and corresponding truck class distribution before matching the site to one of the developed clusters. This would require developing a series of seasonal adjustment factors for each of the individual truck classes to account for the monthly and day of week variations in truck counts.

In a recent study funded by the North Carolina Department of Transportation (NCDOT), Stone et al (*10*) suggested using the annualized truck class distribution calculated from site-specific short term counts rather than the average truck class distribution of the corresponding cluster to describe the prevailing truck pattern in the MEPDG. To simplify the analysis, the authors used two sets of seasonal adjustment factors for single unit (SU) and multiple unit (MU) trucks developed based on information from 44 WIM stations. It was reported that this approach resulted in more accurate representation of the actual truck class distribution than the TTC grouping system and the cluster analysis method.

A similar approach was followed in this study to define the truck class distribution. Given that 143 sites (93 AVC and 50 WIM sites) were available for this project (as compared to 44 sites in the North Carolina study), the seasonal adjustment factors were calculated for all truck classes (4 through 13) rather than for single and multiple unit trucks. Equation 10 was used in the calculation of the seasonal adjustment factors:

$$SAF_{cim} = \frac{AADTT_c}{MADTT_{cim}} \tag{10}$$

where SAF_{cim} is the seasonal adjustment factor for truck class *c*, day of week *i*, and month *m*; $AADTT_c$ is the average annual daily truck traffic of truck class *c*; and $\mathrm{MADTT}_{\mathrm{cim}}$ is the monthly average daily truck traffic for truck class *c*, day of week *i*, and month *m*.

Using the previous equation, 84 (7 days of week x 12 months) seasonal adjustment factors were developed for each truck class. The seasonal adjustment factors were calculated using traffic data from continuous sites only. A continuous site is defined as a site with at least one day of data for all seven days of the week and twelve months of the year. To improve the estimation of the seasonal adjustment factors, the continuous traffic data was checked for any discrepancies in daily truck counts and inconsistent traffic data was eliminated from the analysis. Furthermore, continuous sites with low annual average daily truck count for a particular class (less than 50 trucks per day) were excluded from the analysis because any variations in truck traffic at these sites would significantly skew the results.

Tables 22 to 31 present the seasonal adjustment factors for truck Classes 4 through 13. In these tables, the days of the week are represented by the numbers 1 through 7, where 1 is Sunday and 7 is Saturday. Similarly, the months of the year are represented by the numbers 1 through 12, where 1 is January and 12 is December. A seasonal adjustment factor close to 1.00 indicates that the daily truck count is approximately equal to the annual average daily truck count. As can be noticed from these tables, the seasonal adjustment factors are significantly lower for Monday through Friday than Saturday and Sunday, which is expected due to the higher truck traffic during the weekdays than the weekend. This trend can be observed for all truck classes except Class 11 where the factors for Monday are higher than those for Saturday. This indicates that the Class 11 truck volume is higher on Saturdays than Mondays. Additionally, the seasonal adjustment factors are generally higher in the winter months (11, 12, 1, and 2) than the rest of the year. The effect of the construction season can be observed in the seasonal adjustment factors of Class 7 trucks which include end dump trucks. As can be noticed in Table 25, the seasonal adjustment factors for Class 7 are lower between April and October, during which most of the construction activities are conducted. It is noted that while ODOT intends to continue to utilize the functional classification in pavement design, there were not enough sites to calculate an accurate seasonal adjustment factor for each functional classification. This was especially the case for non-interstates and major highways. The following paragraphs present an example on the use of these truck class seasonal adjustment factors to estimate the annualized truck class distribution from site-specific short term counts.

Table 22: Class 4 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	2.59	1.20	1.07	1.01	1.01	0.96	1.54
2	2.40	1.12	1.10	1.03	0.97	0.92	1.45
3	1.97	1.06	1.00	0.96	0.90	0.88	1.34
4	1.83	1.02	0.96	0.88	0.85	0.83	1.22
5	1.84	0.93	0.87	0.84	0.81	0.75	1.22
6	1.67	0.91	0.86	0.85	0.80	0.77	1.20
7	1.71	0.94	0.93	0.88	0.83	0.83	1.33
8	1.71	0.93	0.89	0.87	0.81	0.80	1.24
9	1.79	0.97	0.93	0.90	0.84	0.78	1.11
10	1.71	1.00	0.92	0.90	0.87	0.79	1.07
11	2.15	1.09	0.98	0.95	0.86	0.85	1.25
12	2.64	1.21	1.07	1.05	1.01	0.97	1.54

Table 23: Class 5 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	6.02	0.96	0.88	0.89	0.86	0.91	2.68
2	5.58	0.93	0.90	0.90	0.85	0.89	2.56
3	5.21	0.88	0.83	0.84	0.82	0.86	2.54
4	4.90	0.85	0.79	0.79	0.77	0.81	2.28
5	4.18	0.81	0.76	0.74	0.72	0.74	2.16
6	3.56	0.83	0.79	0.78	0.76	0.79	2.18
7	3.47	0.83	0.79	0.79	0.77	0.80	2.24
8	3.47	0.82	0.78	0.78	0.75	0.78	2.04
9	3.65	0.79	0.75	0.75	0.72	0.74	1.93
10	3.84	0.81	0.77	0.77	0.75	0.76	2.04
11	4.76	0.85	0.80	0.81	0.78	0.81	2.32
12	5.58	0.91	0.85	0.86	0.83	0.88	2.45

Table 24: Class 6 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	5.98	1.02	1.00	1.00	0.99	1.01	3.54
2	5.76	1.02	1.04	1.02	0.99	1.03	3.39
3	5.45	0.94	0.93	0.93	0.92	0.96	3.40
4	5.86	0.85	0.85	0.84	0.82	0.85	2.99
5	4.93	0.78	0.76	0.75	0.74	0.77	2.46
6	4.44	0.72	0.71	0.71	0.70	0.71	2.17
7	4.36	0.71	0.70	0.70	0.70	0.73	2.37
8	4.28	0.72	0.71	0.70	0.70	0.71	2.30
9	4.49	0.75	0.74	0.71	0.70	0.72	2.24
10	4.40	0.76	0.75	0.77	0.76	0.79	2.46
11	5.01	0.82	0.81	0.81	0.78	0.81	2.71
12	5.67	0.98	0.96	0.97	0.96	0.98	3.24

Table 25: Class 7 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	6.03	1.58	1.57	1.53	1.50	1.57	3.55
2	5.96	1.58	1.57	1.59	1.44	1.48	3.17
3	3.85	1.17	1.22	1.17	1.12	1.14	2.41
4	2.62	1.01	1.01	0.95	0.87	0.97	1.62
5	2.05	0.87	0.88	0.84	0.78	0.70	1.40
6	1.58	0.76	0.80	0.75	0.68	0.66	1.14
7	1.50	0.72	0.79	0.73	0.67	0.63	1.11
8	1.30	0.71	0.77	0.72	0.65	0.64	1.12
9	1.99	0.83	0.86	0.79	0.70	0.69	1.30
10	1.67	0.84	0.88	0.85	0.80	0.78	1.55
11	2.97	1.05	1.02	1.00	0.91	0.95	1.87
12	5.01	1.36	1.36	1.34	1.24	1.27	2.67

Table 26: Class 8 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	6.03	1.16	1.07	1.07	1.05	1.08	3.50
2	5.76	1.16	1.08	1.07	1.02	1.07	3.23
3	4.56	1.04	0.98	0.95	0.92	0.98	2.71
4	2.84	0.93	0.88	0.84	0.79	0.82	2.00
5	2.37	0.86	0.82	0.79	0.75	0.73	1.78
6	1.96	0.82	0.80	0.77	0.72	0.71	1.56
7	1.80	0.79	0.78	0.76	0.70	0.68	1.54
8	1.86	0.79	0.78	0.76	0.72	0.70	1.58
9	2.12	0.84	0.80	0.78	0.73	0.73	1.80
10	2.28	0.87	0.84	0.83	0.80	0.80	1.97
11	3.93	1.00	0.91	0.91	0.88	0.89	2.47
12	5.42	1.11	1.01	1.01	0.97	1.00	2.97

Table 27: Class 9 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	3.62	1.01	0.91	0.90	0.91	1.04	2.97
2	3.52	1.00	0.92	0.90	0.90	1.03	2.86
3	3.44	0.96	0.86	0.86	0.87	1.01	2.84
4	3.49	0.95	0.85	0.84	0.85	0.99	2.86
5	3.54	0.92	0.84	0.82	0.83	0.96	2.71
6	3.31	0.93	0.84	0.83	0.84	0.95	2.66
7	3.50	0.96	0.87	0.86	0.88	1.00	2.84
8	3.39	0.93	0.84	0.83	0.84	0.97	2.74
9	3.51	0.92	0.84	0.82	0.82	0.94	2.64
10	3.30	0.93	0.83	0.83	0.84	0.96	2.71
11	3.21	0.93	0.84	0.85	0.84	0.97	2.72
12	3.65	1.02	0.91	0.90	0.90	1.03	2.88

Table 28: Class 10 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	15.42	0.97	0.92	0.88	0.88	1.00	6.32
2	15.32	1.00	0.99	0.96	0.93	1.08	6.53
3	13.79	0.93	0.87	0.88	0.88	1.01	6.76
4	14.25	0.87	0.81	0.79	0.81	0.94	6.18
5	12.99	0.81	0.75	0.74	0.75	0.86	4.87
6	12.59	0.76	0.73	0.71	0.72	0.81	3.84
7	12.34	0.73	0.69	0.69	0.71	0.81	4.18
8	11.89	0.71	0.68	0.68	0.68	0.75	3.46
9	11.77	0.72	0.69	0.67	0.66	0.76	3.78
10	10.61	0.76	0.67	0.67	0.69	0.80	3.94
11	13.28	0.79	0.71	0.74	0.71	0.82	4.60
12	13.43	1.01	0.88	0.87	0.90	1.01	6.29

Table 29: Class 11 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	5.68	1.50	0.82	0.80	0.79	0.83	1.34
2	5.34	1.50	0.83	0.79	0.79	0.84	1.32
3	5.19	1.43	0.77	0.75	0.75	0.81	1.29
4	5.81	1.47	0.76	0.74	0.74	0.79	1.30
5	5.38	1.42	0.82	0.73	0.73	0.78	1.24
6	5.37	1.41	0.76	0.73	0.73	0.79	1.24
7	5.57	1.44	0.79	0.74	0.75	0.80	1.27
8	5.39	1.39	0.75	0.73	0.73	0.78	1.23
9	5.38	1.38	0.80	0.71	0.71	0.77	1.21
10	5.66	1.37	0.74	0.72	0.71	0.77	1.22
11	5.44	1.39	0.74	0.73	0.73	0.79	1.26
12	5.50	1.46	0.78	0.76	0.75	0.82	1.32

Table 30: Class 12 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	4.08	1.60	0.82	0.78	0.79	0.89	1.44
2	4.28	1.62	0.84	0.80	0.80	0.92	1.46
3	3.74	1.50	0.78	0.75	0.76	0.88	1.42
4	3.74	1.49	0.76	0.74	0.73	0.85	1.39
5	3.60	1.47	0.80	0.72	0.72	0.82	1.33
6	3.81	1.48	0.76	0.72	0.72	0.83	1.34
7	4.04	1.50	0.78	0.74	0.75	0.85	1.37
8	3.53	1.47	0.75	0.72	0.73	0.83	1.33
9	3.44	1.43	0.78	0.71	0.71	0.81	1.29
10	3.63	1.45	0.75	0.72	0.73	0.82	1.32
11	3.48	1.48	0.73	0.71	0.72	0.80	1.28
12	3.18	1.47	0.73	0.70	0.69	0.80	1.24

Table 31: Class 13 Seasonal Adjustment Factors

	Day of Week						
Month	1	2	3	4	5	6	7
1	11.73	0.93	0.84	0.90	0.92	0.95	5.29
2	11.36	1.01	0.94	0.94	0.95	1.00	5.45
3	10.03	0.88	0.88	0.91	0.89	1.00	6.35
4	9.13	0.86	0.79	0.82	0.80	0.87	5.67
5	11.55	0.78	0.72	0.70	0.70	0.78	4.91
6	8.01	0.71	0.70	0.70	0.69	0.76	3.70
7	8.06	0.71	0.68	0.69	0.71	0.79	4.65
8	6.40	0.70	0.66	0.69	0.68	0.77	3.87
9	6.88	0.72	0.72	0.68	0.70	0.76	3.94
10	6.98	0.72	0.66	0.70	0.69	0.80	3.36
11	7.79	0.78	0.75	0.78	0.74	0.82	4.39
12	10.40	0.98	0.88	0.92	0.87	0.96	5.22

An example on the effect of seasonal adjustment factors on daily truck class distributions is presented in Figures 57 and 58. Figure 57 shows the minimum and maximum unadjusted daily truck class distributions for Site 153 in 2009, while Figure 58 shows the minimum and maximum daily truck class distributions after the application of the seasonal adjustment factors. This data is based on daily truck counts obtained Monday through Thursday between April and October, which is the typical short-term count collection period for ODOT. As can be seen from these figures, the application of the seasonal adjustment factors significantly reduced the difference between the minimum and maximum daily truck class distributions, especially for truck Classes 5, 6, and 11. Tables 32 and 33 show the unadjusted and adjusted truck class distributions before and after the application of seasonal adjustment factors. As can be seen from these tables, the unadjusted daily Class 11 percentages ranged from 2.8% to 5.4%, but after the application of the seasonal adjustment factors they ranged from 4.6% to 5.2%. When compared to the annual percent of Class 11 trucks of 5% for Site 153, it can be seen that the application of the seasonal adjustment factors significantly improved the accuracy of the estimation of the annual truck class distribution from short term counts.

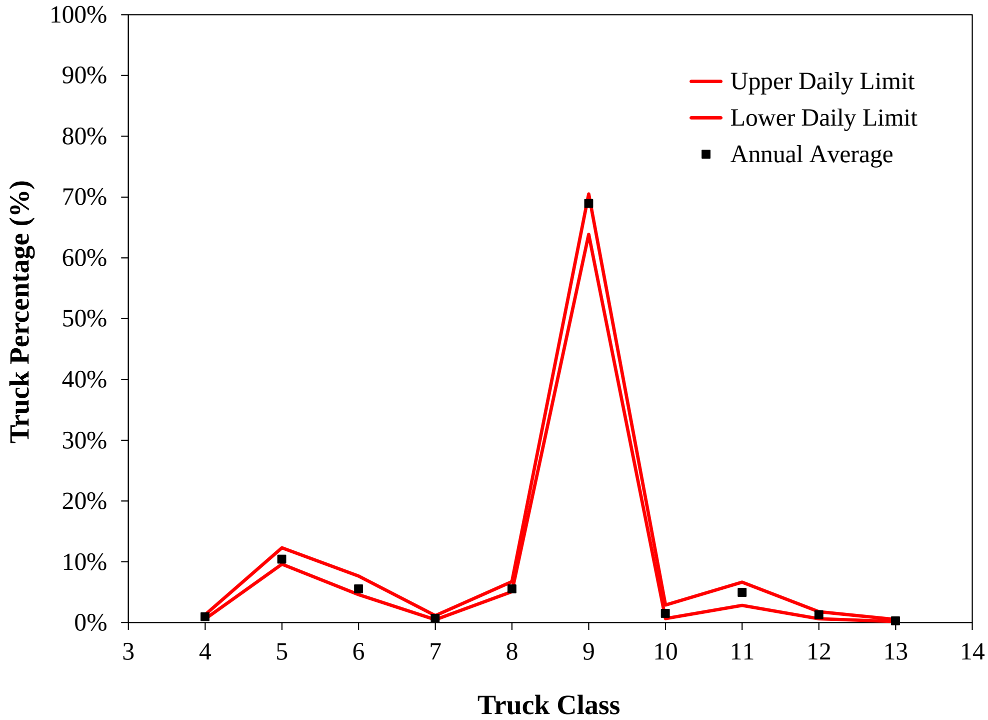


Figure 57: Unadjusted Truck Class Distributions for Site 153 in 2009

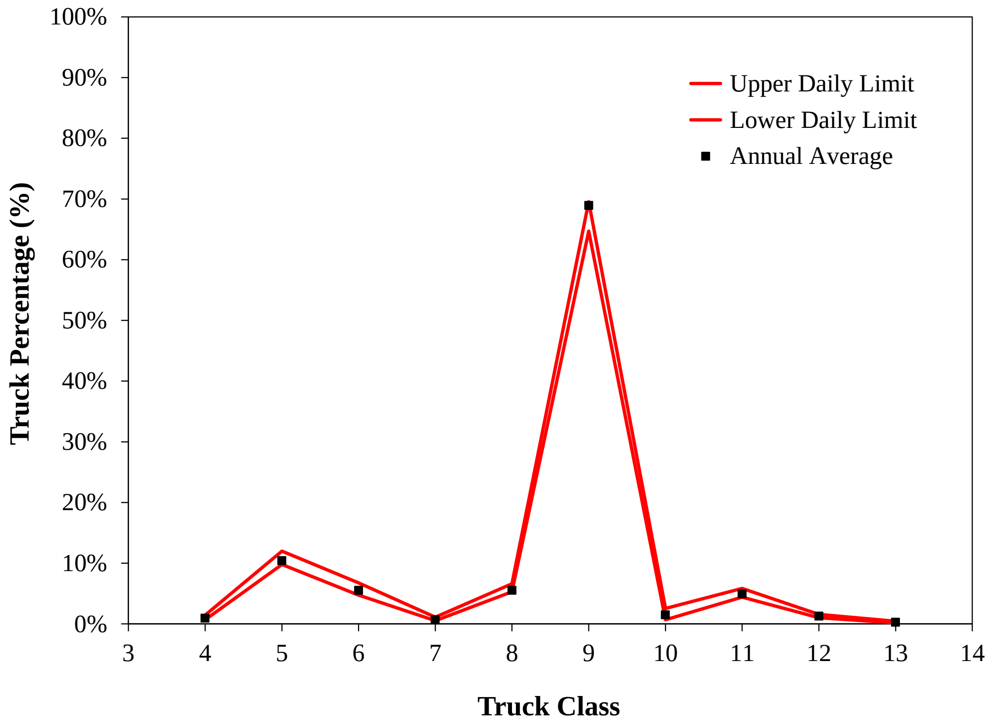


Figure 58: Adjusted Truck Class Distribution for Site 153 in 2009

Table 32: Unadjusted Monday-Thursday Truck Class Distribution for Site 153 in April 2009

		Class									
Month	Day	4	5	6	7	8	9	10	11	12	13
4	1	0.9	9.7	5.5	0.5	5.5	69.3	1.7	5.3	1.4	0.2
4	2	1.0	10.7	5.5	0.7	5.0	69.2	1.2	5.1	1.4	0.2
4	6	0.7	11.8	6.2	0.5	5.6	69.8	1.8	2.8	0.8	0.2
4	7	0.6	10.1	4.9	0.5	5.2	70.8	1.2	5.2	1.3	0.3
4	8	0.6	9.6	5.1	0.5	5.6	70.4	1.3	5.1	1.6	0.2
4	9	0.9	11.1	5.6	0.5	6.1	68.1	1.1	5.0	1.4	0.2
4	13	0.5	11.2	5.7	0.7	6.3	70.5	1.2	2.8	0.8	0.2
4	14	0.7	9.9	4.1	0.4	5.3	71.9	1.2	5.0	1.3	0.2
4	15	0.7	10.3	5.2	0.6	5.6	69.9	0.9	5.0	1.5	0.2
4	16	0.8	11.3	5.4	0.6	5.8	68.2	1.0	5.4	1.4	0.1
4	20	0.7	11.1	5.9	0.5	5.5	70.6	1.3	3.1	0.9	0.3
4	21	0.7	10.0	4.9	0.7	5.3	70.3	1.3	5.2	1.5	0.3
4	22	0.8	10.1	5.1	0.7	5.9	69.1	1.1	5.2	1.5	0.4
4	23	0.8	10.7	6.1	0.8	5.4	67.6	1.3	5.3	1.6	0.3
4	27	1.0	11.7	6.1	1.0	6.4	68.4	1.2	3.2	0.7	0.3
4	28	0.6	11.2	5.4	0.8	5.5	68.3	1.3	5.1	1.4	0.3
4	29	0.7	10.7	5.1	0.9	5.4	68.9	1.4	5.2	1.5	0.2
4	30	0.8	11.1	5.2	0.5	5.6	68.4	1.2	5.3	1.6	0.2

Table 33: Adjusted Monday-Thursday Truck Class Distribution for Site 153 in April 2009

		Class									
Month	Day	4	5	6	7	8	9	10	11	12	13
4	1	1.0	9.8	6.0	0.6	6.0	68.2	1.7	5.0	1.4	0.2
4	2	1.1	10.6	5.8	0.8	5.1	69.1	1.3	4.9	1.3	0.2
4	6	0.8	11.3	5.9	0.5	5.8	67.7	1.8	4.6	1.3	0.2
4	7	0.7	10.2	5.3	0.7	5.8	69.5	1.2	5.0	1.3	0.3
4	8	0.7	9.8	5.6	0.6	6.1	69.4	1.3	4.9	1.5	0.2
4	9	1.0	11.0	5.9	0.6	6.1	68.0	1.1	4.8	1.3	0.2
4	13	0.6	10.8	5.5	0.8	6.6	68.4	1.2	4.7	1.3	0.2
4	14	0.8	10.0	4.5	0.5	6.0	70.7	1.2	4.9	1.2	0.2
4	15	0.8	10.4	5.7	0.7	6.1	68.8	0.9	4.8	1.4	0.2
4	16	0.9	11.2	5.7	0.6	5.8	68.2	1.0	5.1	1.3	0.1
4	20	0.8	10.6	5.7	0.6	5.8	68.4	1.3	5.1	1.6	0.3
4	21	0.8	10.1	5.3	0.8	6.0	69.0	1.3	5.0	1.4	0.3
4	22	0.9	10.2	5.6	0.9	6.4	68.0	1.1	5.0	1.5	0.4
4	23	0.9	10.6	6.5	0.9	5.4	67.5	1.3	5.1	1.5	0.3
4	27	1.2	11.2	5.8	1.1	6.6	66.2	1.2	5.2	1.3	0.3
4	28	0.7	11.4	5.8	1.1	6.1	67.0	1.4	4.9	1.4	0.3
4	29	0.8	10.9	5.6	1.1	5.9	67.8	1.4	5.0	1.4	0.2
4	30	0.9	11.0	5.4	0.6	5.7	68.3	1.2	5.1	1.5	0.2

8.6 Monthly Adjustment Factors

As discussed in Section 2.3.2.3, the MEPDG uses the monthly adjustment factors (MAF) to account for the seasonal variations in truck traffic. Tables 34 through 42 present the MAFs calculated using Equation 2 for different functional classifications. The MAFs were calculated using traffic data from continuous sites only. Since no data was available for functional classifications 9, 17, and 19, they were not represented in the analysis.

Several observations can be made based on the previously mentioned tables. For instance, the monthly adjustment factors for FCs 1, 11, and 12 (rural interstate, urban interstate, and urban freeway) are close to 1.00 for all truck classes. This means that the monthly truck traffic has little variation throughout the year. For the other functional classifications, the monthly adjustment factors are lower than 1.00 from November to March and close to or higher than 1.00 from April to October. For almost all functional classifications, the effect of the construction season in Ohio can be observed in the MAFs for truck Class 7, which are lower than 1.00 between November and March and approximately equal to or greater than 1.00 between April and October. It is noted that for FCs 6, 7, 8, and 16 the MAFs were inconsistent especially for truck Classes 11, 12, and 13. This variability can be attributed to the sites with continuous traffic data as demonstrated in Figure 59.

Since the MAFs for the majority of the functional classifications with sufficient data availability are close to 1.00, it will be reasonably accurate to use the default MEPDG MAFs of 1.00 for all months and truck classes as this is not expected to have a significant impact on pavement design.

Table 34: Monthly Adjustment Factors for FC 1

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.85	0.83	0.86	0.66	0.78	0.96	0.95	0.97	0.94	0.90
2	0.89	0.84	0.87	0.65	0.79	0.97	0.91	0.96	0.94	0.75
3	1.00	0.90	0.92	0.83	0.87	1.01	0.96	0.98	0.99	0.78
4	1.06	0.97	0.99	0.98	0.99	1.01	1.03	1.01	1.02	0.95
5	1.11	1.04	1.07	1.09	1.05	1.02	0.99	1.01	1.02	1.04
6	1.06	1.07	1.12	1.24	1.16	1.02	1.01	1.00	1.02	1.00
7	0.99	1.10	1.12	1.37	1.23	0.97	1.00	0.98	0.97	1.05
8	1.01	1.08	1.10	1.32	1.21	1.00	1.03	1.00	1.00	1.17
9	1.07	1.12	1.06	1.18	1.14	1.02	1.06	1.03	1.02	1.14
10	1.09	1.09	1.01	1.08	1.03	1.02	1.07	1.04	1.01	1.08
11	1.00	1.02	0.98	0.88	0.90	1.01	1.00	1.02	1.01	1.01
12	0.87	0.94	0.88	0.72	0.83	0.98	0.99	0.99	1.06	1.12

Table 35: Monthly Adjustment Factors for FC 2

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.90	0.88	0.77	0.65	0.74	0.94	0.87	0.91	0.83	0.83
2	0.88	0.89	0.76	0.63	0.75	0.94	0.91	0.89	0.88	0.80
3	0.87	0.95	0.85	0.81	0.84	0.99	0.94	0.89	1.09	0.82
4	0.95	1.01	0.96	0.93	1.05	1.00	0.96	0.96	0.93	0.84
5	1.31	1.09	1.07	1.16	1.14	1.02	0.99	1.01	1.02	1.05
6	1.18	1.02	1.15	1.15	1.21	1.02	1.00	1.09	0.93	1.02
7	0.95	1.02	1.17	1.21	1.24	0.99	1.01	1.10	1.13	1.04
8	1.05	1.05	1.18	1.22	1.19	1.03	1.08	1.12	1.07	1.18
9	1.09	1.10	1.19	1.30	1.13	1.05	1.13	1.13	1.07	1.13
10	1.09	1.06	1.10	1.17	1.05	1.04	1.10	1.07	1.09	1.15
11	0.95	1.00	1.01	0.99	0.89	1.03	1.10	0.96	1.08	1.24
12	0.79	0.94	0.79	0.78	0.78	0.94	0.92	0.86	0.89	0.90

Table 36: Monthly Adjustment Factors for FC 6

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	1.06	1.00	0.75	0.70	0.82	0.94	0.98	0.67	1.02	0.75
2	0.95	0.99	0.75	0.73	0.76	0.97	0.89	0.47	0.75	1.03
3	1.00	1.02	0.81	0.83	0.86	1.01	1.04	2.73	0.73	0.80
4	1.14	1.04	0.92	0.89	1.14	1.02	1.15	1.44	0.98	0.77
5	1.13	1.07	1.09	1.03	1.25	1.06	0.97	0.49	0.86	0.84
6	0.81	0.98	1.25	1.21	1.04	1.06	0.87	0.50	1.02	1.01
7	0.78	0.97	1.33	1.28	1.04	0.99	1.03	0.50	1.38	1.35
8	0.84	0.99	1.22	1.30	1.08	0.98	1.02	0.52	1.06	1.67
9	1.13	1.04	1.09	1.25	1.10	1.00	1.03	0.99	0.62	0.88
10	1.12	1.02	0.98	1.03	1.12	0.99	1.10	1.15	0.66	1.20
11	1.05	0.97	0.99	0.91	0.92	1.01	0.96	1.65	1.14	0.62
12	1.00	0.92	0.83	0.85	0.85	0.97	0.96	0.88	1.77	1.08

Table 37: Monthly Adjustment Factors for FC 7

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.98	0.91	0.65	0.56	0.52	1.01	1.23	1.13	0.73	0.49
2	1.12	0.84	0.63	0.53	0.50	0.97	1.10	1.07	0.80	0.46
3	1.12	0.97	0.70	0.72	0.70	1.01	1.16	0.85	0.93	1.01
4	1.24	0.99	0.85	0.93	0.97	1.00	1.12	1.08	1.04	1.32
5	1.43	1.07	1.20	1.28	1.52	1.02	0.93	1.06	1.11	0.91
6	0.74	1.05	1.38	1.54	1.22	1.03	0.92	1.17	1.12	1.12
7	0.59	1.03	1.13	1.31	1.56	0.98	0.80	0.93	1.22	1.80
8	0.83	1.12	1.15	1.38	1.75	0.97	0.78	0.79	1.41	1.96
9	1.27	1.12	1.26	1.30	1.26	1.02	0.83	1.00	0.89	1.21
10	1.13	1.03	1.28	1.04	0.79	1.01	1.09	0.96	1.01	1.02
11	0.90	0.95	0.97	0.83	0.66	1.01	0.91	0.94	0.94	0.36
12	0.66	0.90	0.80	0.57	0.55	0.98	1.12	1.02	0.80	0.34

Table 38: Monthly Adjustment Factors for FC 8

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.84	0.95	0.76	0.75	0.74	0.86	0.81	0.48	0.28	1.77
2	0.91	0.89	0.59	0.41	0.72	0.86	0.75	0.19	0.76	1.64
3	0.96	0.97	0.84	0.70	0.82	0.94	0.92	0.45	1.11	0.80
4	1.03	1.00	0.98	0.77	0.99	0.94	0.91	1.13	0.91	2.30
5	1.09	1.02	1.00	0.91	1.14	1.07	0.88	2.63	1.12	1.31
6	1.18	1.14	1.14	0.99	1.20	1.11	1.13	2.22	0.92	0.70
7	1.09	1.07	1.09	1.35	1.10	1.04	1.09	1.45	1.05	0.00
8	1.01	1.03	1.15	1.43	1.16	1.05	1.05	0.88	0.47	0.25
9	1.03	1.08	1.17	1.39	1.26	1.06	1.07	0.69	0.58	1.05
10	1.02	1.02	1.15	1.21	1.07	1.09	1.15	0.65	1.12	0.59
11	0.98	0.92	1.22	1.40	0.98	1.08	1.20	0.67	1.53	0.84
12	0.86	0.90	0.93	0.69	0.82	0.91	1.03	0.57	2.14	0.75

Table 39: Monthly Adjustment Factors for FC 11

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.89	0.89	0.86	0.70	0.82	0.96	0.91	0.96	0.93	0.76
2	0.91	0.90	0.85	0.71	0.82	0.97	0.88	0.96	0.93	0.86
3	0.95	0.95	0.89	0.81	0.88	1.00	0.90	1.00	0.98	0.81
4	1.01	1.00	0.97	0.99	0.99	1.00	0.95	1.00	1.01	0.91
5	1.07	1.06	1.05	1.14	1.04	1.02	1.00	1.01	1.00	1.02
6	1.11	1.06	1.11	1.25	1.15	1.02	1.06	1.02	1.02	1.19
7	1.04	1.05	1.12	1.25	1.20	0.97	1.06	1.00	0.98	1.25
8	1.06	1.06	1.13	1.24	1.17	1.01	1.12	1.02	1.00	1.23
9	1.05	1.07	1.10	1.18	1.11	1.03	1.09	1.02	1.02	1.11
10	1.06	1.03	1.05	1.07	1.03	1.02	1.11	1.02	1.03	1.06
11	0.99	0.99	1.01	0.93	0.93	1.02	1.07	1.01	1.03	0.94
12	0.86	0.93	0.86	0.75	0.86	0.99	0.86	0.97	1.06	0.86

Table 40: Monthly Adjustment Factors for FC 12

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.86	0.92	0.91	0.72	0.81	0.95	0.91	1.05	0.93	0.82
2	0.87	0.92	0.85	0.70	0.82	0.94	0.94	1.09	1.03	0.88
3	0.91	0.94	0.85	0.78	0.86	0.98	0.86	0.87	0.96	0.83
4	1.02	1.00	0.93	0.95	0.96	1.02	0.99	0.93	1.02	0.94
5	1.19	1.09	1.05	1.10	1.09	1.04	1.08	0.98	1.04	1.23
6	1.09	1.03	1.17	1.22	1.18	1.05	1.20	1.05	0.93	1.06
7	0.94	1.01	1.14	1.16	1.17	0.98	1.11	0.99	0.82	1.04
8	0.95	1.04	1.13	1.17	1.15	1.01	1.09	1.01	0.98	1.02
9	1.14	1.08	1.11	1.17	1.11	1.00	1.05	1.14	1.11	1.16
10	1.15	1.03	1.05	1.18	1.06	1.02	0.98	1.03	1.12	1.08
11	0.97	0.99	0.98	1.04	0.95	1.03	0.97	1.00	1.01	1.04
12	0.89	0.95	0.84	0.83	0.85	0.98	0.81	0.86	1.04	0.91

Table 41: Monthly Adjustment Factors for FC 14

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.80	0.92	0.74	0.53	0.80	0.89	0.55	1.08	0.56	0.71
2	0.88	0.91	0.72	0.50	0.83	0.90	0.53	1.17	0.58	0.60
3	0.92	0.94	0.77	0.62	0.92	0.94	0.63	0.98	0.75	0.87
4	1.19	1.03	0.91	0.89	1.07	1.00	0.82	1.14	1.00	0.88
5	1.07	1.07	1.03	1.26	1.08	1.04	1.15	1.02	1.22	1.02
6	1.07	1.02	1.18	1.38	1.11	1.05	1.19	1.07	1.02	1.25
7	0.99	0.99	1.24	1.40	1.11	1.05	1.53	0.98	1.11	1.46
8	1.02	1.03	1.26	1.37	1.12	1.09	1.44	1.02	1.33	1.12
9	1.09	1.09	1.22	1.31	1.07	1.07	1.31	0.91	1.12	1.06
10	1.11	1.06	1.13	1.18	1.02	1.05	1.11	0.99	1.09	1.06
11	0.95	1.00	1.01	0.95	0.94	1.03	1.09	0.78	1.11	0.99
12	0.91	0.92	0.79	0.61	0.92	0.89	0.64	0.85	1.11	0.99

Table 42: Monthly Adjustment Factors for FC 16

	Class									
Month	4	5	6	7	8	9	10	11	12	13
1	0.73	1.05	0.72	0.24	0.78	0.81	0.41	0.57	1.43	0.60
2	1.03	1.03	0.83	0.59	0.83	0.85	1.09	0.24	0.37	0.93
3	0.89	1.04	0.84	0.48	0.94	0.85	1.22	3.05	1.61	0.89
4	1.07	1.04	0.96	0.94	1.04	0.93	0.72	1.13	1.51	1.15
5	1.13	1.08	0.93	1.03	1.07	0.94	0.56	0.45	0.00	1.33
6	0.92	0.81	1.17	1.46	1.08	1.06	0.59	0.31	4.00	1.35
7	0.96	0.80	1.14	1.79	1.06	1.05	0.78	0.45	0.00	1.14
8	1.02	0.87	0.90	0.82	1.08	1.28	0.90	0.47	0.00	0.86
9	1.24	1.12	1.12	1.31	1.00	1.21	1.30	0.84	0.00	1.24
10	1.15	1.11	1.34	1.40	1.09	1.10	1.55	1.90	1.21	1.17
11	0.96	1.06	1.14	1.09	1.10	0.98	1.52	1.76	1.37	0.88
12	0.91	0.97	0.91	0.85	0.95	0.92	1.35	0.81	0.48	0.47

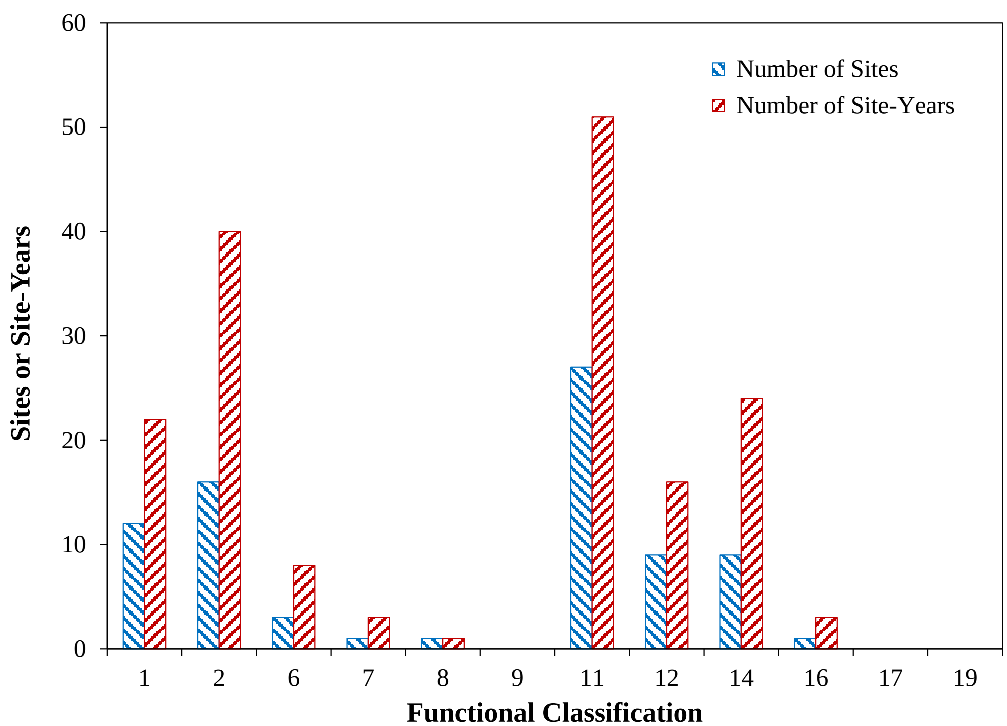


Figure 59: Data Availability for Estimation of Truck Class Seasonal Adjustment Factors

8.7 Hourly Distribution Factors

Figures 60 to 68 show the hourly distribution factors and the associated coefficients of variation obtained for different functional classifications. As can be noticed from these figures, the truck traffic is more uniformly distributed during the day on major highways (FCs 1, 2, 11, and 12) with a peak between 10:00 am and 2:00 pm, while other functional classifications show wide variations between daytime and nighttime truck traffic and have clear peaks during the morning and evening rush hours. Additionally, it can be noticed that the coefficients of variation are lower during the peak hours, which can be attributed to the higher truck volumes. Furthermore, it can be noticed that the coefficients of variation are lower for FCs 1 and 11 (rural and urban interstates, respectively) than the rest of the functional classifications. This could also be attributed to the more consistent and significantly higher truck volumes.

It is noted that functional classifications 9, 17, and 19 were not represented in the analysis due to the lack of sites with these functional classifications. Therefore, it is recommended to use FC 8 hourly distribution factors for FC 9 and FC 16 hourly distribution factors for FCs 17 and 19 in the design of pavement structures using the MEPDG.

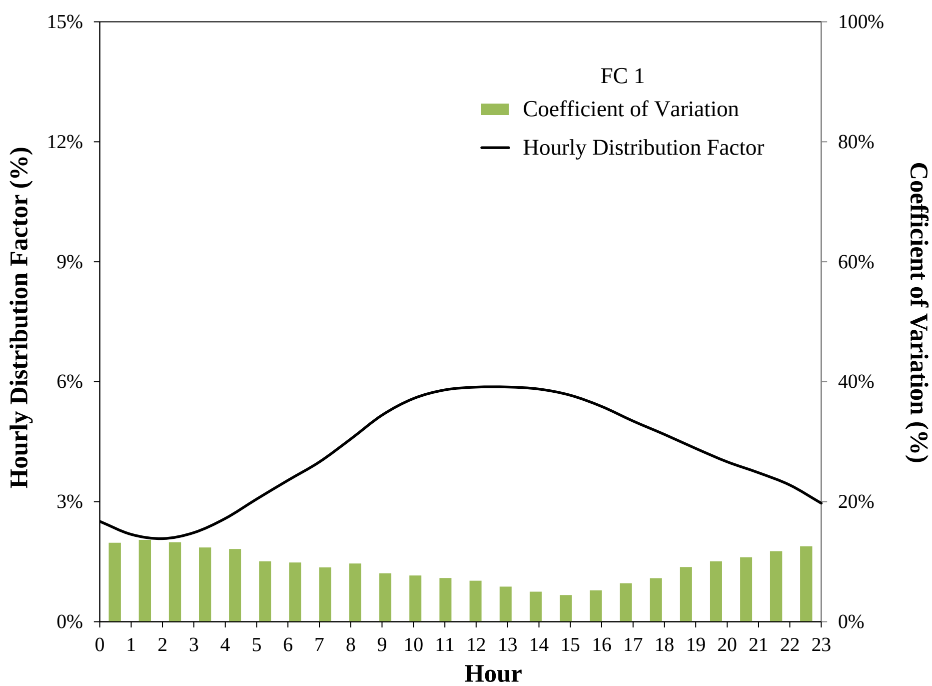


Figure 60: Hourly Distribution Factors and Associated Coefficients of Variation for FC 1

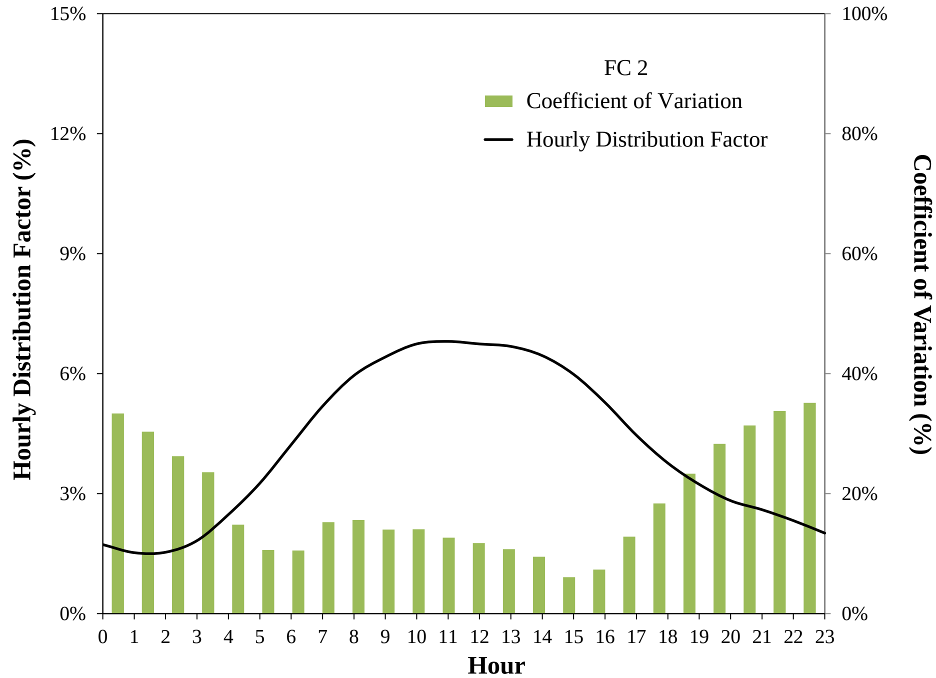


Figure 61: Hourly Distribution Factors and Associated Coefficients of Variation for FC 2

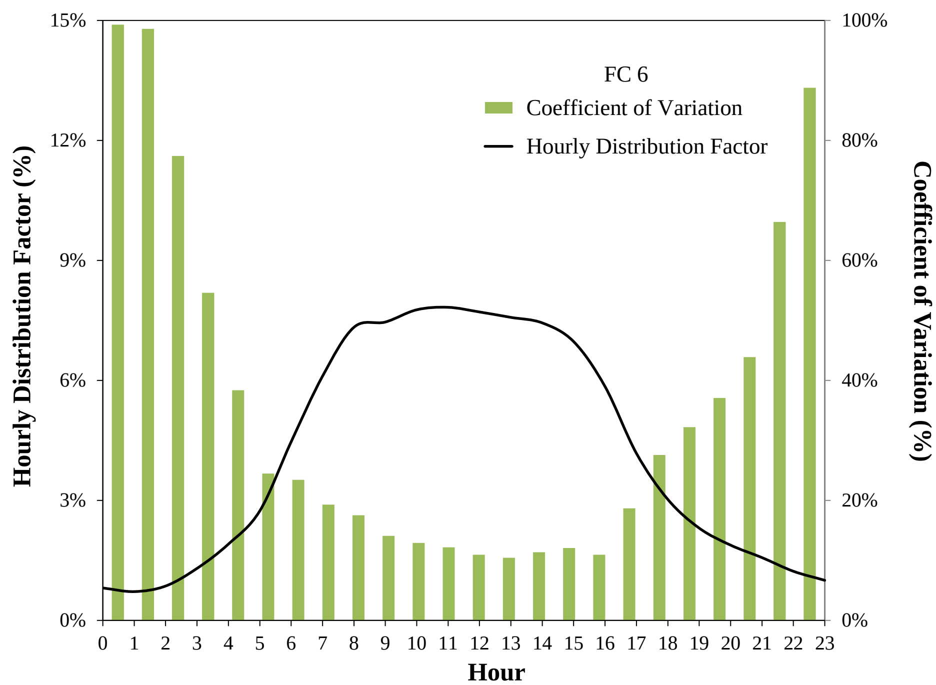


Figure 62: Hourly Distribution Factors and Associated Coefficients of Variation for FC 6

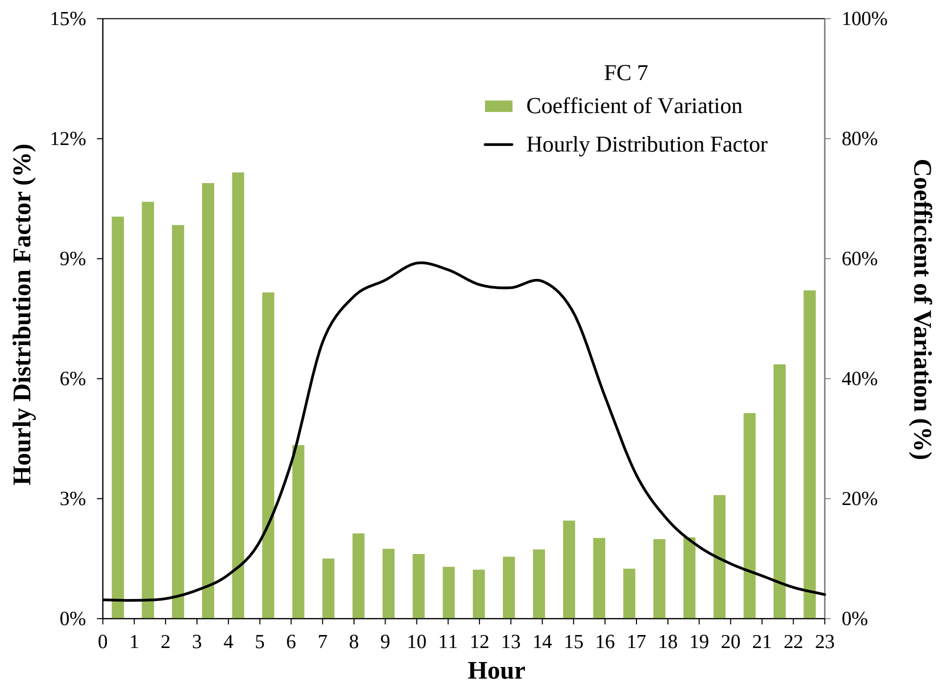


Figure 63: Hourly Distribution Factors and Associated Coefficients of Variation for FC 7

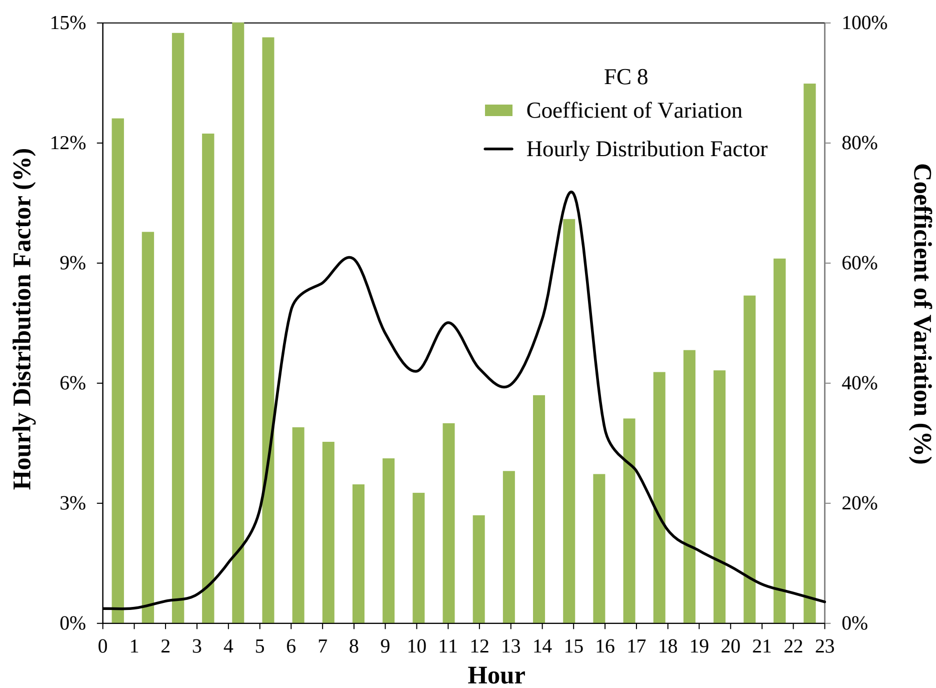


Figure 64: Hourly Distribution Factors and Associated Coefficients of Variation for FC 8

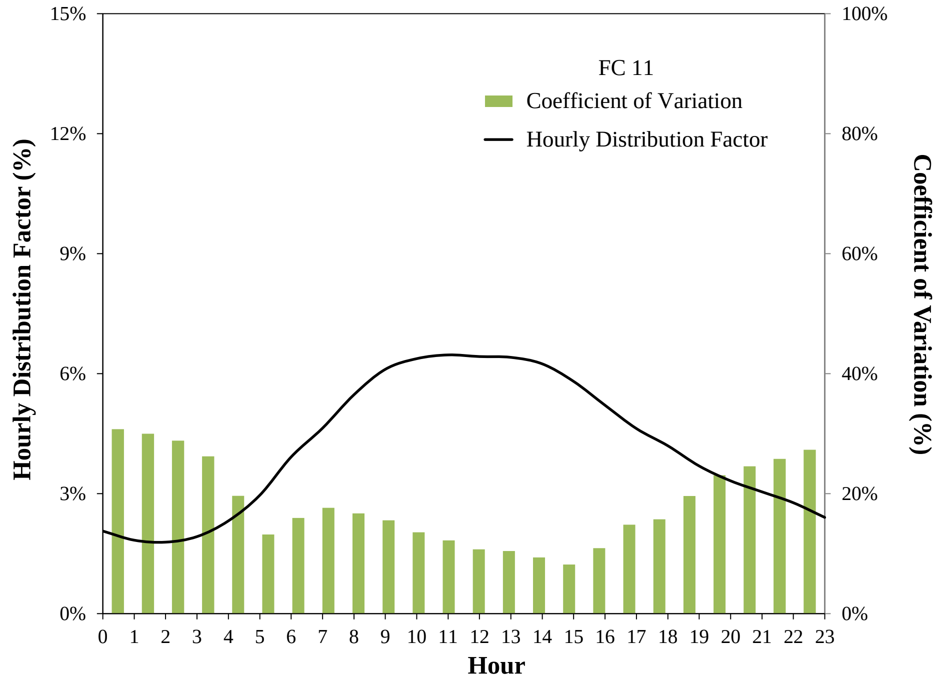


Figure 65: Hourly Distribution Factors and Associated Coefficients of Variation for FC 11

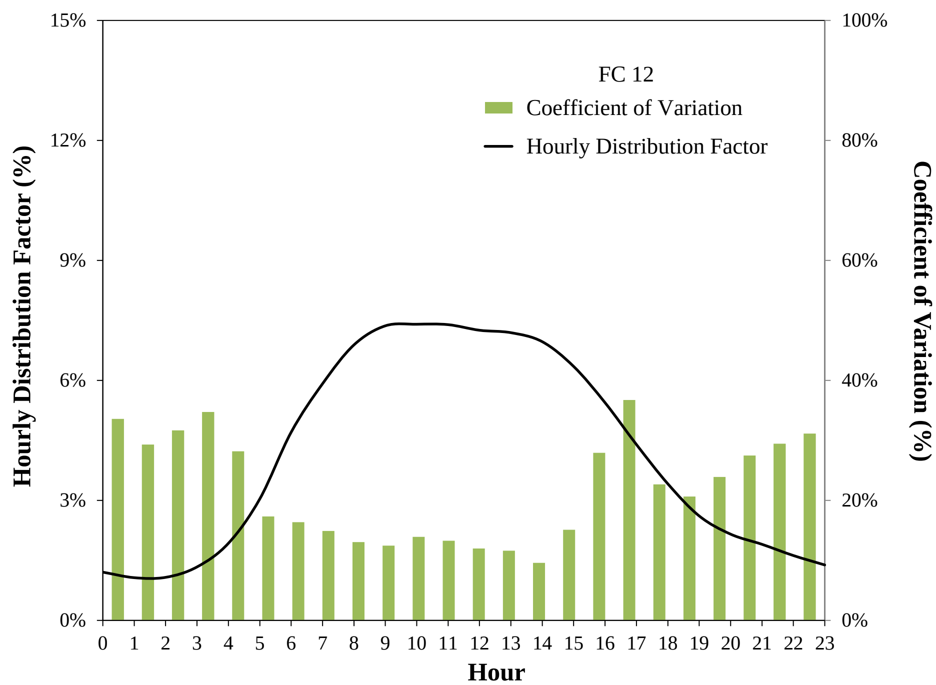


Figure 66: Hourly Distribution Factors and Associated Coefficients of Variation for FC 12

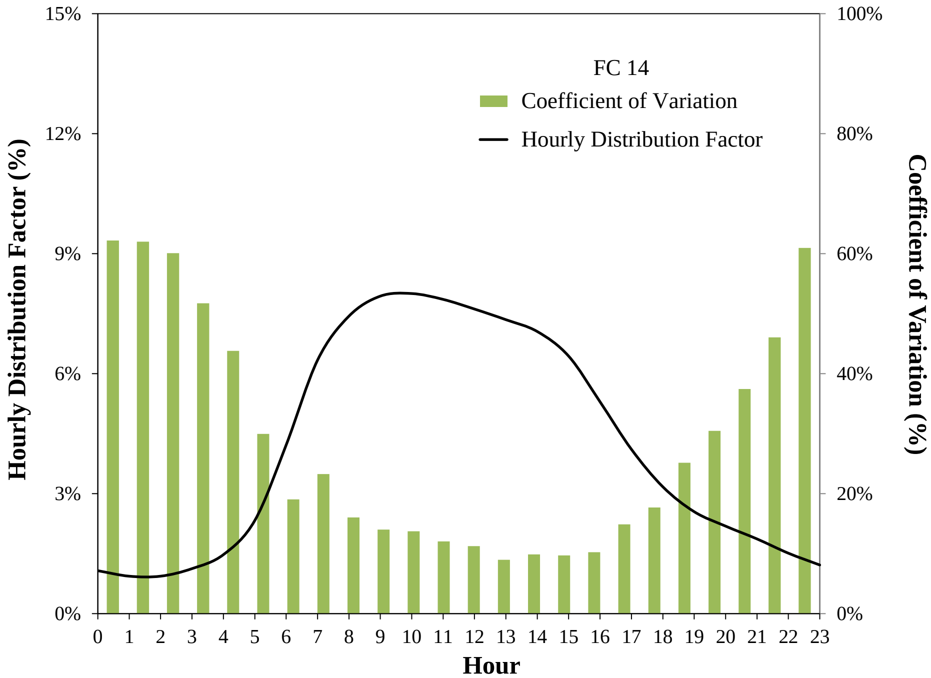


Figure 67: Hourly Distribution Factors and Associated Coefficients of Variation for FC 14

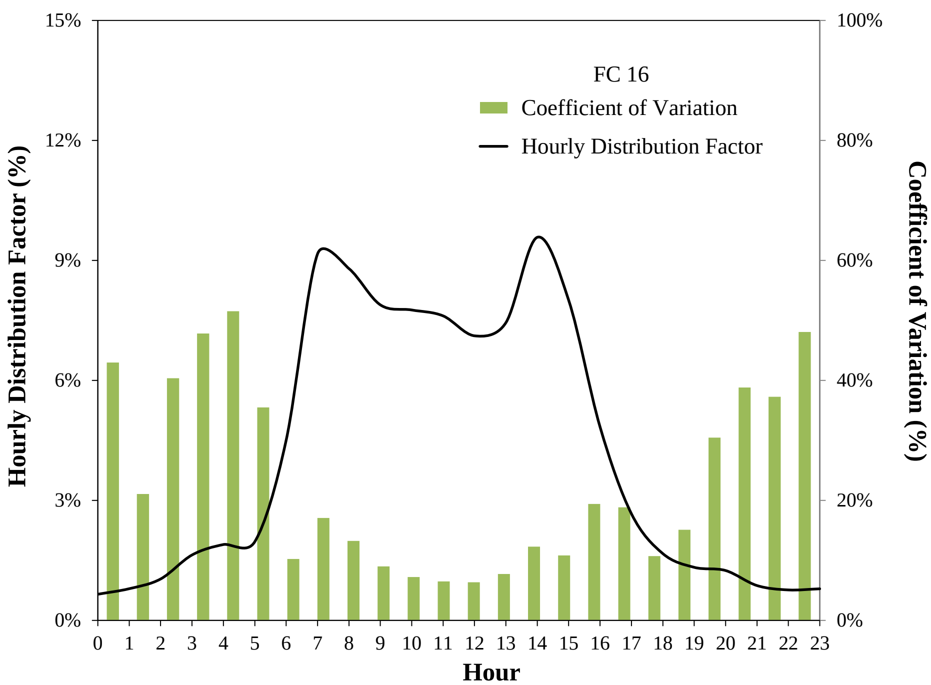


Figure 68: Hourly Distribution Factors and Associated Coefficients of Variation for FC 16

8.8 Traffic Growth Factors

As discussed in Section 2.3.2.5, the MEPDG uses three models to describe the growth in truck volume: no growth model (Equation 3), linear growth model (Equation 4), and compound growth model (Equation 5). ODOT currently uses the linear growth model in predicting truck growth for pavement design. The ODOT Modeling and Forecasting Section (also called Certified Traffic) uses advanced travel demand models to estimate future traffic volumes and truck percentages. When a travel demand model is not available, trend line analysis is used to estimate the growth in AADT and AADTT. However, it is not recommended to blindly use future traffic volume estimates obtained using the trend line analysis method without checking the reasonability of these projections based on external factors related to the project. For additional information about ODOT's travel demand models, the reader is referred to ODOT Certified Traffic Manual (*11*) and the Modeling and Forecasting Section website. This section focuses on the use of trend line analysis to estimate the linear growth rate for both AADT and AADTT, and comment on the applicability of the linear growth model to describe the change in truck volumes over time.

A number of factors can affect the growth rate of traffic along a roadway including, geographic location (urban or rural), economic activities, roadway capacity, and adjacent land use. These factors can result in different growth rates for AADT and AADTT. The growth rate for AADT accounts for all vehicles traveling along a roadway, while the growth rate for AADTT only accounts for vehicle classes 4 through 13. The historical AADT and AADTT at selected sites distributed throughout the State of Ohio were examined to identify the differences in growth rates between all vehicles and trucks only. As can be seen in Figure 69, these sites are located along major highways that are less influenced by localized changes in traffic growth, but are more representative of statewide growth trends. The historical AADT and AADTT at these sites are depicted in Figures 70 through 75. As can be seen from these figures, the growth rate for AADT is not necessarily indicative of the growth rate for AADTT. For example, the AADT growth rate for Site 50 is 1.4% and the AADTT growth rate is 2.4% (i.e., AADT growth rate > AADTT growth rate); the AADT growth rate for Site 139 is 2.0% and the AADTT growth rate is 1.0% (i.e., AADT growth rate < AADTT growth rate); and the AADT growth rate for Site 531 is 2.0% and the AADTT growth rate is 1.9% (i.e., AADT growth rate ≈ AADTT growth rate). It is noted that for all sites the AADT and AADTT growth rates were calculated using 2012 (current year) as the base-year.

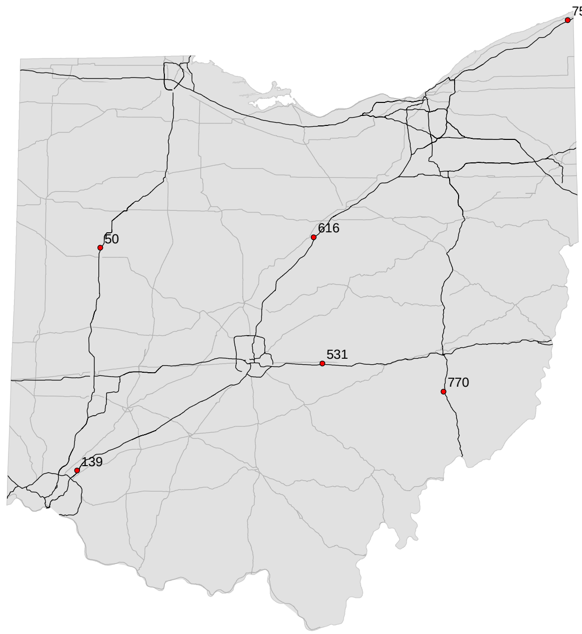


Figure 69: Location of Sites Used for Traffic Growth Analysis

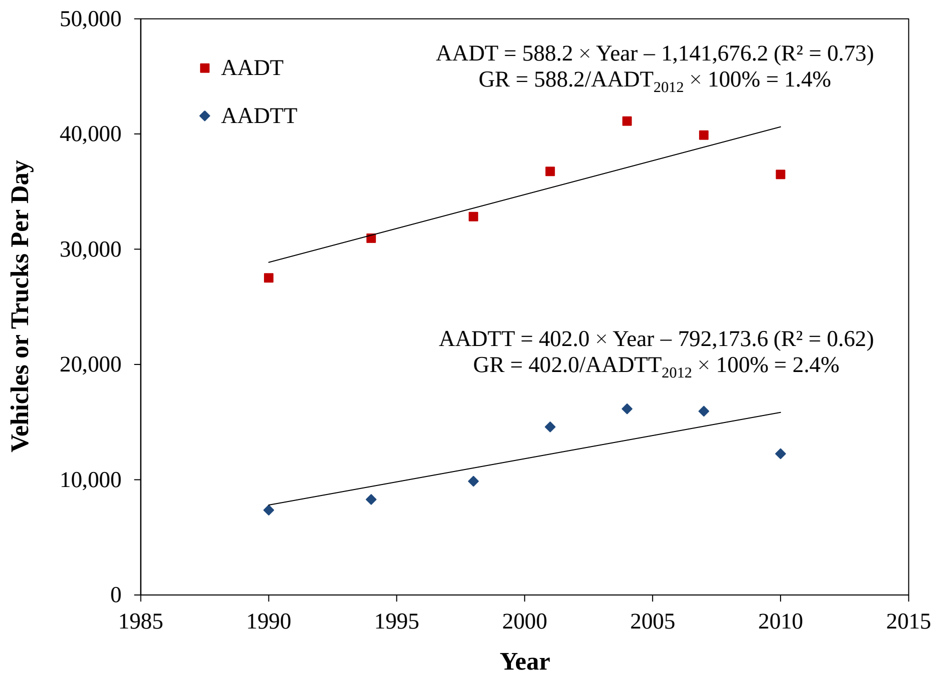


Figure 70: Traffic Growth Rate Site 50

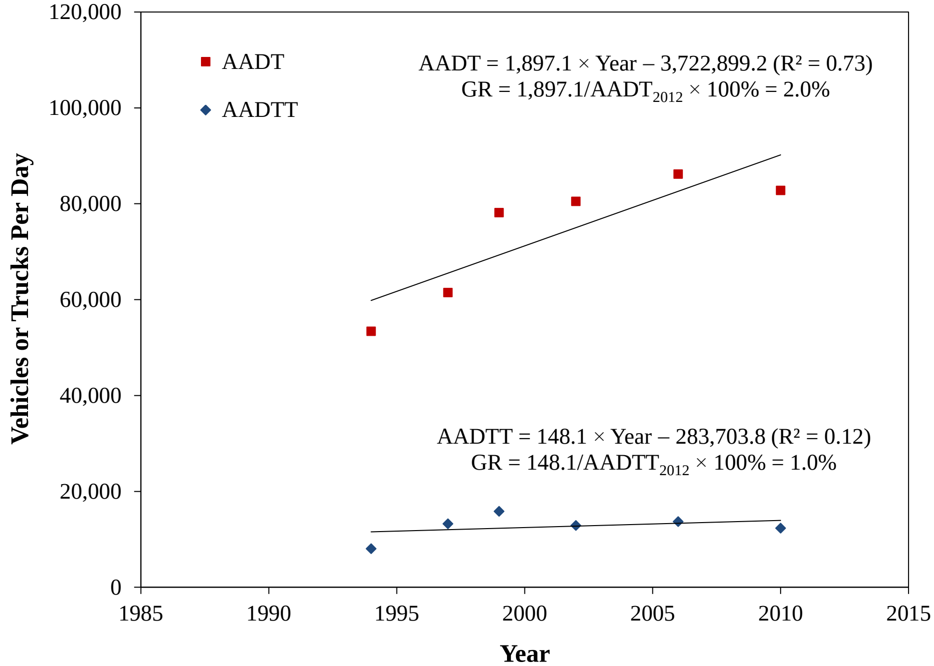


Figure 71: Traffic Growth Rate Site 139

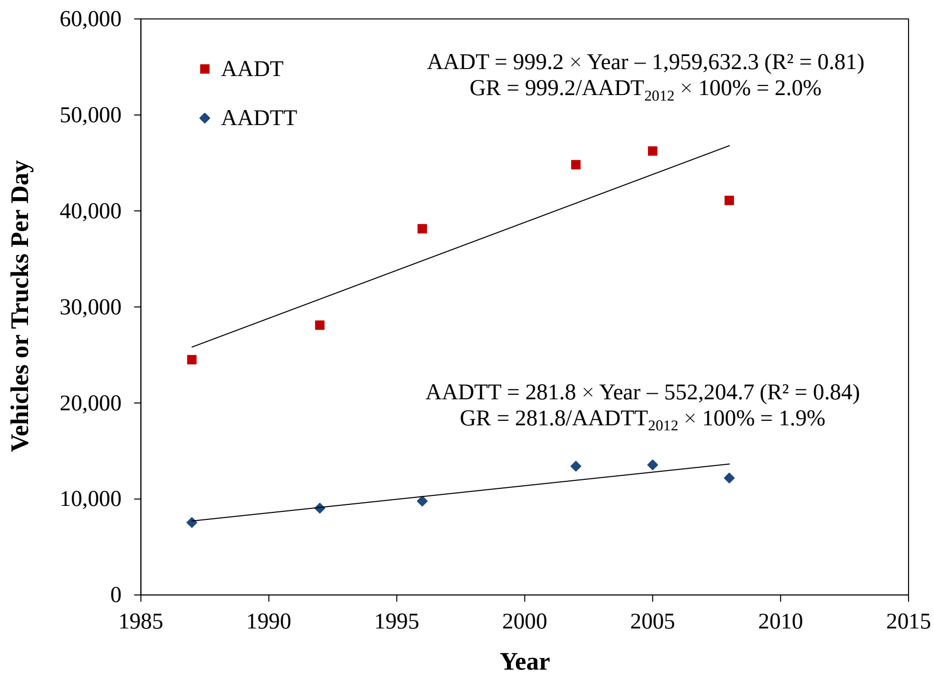


Figure 72: Traffic Growth Rate Site 531

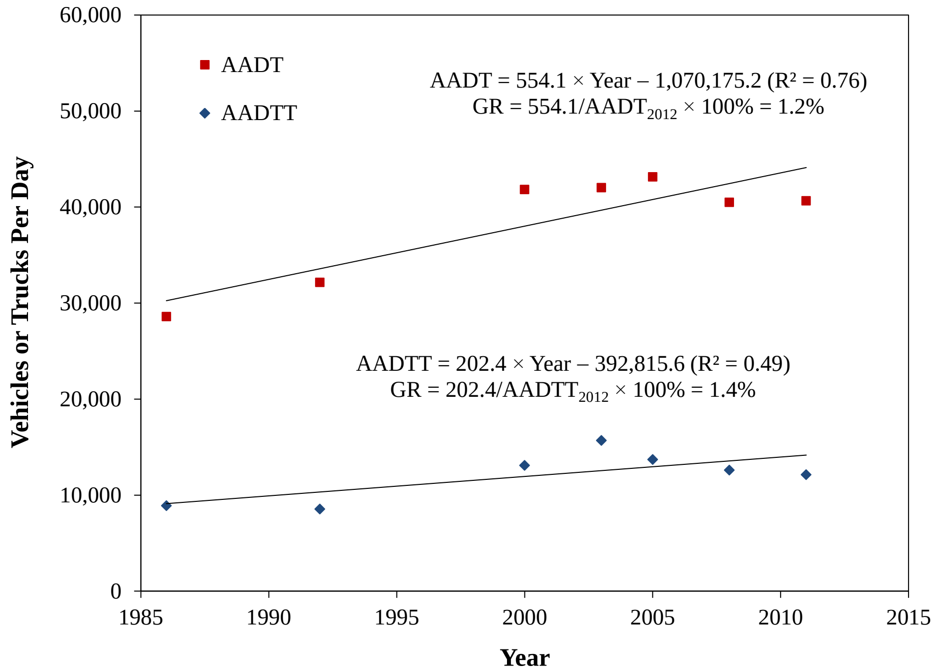


Figure 73: Traffic Growth Rate Site 616

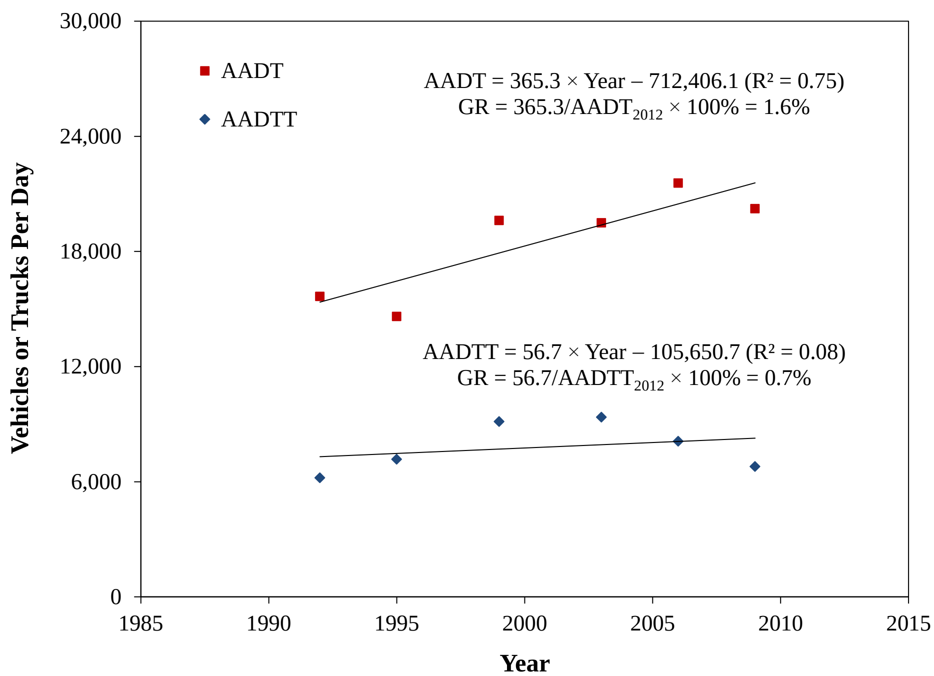


Figure 74: Traffic Growth Rate Site 750

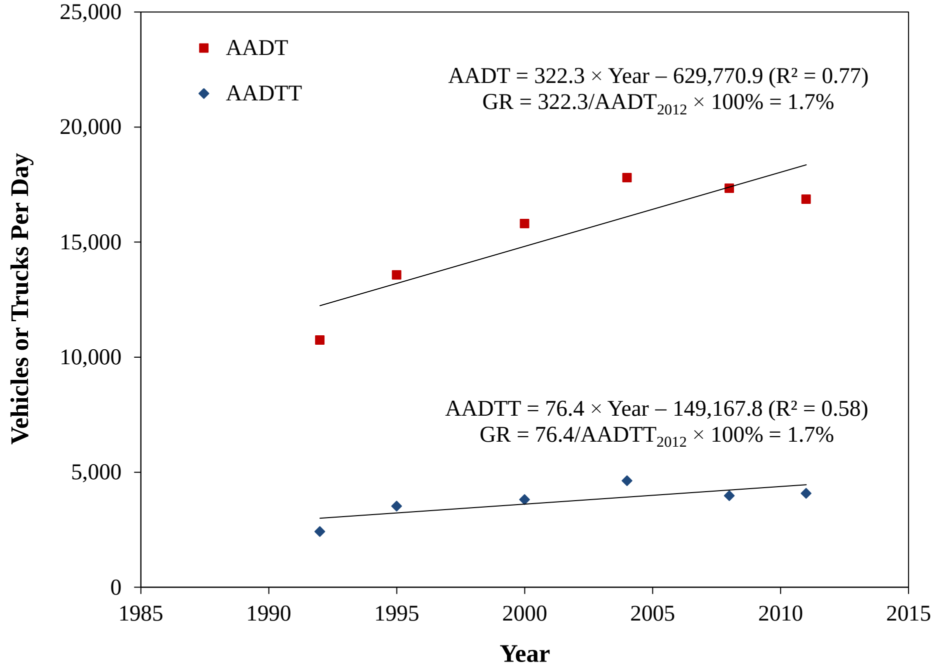


Figure 75: Traffic Growth Rate Site 770

The previous figures also demonstrate that the traffic monitoring period over which the growth rate is estimated significantly impacts the predicted growth rate value. As observed from these figures, the traffic growth appears to be approximately linear until the beginning of the twenty-first century, followed by no growth or even a reduction in traffic with a peak around 2003 to 2005. This trend seems to be fairly consistent for the majority traffic monitoring sites in Ohio. Therefore, care should be taken in the selection of the growth rate based on more recent traffic data, because they may not necessarily reflect the long-term growth in traffic. Tables 43 and 44 show the effect of the traffic monitoring period on the AADT and AADTT growth rates for Site 616 predicted using a linear growth model. As can be seen from these tables, the predicted growth rates are dependent on the number of years included in the development of the linear growth model. It can also be noticed that the predicted linear growth rates using less than 15 years are not necessarily representative of the overall traffic growth trends. Therefore, it is recommended to use a minimum of 20 years (or even 25 years) in the estimation of the traffic growth rate. Furthermore, it is recommended to obtain the truck growth rate from the Modeling and Forecasting Section that uses more advanced travel demand models to account for the large number of factors that can influence traffic growth.

Table 43: Effect of Traffic Monitoring Period on AADT Growth Rate for Site 616

Monitoring Period	Linear Growth Model	R^2	Estimated $AADT_{2012}$	Predicted GR(%)
1986-2011	AADT = 554.1×Year – 1,070,175.2	0.76	44,659	1.2%
1992-2011	AADT = 425.2×Year – 811,774.5	0.51	43,800	1.0%
2000-2011	AADT = -150.5×Year – 343,363.5	0.35	40,629	-0.4%
2003-2011	AADT = -263.3×Year – 570,016.7	0.55	40,190	-0.7%
2005-2011	AADT = -413.3×Year – 871,396.7	0.70	39,770	-1.0%
2008-2011	AADT = 53.3×Year – 66,603.3	N/A	40,703	0.1%

Table 44: Effect of Traffic Monitoring Period on AADTT Growth Rate for Site 616

Monitoring Period	Linear Growth Model	R^2	Estimated $AADTT_{2012}$	Predicted GR(%)
1986-2011	AADTT = 202.4 × Year – 392,815.6	0.49	14,373	1.4%
1992-2011	AADTT = 186.1 × Year – 360,265.7	0.28	14,264	1.3%
2000-2011	AADTT = -180.2 × Year – 374,846.3	0.31	12,247	-1.5%
2003-2011	AADTT = -422.5 × Year – 861,408.5	0.87	11,304	-3.7%
2005-2011	AADTT = -263.3 × Year – 541,576.7	0.95	11,750	-2.2%
2008-2011	AADTT = -157.0 × Year – 327,177.0	N/A	11,963	-1.3%

8.9 Axle Load Distribution Factors

As discussed in Section 2.3.3, the MEPDG requires defining single, tandem, tridem and quad axle load spectra for truck Classes 4 through 13 and each month of the year. This information can be obtained by analyzing individual axle weight and spacing data collected using WIM systems whereby individual axles are grouped into single, tandem, tridem, and quad axles according to their spacing. Table 45 presents the vehicle classification tree used by ODOT (modified FHWA Scheme F) to determine the vehicle class from the number of axles and axle spacing. As can be noticed from this table, ODOT uses an axle spacing of 6 ft (1.82 m) to differentiate between the various axle groups. Tandem axles are a group of two axles spanning no more than 6 ft (1.83 m); tridem axles are a group of three axles spanning no more than 12 ft (3.66 m) with no more than 6 ft (1.83 m) spacing between any two successive axles; and quad axles are a group of four axles spanning no more than 18 ft (5.49 m) with no more than 6 ft (1.83 m) spacing between any two successive axles.

Using the previous axle spacings, the WIM data was analyzed to identify the possible axle groups for each truck class (Table 46). As can be seen from this table, it is possible for a particular truck class, with a certain number of axles, to have several axle groupings based on the spacing between the axles. For example, the following axle group combinations were identified for Class 9 trucks with five axles: single-tandem-tandem (STaTa), single-tandem-single-single (STaSS), single-single-tridem (SSTr), and single-quad (SQa). However, little data was available for SQa to contribute to the formation of quad axle load spectra for Class 9. Therefore, this group combination was omitted from the analysis for Class 9 trucks. The WIM data also revealed two possible axle groupings for Class 10 trucks with seven axles: STaQa and STrTr, but more than ten possible axle group combinations for Class 13 trucks with seven axles: STaTaSS, STaSSTa, STaTaTa, STaSSSS, STrSSS, STaSTr, STaTrS, SQaSS, SQaTa, STaQa, STrTr, and STrTaS. Furthermore, extremely few Class 13 trucks with eight axles were identified and no Class 13 trucks with nine axles were observed. This information along with the number of trucks belonging to each of these truck classes affects the accuracy of the resulting axle load distributions.

Once the axle groups have been identified, the axle load distribution factors were calculated for each axle group (single, tandem, tridem and quad) and truck class (4 through 13). The axle load distribution factors were defined according to the following load intervals: Single axles are 3,000 to 40,000 lbs at 1,000-lb intervals (13.3 to 177.9 kN at 4.4-kN intervals), tandem axles are 6,000 to 80,000 lbs at 2,000-lb intervals (26.7 to 355.9 kN at 8.9-kN intervals), and both tridem and quad axles are 12,000 to 102,000 lbs at 3,000-lb intervals (53.4 to 453.7 kN at 13.3-kN intervals). The distribution factors were defined for each month during the year to account for the seasonal variations in truck loading. The annual distribution factors were also obtained to represent the axle load spectra for locations where continuous traffic weight data was not available.

Table 45: ODOT Vehicle Classification Tree

				Axle Space Between Axle Numbers (feet)											
Class	Vehicle Description	**Bin**	**Axles**	**1 - 2**	**2 - 3**	**3 - 4**	**4 - 5**	**5 - 6**	**6 - 7**	**7 - 8**	**8 - 9**	**9 - 10**	**10 - 11**	**11 - 12**	**12 - 13**
1	Motorcycles	**1**	**2**	1.0 - 5.9											
2	Passenger Cars	**2**	**2**	6.0 - 10.2											
3	Other(Limo, Van, RV)	**3**	**2**	10.3 - 13.0											
4	Bus w/ 2 Axles	**4**	**2**	23.1 - 40.0											
5	2 Axle, Six Tire, Single Unit Trucks	**5**	**2**	13.1 - 23.0											
2	Any 2 axle vehicles	**6**	**2**	1.0 - 45.0											
2	Passenger Cars w/1 axle trailer	**7**	**3**	6.0 - 10.2	6.0 - 18.0										
3	Other w/1 Axle tralier	**8**	**3**	10.3 - 13.0	6.0 - 18.0										
4	Bus w/ 3 Axles	**9**	**3**	23.1 - 40.0	1.0 - 6.0										
6	3 Axle, Single Unit Trucks	**10**	**3**	6.10 - 23.0	1.0 - 6.0										
8	3 Axle, Single Trailer Trucks	**11**	**3**	6.10 - 22.0	11.0 - 40.0										
4	Any 3 axle vehicles	**12**	**3**	1.0 - 45.0	1.0 - 45.0										
2	Passenger Cars w/2 axle trailer	**13**	**4**	6.0 - 10.2	6.0 - 18.0	1.0 - 6.0									
3	Other w/2 AT	**14**	**4**	10.3 - 13.0	6.0 - 18.0	1.0 - 6.0									
7	4 Axle, Single Unit Trucks	**15**	**4**	6.1 - 23.0	1.0 - 6.0	1.0 - 13.0									
7	4 Axle, Single Unit Trucks	**16**	**4**	6.1 - 23.0	8.0 - 20.0	1.0 - 6.0									
8	4 Axle, Single Trailer Trucks	**17**	**4**	6.1 - 22.0	11.0 - 44.0	3.5 - 12.0									
8	4 Axle, Single Trailer Trucks	**18**	**4**	6.1 - 22.0	1.0 - 6.0	6.1 - 44.0									
8	Any 4 axle vehicles	**19**	**4**	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0									
3	Other w/3 AT	**20**	**5**	10.3 - 13.0	6.0 - 18.0	1.0 - 6.0	1.0 - 6.0								
7	5 Axle, Single Unit Trucks	**21**	**5**	6.1 - 23.0	1.0 - 6.0	1.0 - 6.0	1.0 - 13.0								
9	5 Axle, Single Trailer Trucks	**22**	**5**	6.1 - 24.5	1.0 - 6.0	6.1 - 46.0	1.0 - 13.0								
9	5 Axle, Single Trailer Trucks	**23**	**5**	6.1 - 24.5	15.0 - 25.0	1.0 - 6.0	1.0 - 6.0								
11	5 or less Axle, Single Trailer Trucks	**24**	**5**	6.1 - 23.0	11.1 - 30.0	6.1 - 20.0	11.1 - 30.0								
9	Any 5 axle vehicles	**25**	**5**	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0								
7	6 Axle, Single Unit Trucks	**26**	**6**	6.1 - 23	1.0 - 6.0	1.0 - 6.0	1.0 - 6.0	1.0 - 13.0							
10	6 Axle, Single Trailer Trucks	**27**	**6**	6.1 - 23.0	1.0 - 6.0	6.1 - 46.0	1.0 - 11.0	1.0 - 11.0							
12	6 Axle, Multi Trailer Trucks	**28**	**6**	6.1 - 23.0	1.0 - 6.0	11.1 - 26.0	6.1 - 18.0	11.1 - 26.0							
10	Any 6 axle vehicles	**29**	**6**	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0							
7	7 Axle, Single Unit Trucks	**30**	**7**	6.1 - 23.0	1.0 - 6.0	1.0 - 6.0	1.0 - 6.0	1.0 - 6.0	1.0 - 6.0						
10	7 Axle, Single Trailer Trucks	**31**	**7**	6.10 - 23.0	1.0 - 6.0	6.1 - 30.0	1.0 - 6.0	1.0 - 6.0	1.0 - 6.0						
10	7 Axle, Single Trailer Trucks	**32**	**7**	6.1 - 23.0	1.0 - 6.0	1.0 - 6.0	6.1 - 45.0	1.0 - 6.0	1.0 - 6.0						
13	7 Axle, Multi Trailer Trucks	**33**	**7**	6.1 - 23.0	1.0 - 6.0	11.1 - 26.0	1.0 - 6.0	6.1 - 20.0	11.1 - 26.0						
13	7 Axle, Multi Trailer Trucks	**34**	**7**	6.1 - 23.0	1.0 - 6.0	11.1 - 26.0	6.1 - 20.0	6.1 - 26.0	1.0 - 6.0						
13	Any 7 axle vehicles	**35**	**7**	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0						
13	8 Axle, Multi Trailer Trucks	**36**	**8**	6.1 - 23.0	1.0 - 6.0	11.1 - 26.0	1.0 - 6.0	6.1 - 20.0	11.1 - 26.0	1.0 - 6.0					
14	Michigan Grain Train	**37**	**8**	6.1 - 23.0	1.0 - 6.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0					
13	9 Axle, Multi Trailer Trucks	**38**	**9**	6.1 - 23.0	1.0 - 6.0	11.1 - 26.0	1.0 - 6.0	6.1 - 20.0	11.1 - 26.0	6.1 - 20.0	11.1 - 26.0				
14	Michigan Grain Train	**39**	**9**	6.1 - 23.0	1.0 - 6.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0				
14	Michigan Grain Train	**40**	**10**	6.1 - 23.0	1.0 - 6.0	1.0 - 20.0	1.0 -- 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0			
14	Michigan Grain Train	**41**	**11**	6.1 - 23.0	1.0 - 6.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0	1.0 - 20.0		
15	Other	**42**	**12 - 13**	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0	1.0 - 45.0

Table 46: Possible Axle Groups for Truck Class 4 Through 13

Truck Class	No. of Axles	Possible Axle Groups
4	2	SS
	3	STa
5	2	SS
6	3	STa
7	4	STr, STaS, SSTa
	5	SQa, STrS
	6	SQaS, SSQa
	7	STaQa
8	3	SSS
	4	SSTa, SSSS, STaS
9	5	STaTa, STaSS, SSTr (Very Few), SQa (Extremely Few)
10	6	STaSSS, STaTaS, STaTr, STaSTa, STrSS, STrTa
	7	STaQa, STrTr
11	5	SSSSS
12	6	STaSSS
13	7	STaTaSS, STaSSTa, STaTaTa, STaSSSS, STrSSS, STaSTr, STaTrS, SQaSS, SQaTa, STaQa, STrTr, STrTaS
	8	STaTaSTa (Extremely Few)
	9	(Not Present)

The cluster analysis method was used to group sites based on the axle load spectra of Class 9 tandem axles in order to obtain the statewide axle load spectra. Cluster analysis is a statistical method that organizes objects or data points with similar characteristics into groups called clusters. Based on the clustering results, similar sites could be identified and the average single, tandem, tridem, and quad axle load spectra could be determined. The analysis was performed based on Class 9 tandem axles because they are the most common types of axles, and their axle load spectra consistently fall within expected weight ranges. Furthermore, annual rather than monthly axle load spectra were used in the analysis due to the lack of continuous twelve months of load data for a large number of the sites.

The cluster analysis was conducted using a statistical analysis program called StatistiXL that runs as an add-in to Microsoft Excel. This program can be used to cluster qualitative as well as quantitative data using various similarity distances and different clustering methods. The similarity distance is the criteria according to which the program will determine the similarity between different sites. The Euclidean distance and the squared Euclidean distance are the most common similarity distances used in transportation analysis. The clustering method is how the program will group sites once similarities have been identified. The following clustering methods are available in StatistiXL: nearest neighbor, furthest neighbor, group average, centroid, Wards, and Lance and Williams. The selection of the similarity distance and the clustering method is dependent on the data being analyzed. The output of the analysis is typically presented as a "cluster tree" that associates objects based on their attributes.

The cluster analysis was conducted on the WIM data obtained from 2006 to 2011 using the squared Euclidean distance and the group average method. The cluster tree that resulted from the analysis is presented in Figure 76. As can be seen from this figure, the sites are described by their identification number and year. For example, 718-2006 refers to Site 718 and year 2006. This figure shows that when multiple years of data are available for an individual site, they generally appear close to each other in the cluster tree, which indicates that the axle load spectra are similar from year to year. Any site that showed a significant variation between years was checked to determine if the data was accurate. A total of four clusters were developed using an iterative procedure that identified the optimum number of clusters. The individual sites forming the four clusters are highlighted in the cluster tree. An enlarged section of Cluster 1 is shown in the same figure.

Figure 77 shows the average Class 9 tandem axle load spectra for the four clusters and the default MEPDG Class 9 tandem axle load spectra. It can be observed from this figure that the first peak corresponding to the empty weight falls between 10 and 15 kips and the second peak corresponding to the full weight falls between 28 and 36 kips for all clusters. However, the heights of these peaks vary significantly between clusters. For Cluster 1, the first peak is lower than the second peak. This indicates that there are more Class 9 trucks traveling with full loads than with empty loads. In addition, Cluster 1 is distinctly different than the rest of the clusters in that the area between the peaks is relatively flat, which indicates the presence of a relatively large number of partially full Class 9 trucks. For Clusters 2 through 4, the first peak is higher than the second peak, which implies that there are more empty Class 9 trucks than full. However, these clusters vary in the difference between the height of the first and second peaks.

Figures 78 through 81 show the individual site and average Class 9 tandem load spectra for each cluster. These figures provide a graphical representation of the similarities shown in the cluster tree. As can be seen from these figures, the individual axle load spectra are close to the average axle load spectra for each cluster. In addition, it can be noticed that there are more axle load spectra in Clusters 1, 2, and 3 than Clusters 4.

Table 47 shows the distribution of the sites in each cluster and the corresponding functional classification. As can be seen from this table, the majority of the sites classified as FC 1 (rural interstate) were grouped into Clusters 1 and 2 and the majority of the sites classified as FC 11 (urban interstate) were grouped into Clusters 1, 2, and 3. As mentioned earlier, Cluster 1 contains a relatively even distribution of empty, partially full, and full Class 9 trucks, whereas Clusters 2 and 3 mainly empty and full Class 9 trucks, with a very small percentage of partially full trucks. It can also be noticed from this table that FCs 2, 6, and 12 were primarily grouped into Cluster 3, while FCs 8 and 14 were primarily grouped into Cluster 2, and FC 7 is the only function classification primarily grouped into Cluster 4. Given the relatively small number of sites belonging to each functional classification, it was not possible to generate statewide axle load spectra based on functional classification, and more representative statewide averages were obtained using the cluster analysis.

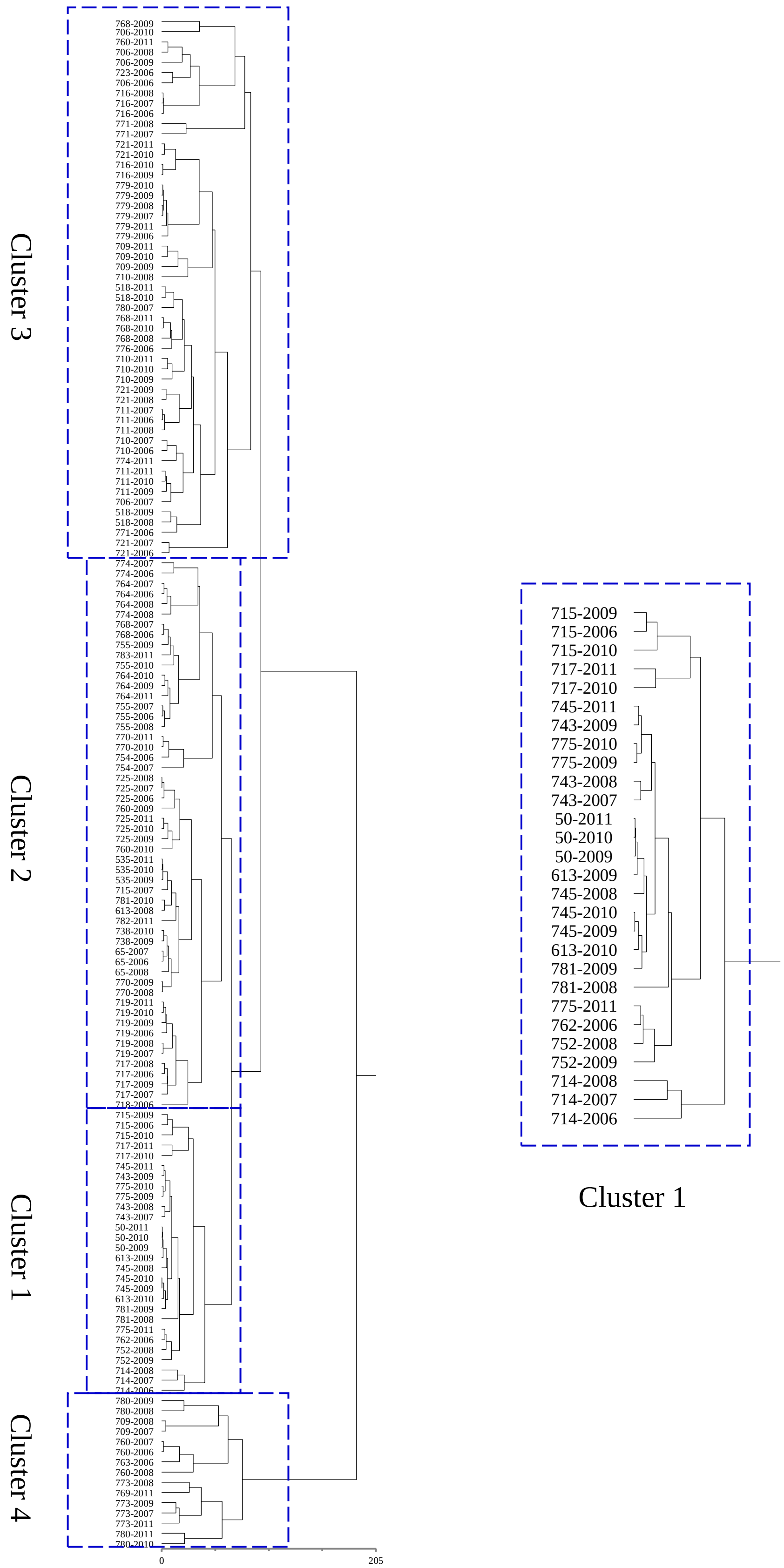


Figure 76: (Left) Class 9 Tandem Axle Load Spectra Cluster Tree (Right) Close-up of Cluster 1

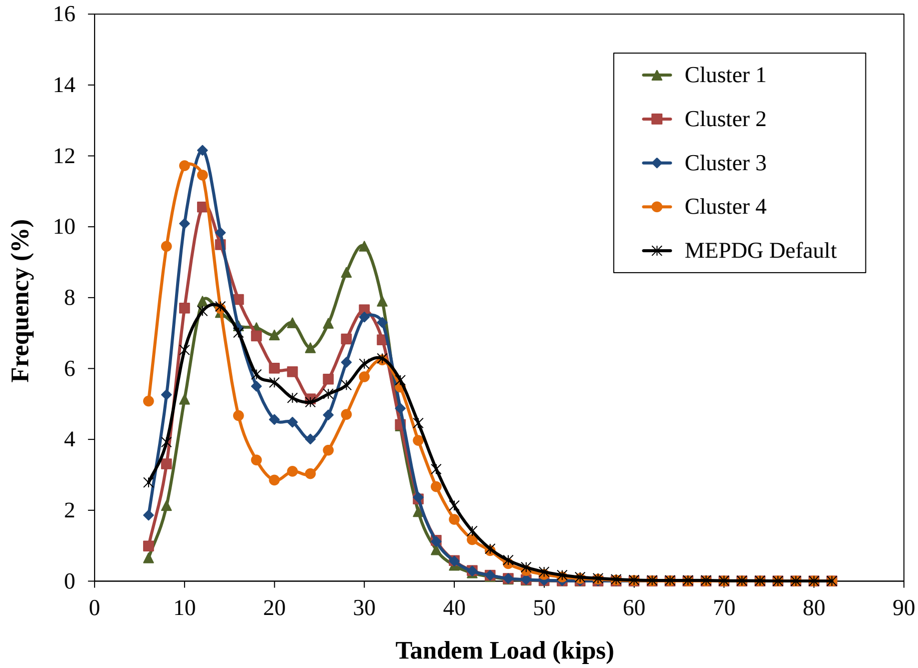


Figure 77: Class 9 Average Tandem Axle Load Spectra for Clusters 1 to 4 and MEPDG Default

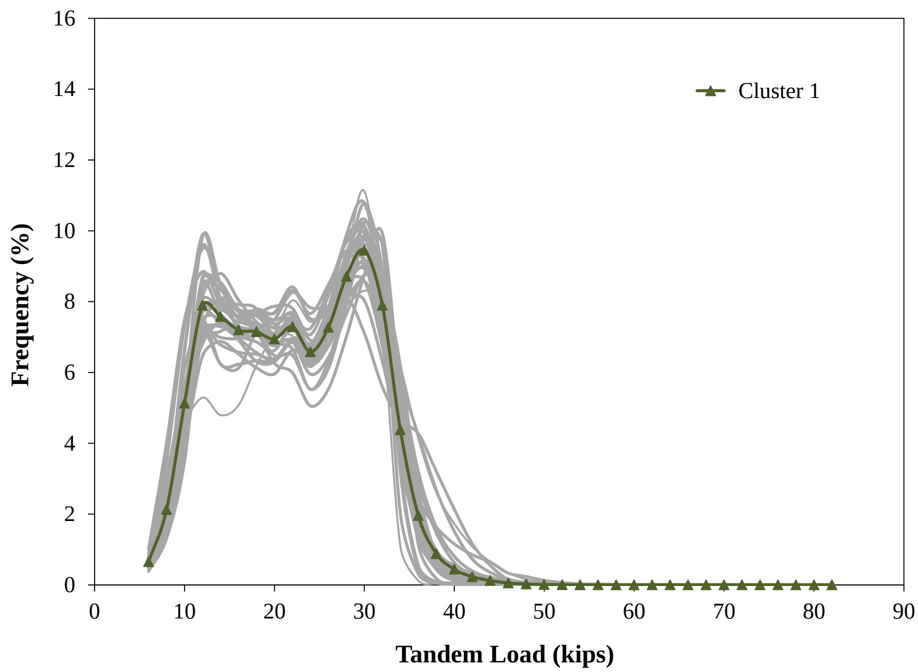


Figure 78: Class 9 Average Tandem Axle Load Spectra for Cluster 1

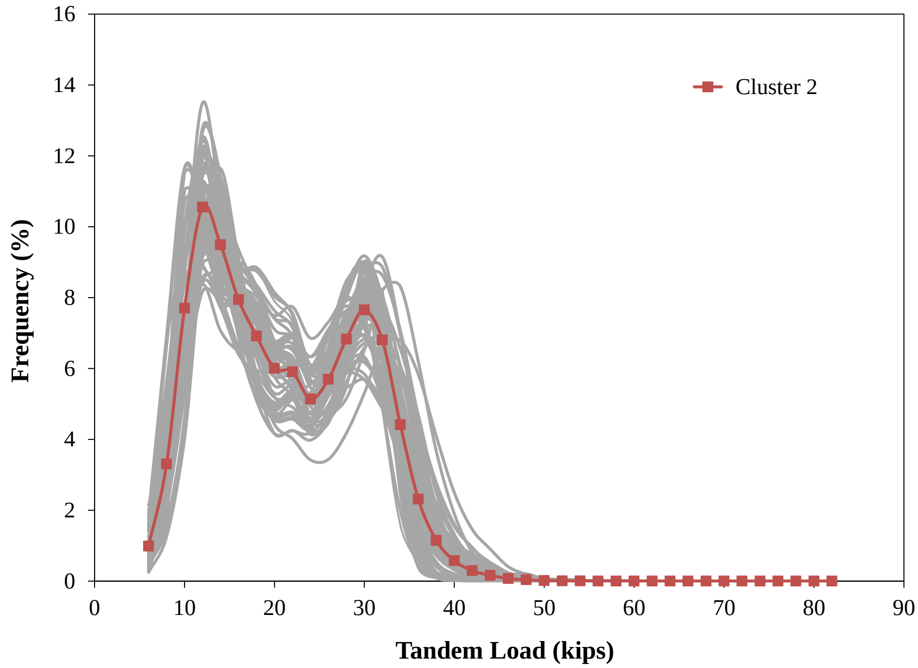


Figure 79: Class 9 Average Tandem Axle Load Spectra for Cluster 2

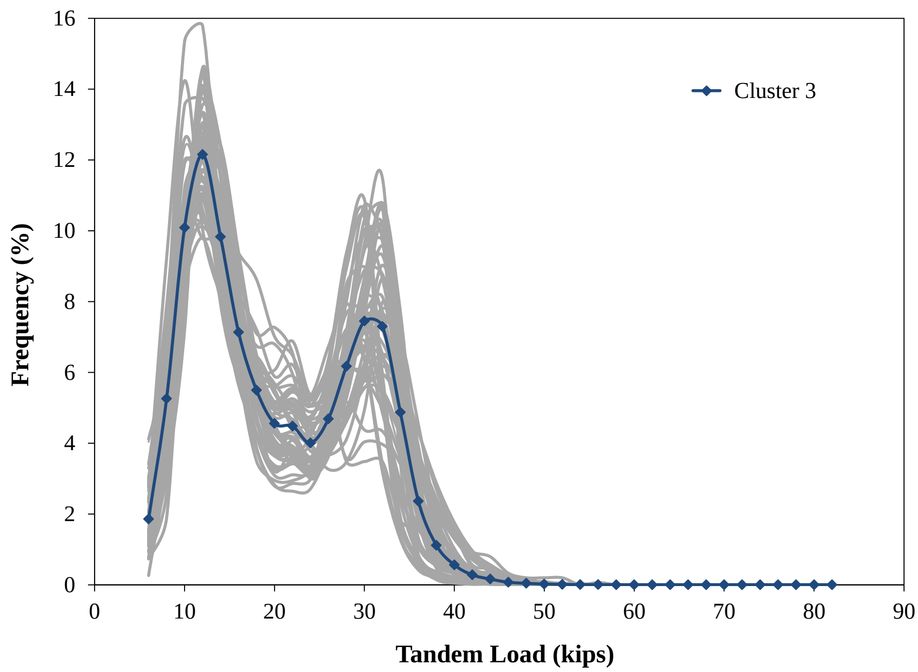


Figure 80: Class 9 Average Tandem Axle Load Spectra for Cluster 3

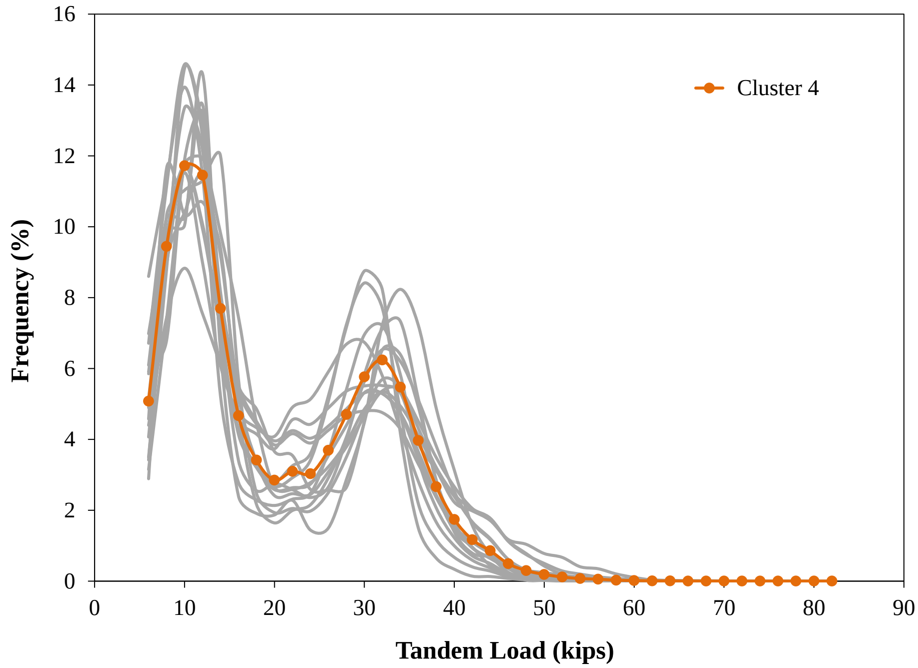


Figure 81: Class 9 Average Tandem Axle Load Spectra for Cluster 4

Table 47: Relationship between Weight Clusters and Functional Classification

		Functional Classification											
		1	2	6	7	8	9	11	12	14	16	17	19
Wt. Cluster	1	20	3					5					
	2	19	1	2		3		13		16			
	3		16	10	1	1		7	13	5			
	4			4	5				3	3			

Figures 82 through 85 show the WIM sites and their locations within Ohio for each of the four weight clusters. As can be noticed from these figures, some sites appear in multiple figures because they were grouped into different clusters in different years. It can also be noticed that all sites located along major interstates were grouped into Clusters 1 or 2, while sites located along non-major interstates and highways were grouped into Clusters 3 and 4. Furthermore, it can be noticed that the majority of the rural interstate sites were classified as Cluster 1, while the urban interstates were classified as either Cluster 1 or Cluster 2.

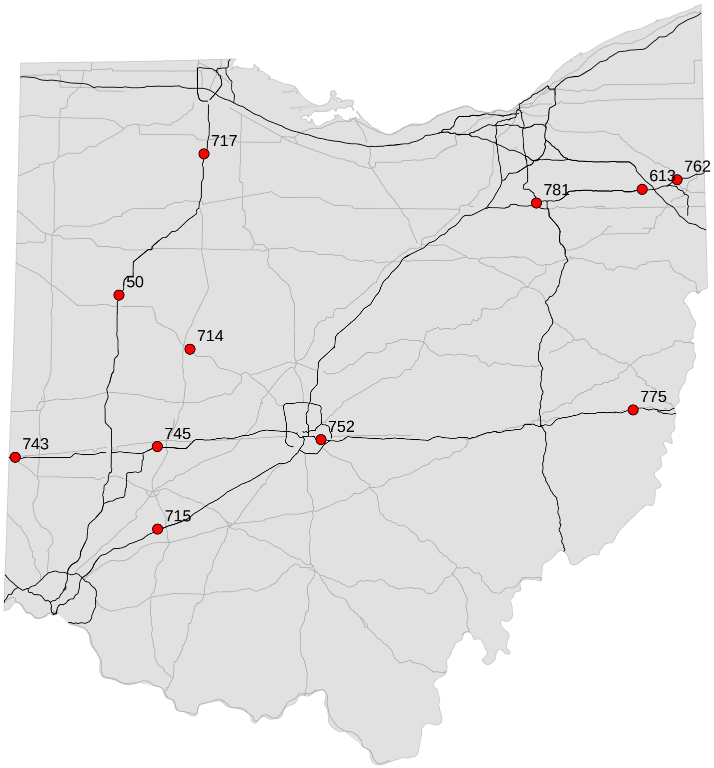


Figure 82: Location of Sites Grouped into Cluster 1

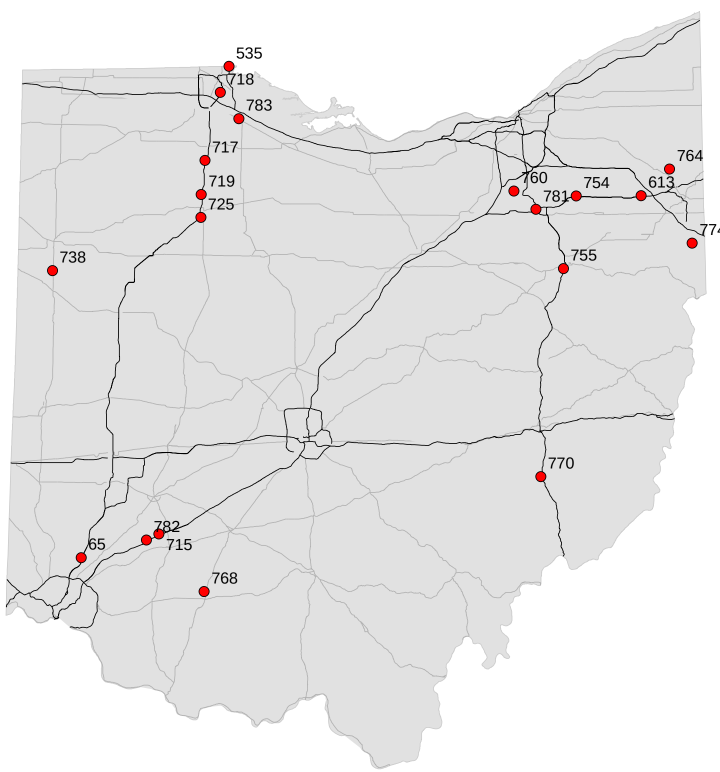


Figure 83: Location of Sites Grouped into Cluster 2

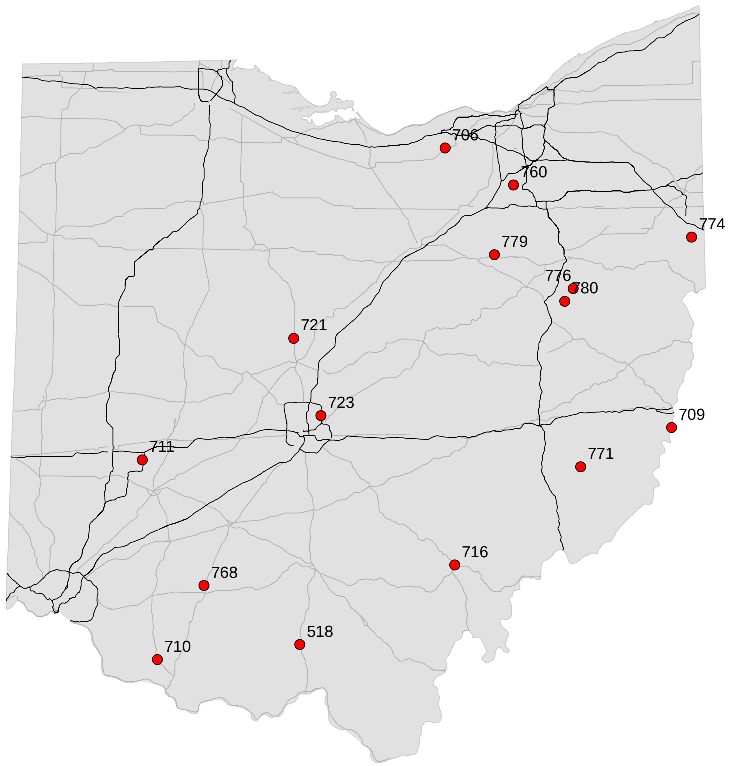


Figure 84: Location of Sites Grouped into Cluster 3

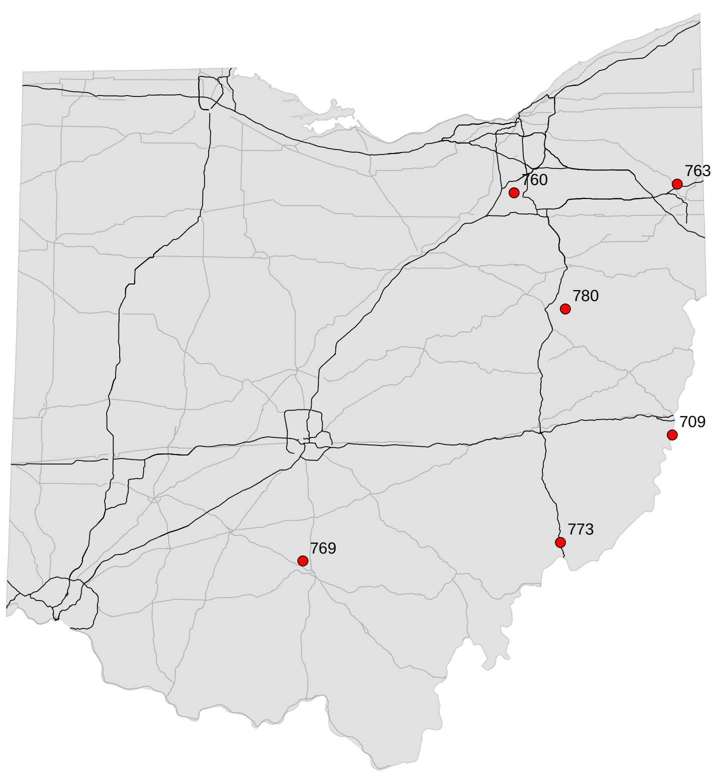


Figure 85: Location of Sites Grouped into Cluster 4

Figure 86 shows the relationship between AADT and corresponding cluster. As can be noticed from this figure, Clusters 1 and 2 generally had higher AADT levels, while Clusters 3 and 4 had significantly lower AADT levels. However, there is a large distribution of AADT for each of the clusters with significant overlap. Figure 87 shows the relationship between AADTT and Clusters 1 through 4. Similar to AADT, Clusters 1 and 2 generally had higher AADTT levels, while Clusters 3 and 4 had significantly lower AADTT levels. However, due to the large variations in AADTT for the four clusters, it will not be possible to identify the appropriate cluster based on the AADTT level.

Figure 88 show the percent trucks (%T) for each of the four clusters. As can be noticed from this figure, higher %T values were generally obtained for Clusters 1 and 2, and significantly lower %T values were obtained for Clusters 3 and 4. While there seems to be a more consistent trend between %T and Clusters 1 through 4 than AADT and AADTT, there is significant overlap between clusters that would prevent using %T to associate sites with a particular cluster. Finally, Figure 89 shows the relationship between the B:C ratio and the weight clusters. As can notice from this figure, there is a large distribution of B:C ratio for each of the four clusters. Therefore, a clear trend could not be established to identify clusters based on the B:C ratio. It should be noted that the observations made for AADT, AADTT, %T, and B:C ratio are consistent with those made based on functional classification, which is expected since the latter accounts for these traffic attributes.

Figure 90 through 993 shows the average single, tandem, tridem, and quad axle load spectra for each other the four weight clusters. It can be noticed from these figures that all truck classes except Class 5 contained a tandem axle; only truck Classes 7, 9, 10, and 13 contained a tridem axle; and only truck Classes 7, 10, and 13 contained a quad axle. The single axle load spectra had a single clear peak around 10 kips, the tandem axle load spectra had two clear peaks at about 10 kips and 30 kips, the tridem axle load spectra had one clear peak at approximately 40 kips, and the quad axle load spectra had one clear peak close to 50 kips.

It can also be observed from these figures that the overall trends of the single, tandem, tridem, and quad axle load spectra are similar for all four weight clusters. Therefore, it might be reasonable to developed a statewide average axle load spectra based on information from all sites across the state to represent the load distribution for each axle type and truck class. Through further examination, it was found that most clusters were affected by the presence of inconsistent axle load spectra for certain truck classes, which can be partially explained by the presence of a small number of trucks from that truck class at that site. As a result, sites that showed inconsistent gross vehicle weight distribution for a particular truck class were excluded from the calculation of the statewide average.

Figures 94 through 103 show the statewide average gross vehicle weight distribution for each truck class. These figures also show the variation from the mean represented using the standard deviation. The individual sites used in the development of the statewide averages are listed in Table 48. As can be noticed from these figures, Class 4 has two peaks at approximately 20 and 60 kips; Class 5 has a single peak at approximately 20 kips; Class 6 has two visible peaks at approximately 20 and 30 kips and one less visible peak at approximately 40 kips; Class 7 has two peaks at approximately 20 and 60 kips; Class 8 has one peak between 30 and 40 kips; Class 9 has two peaks, one at approximately 30 kips and one between 70 and 80 kips; Class 10 has two peaks at approximately 40 and 80 kips; Class 11 has one peak at approximately 60 kips; Class 12 has two peaks, one at approximately 40 kips and one between 60 and 70 kips; and Class 13 has three peaks, one between 40 and 50 kips, one between 70 and 80 kips, and one between 100 and 120 kips. It is noted that many of the Class 13 trucks that had loads between 100 and 120 kips were recorded at sites in western Ohio where the gross vehicle weight limit is greater than 80 kips. It can also be observed from these figures that truck Classes 4, 6, 7, 12, and 13 have high variations from the mean, while the other truck classes have minimal variations. Any variations in the gross vehicle weight are reflected in the single, tandem, tridem, and quad axle load spectra, which could explain any lack of consistency for these spectra.

Figure 104 shows the statewide average single, tandem, tridem, and quad axle load spectra for each truck class. By comparing these axle load spectra to those obtained for the four clusters, it can be noticed that they are close to each other. Similar to the clusters, the statewide average axle load spectra have distinct trends for each axle type. While, in contrast to the clusters, the statewide average axle load spectra are more consistent, which is expected since sites with inconsistent gross vehicle weight distributions were eliminated from the analysis. In order to fully understand the influence of these axle load spectra on pavement design, the following chapter compares the performance of a new flexible pavement and a new rigid pavement as predicted using the MEPDG for Clusters 1 through 4 and the statewide average.

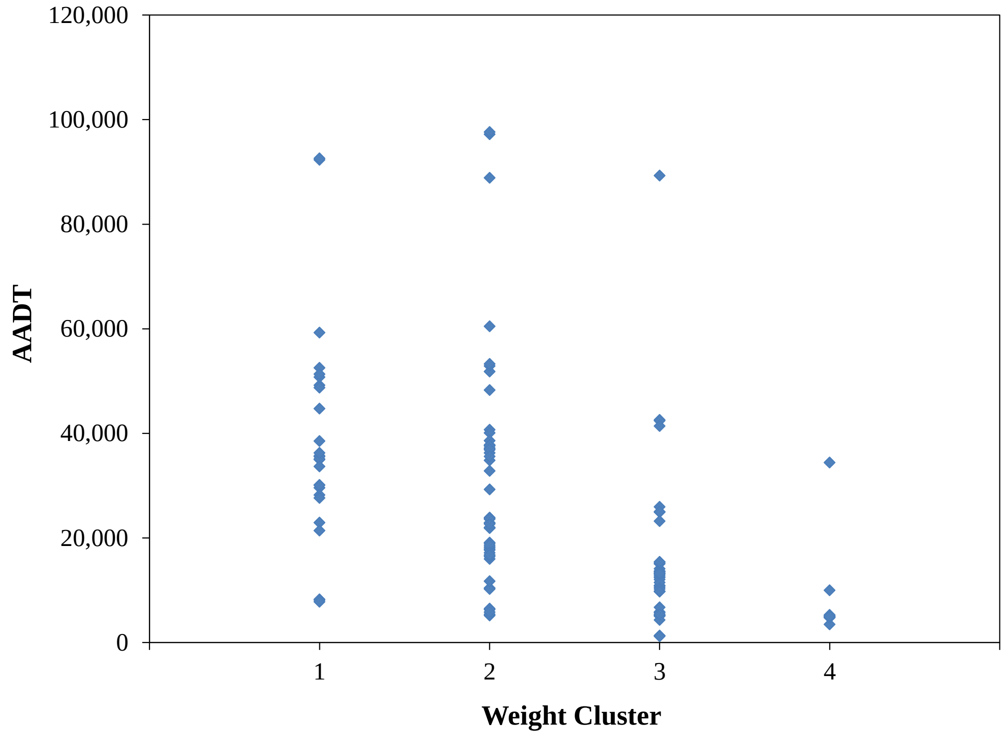


Figure 86: Relationship between AADT and Clusters 1 through 4

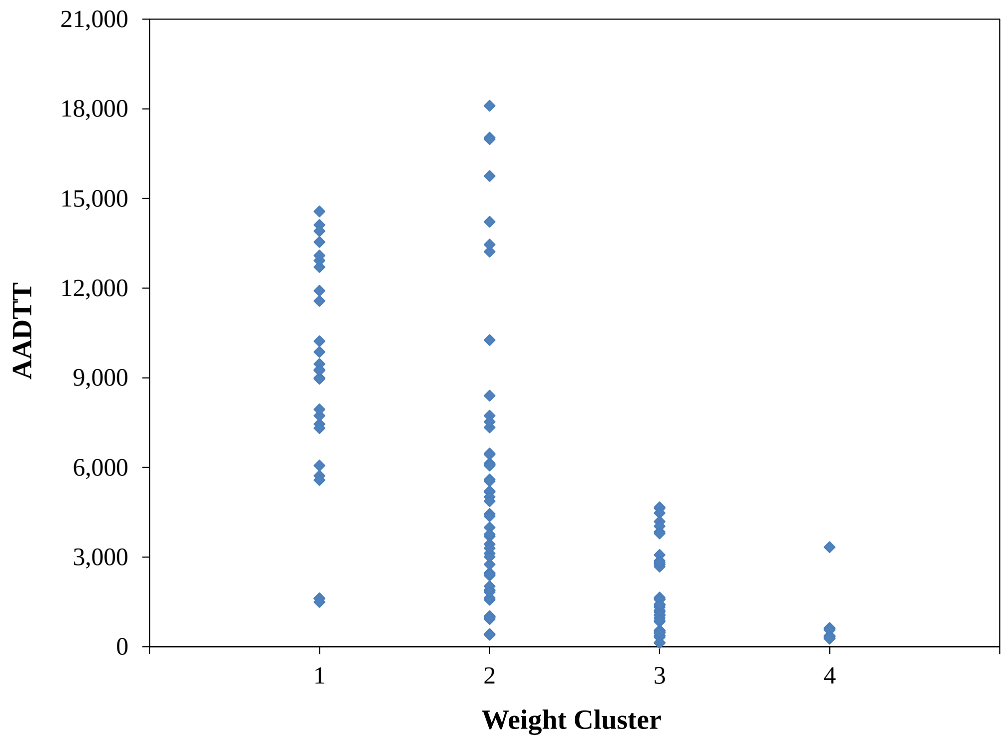


Figure 87: Relationship between AADTT and Clusters 1 through 4

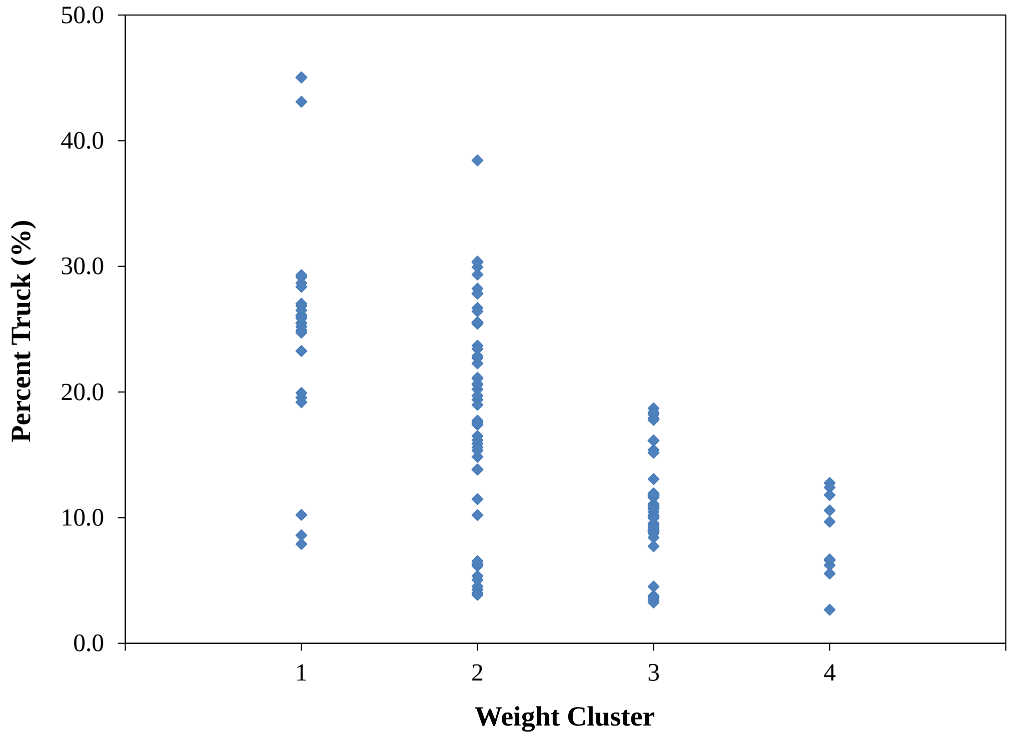


Figure 88: Relationship between %T and Clusters 1 through 4

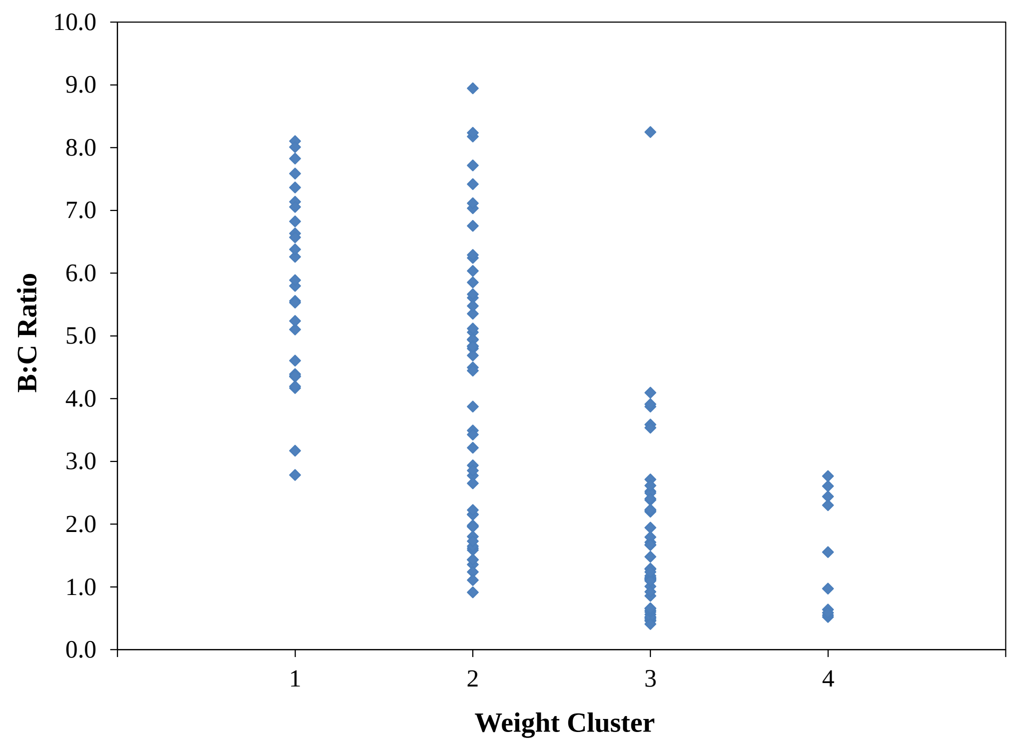


Figure 89: Relationship between B:C Ratio and Clusters 1 through 4

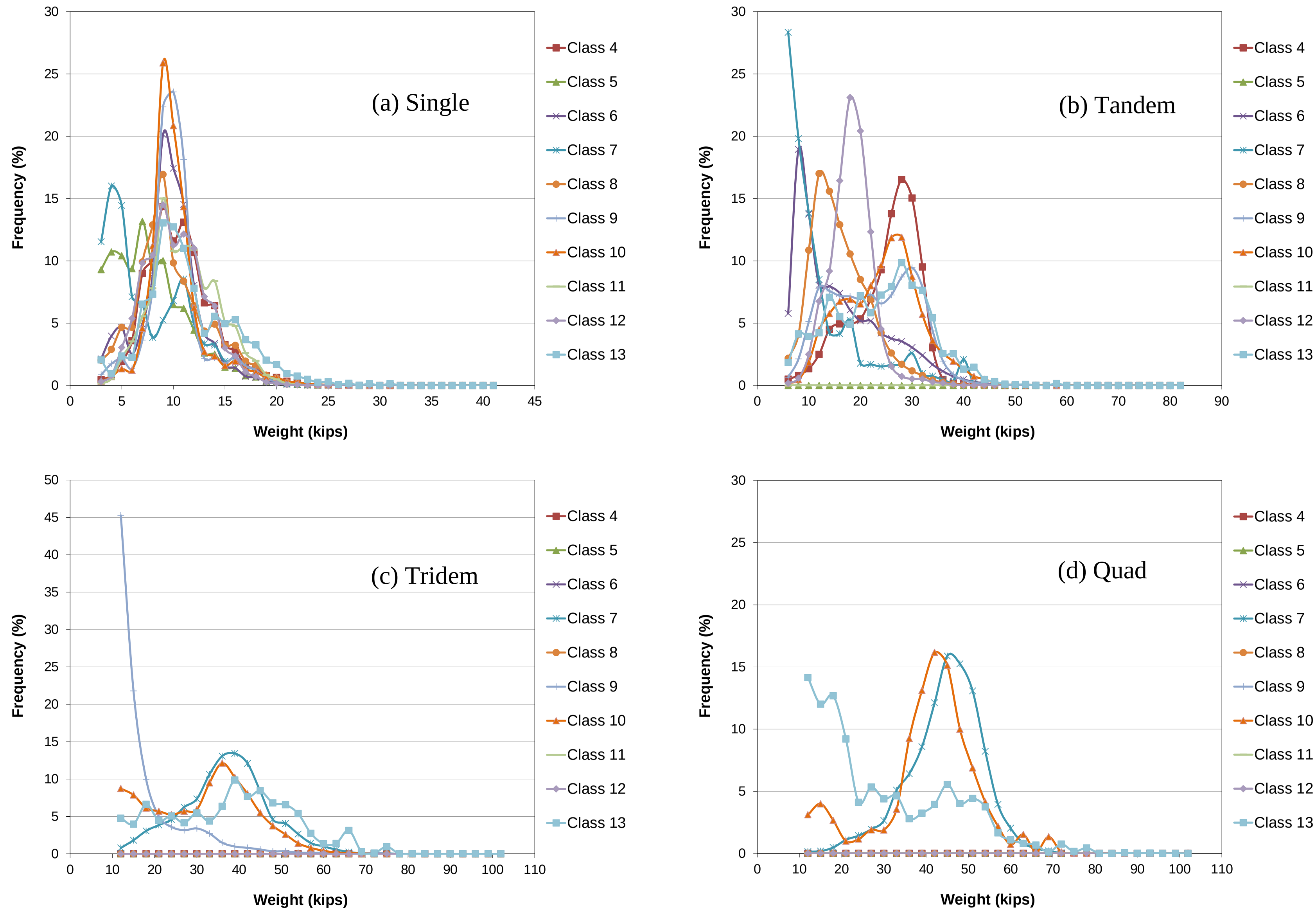


Figure 90: Cluster 1 (a) Single, (b) Tandem, (c) Tridem, and (d) Quad Axle Load Distributions

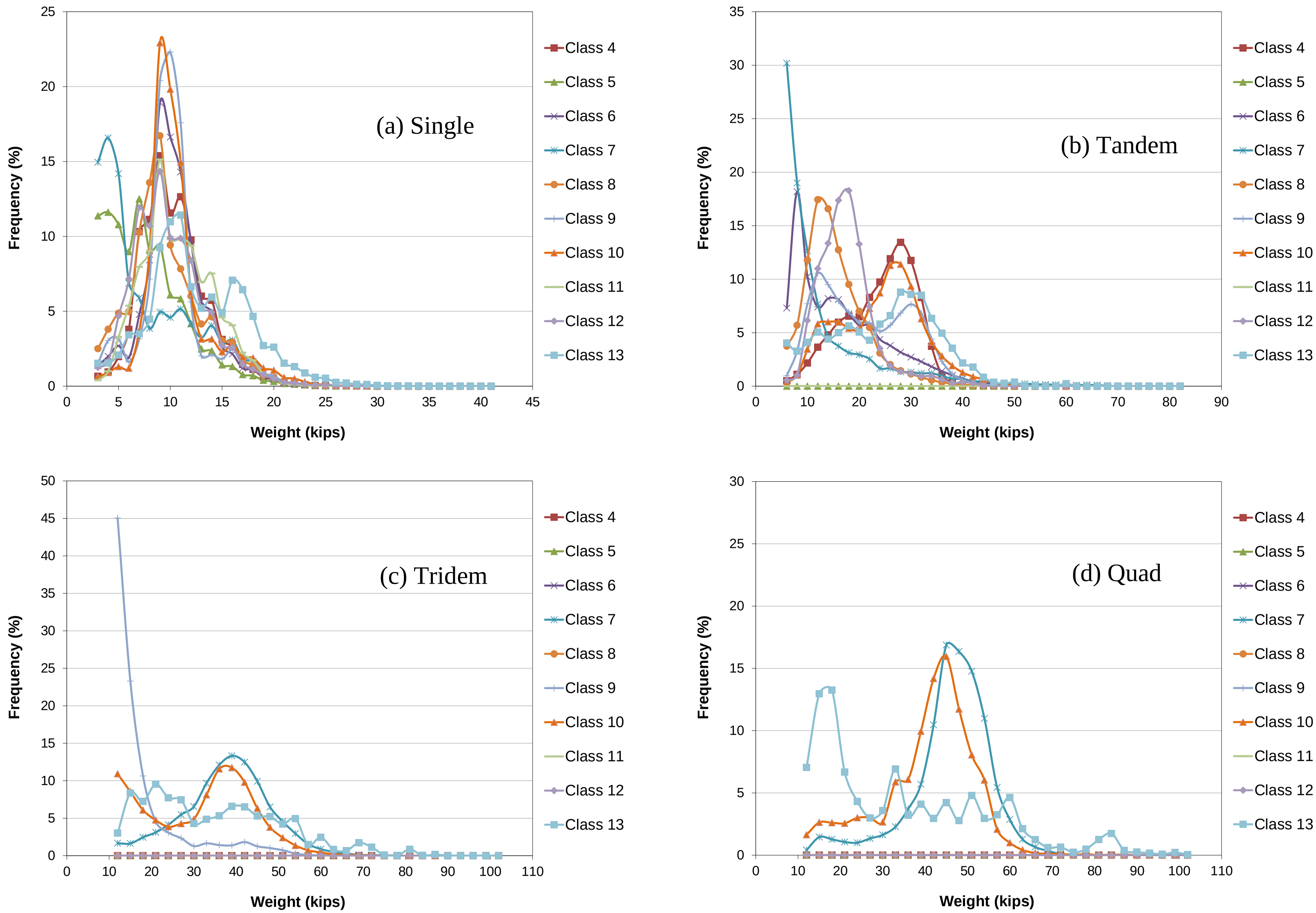


Figure 91: Cluster 2 (a) Single, (b) Tandem, (c) Tridem, and (d) Quad Axle Load Distributions

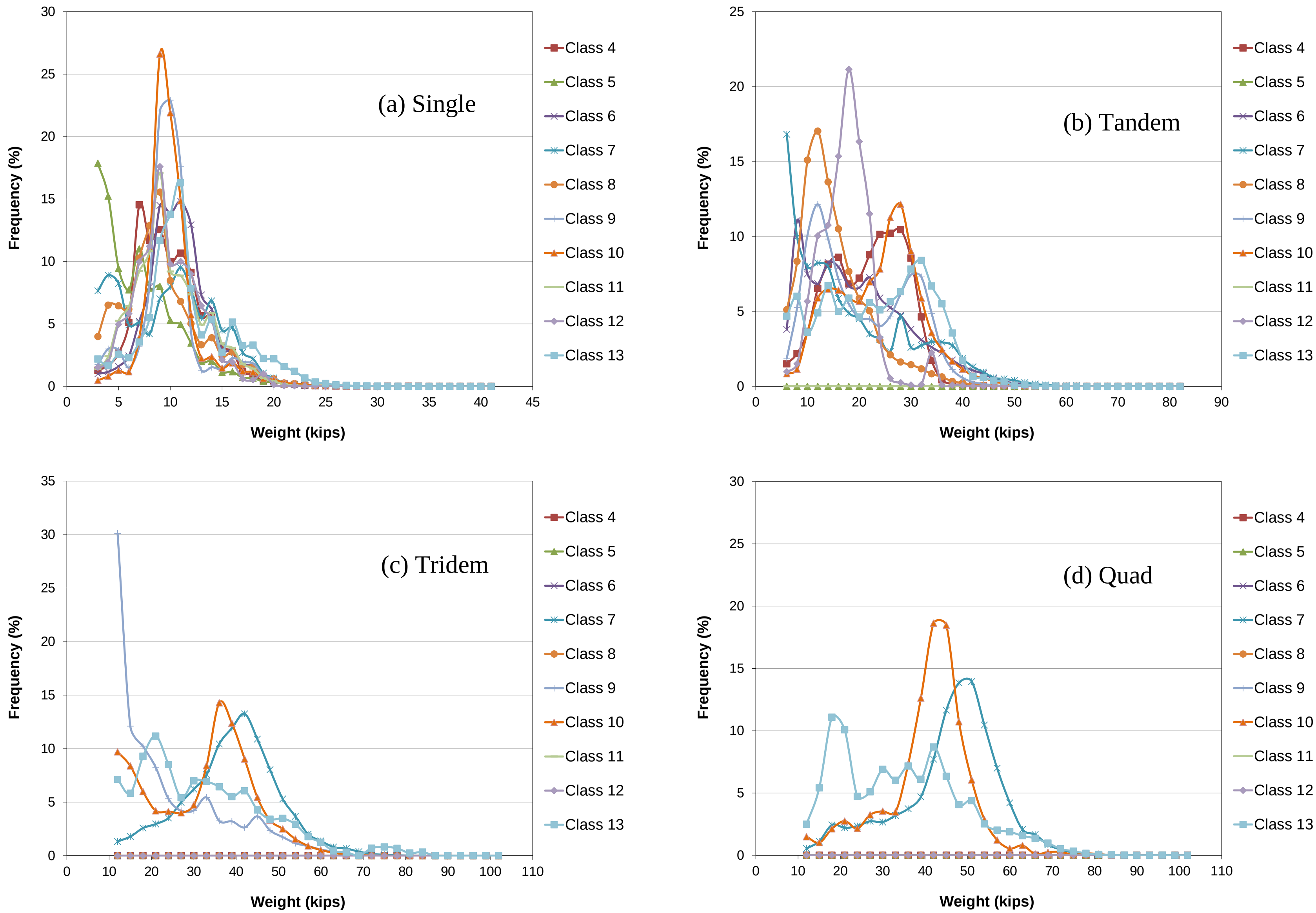


Figure 92: Cluster 3 (a) Single, (b) Tandem, (c) Tridem, and (d) Quad Axle Load Distributions

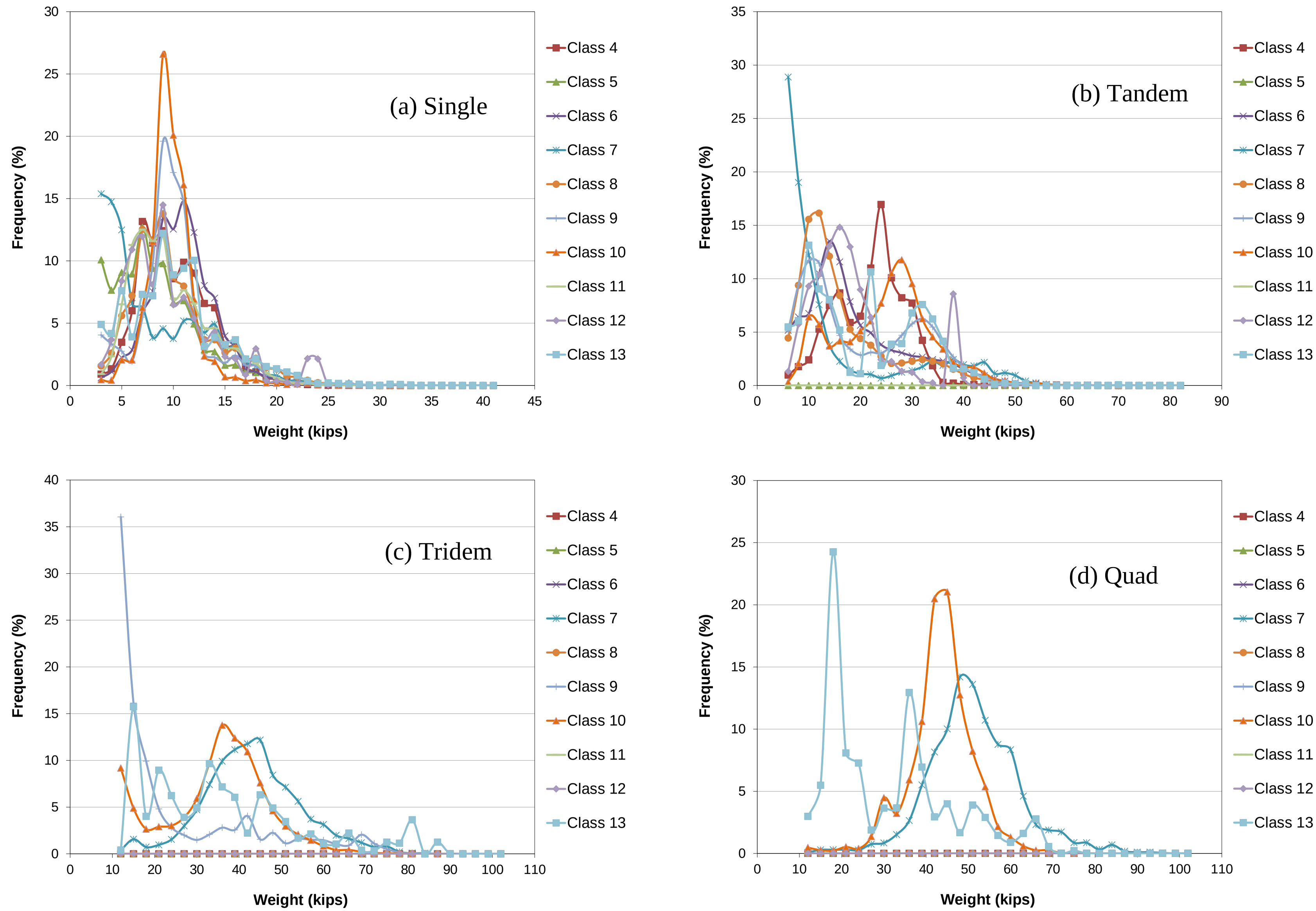


Figure 93: Cluster 4 (a) Single, (b) Tandem, (c) Tridem, and (d) Quad Axle Load Distributions

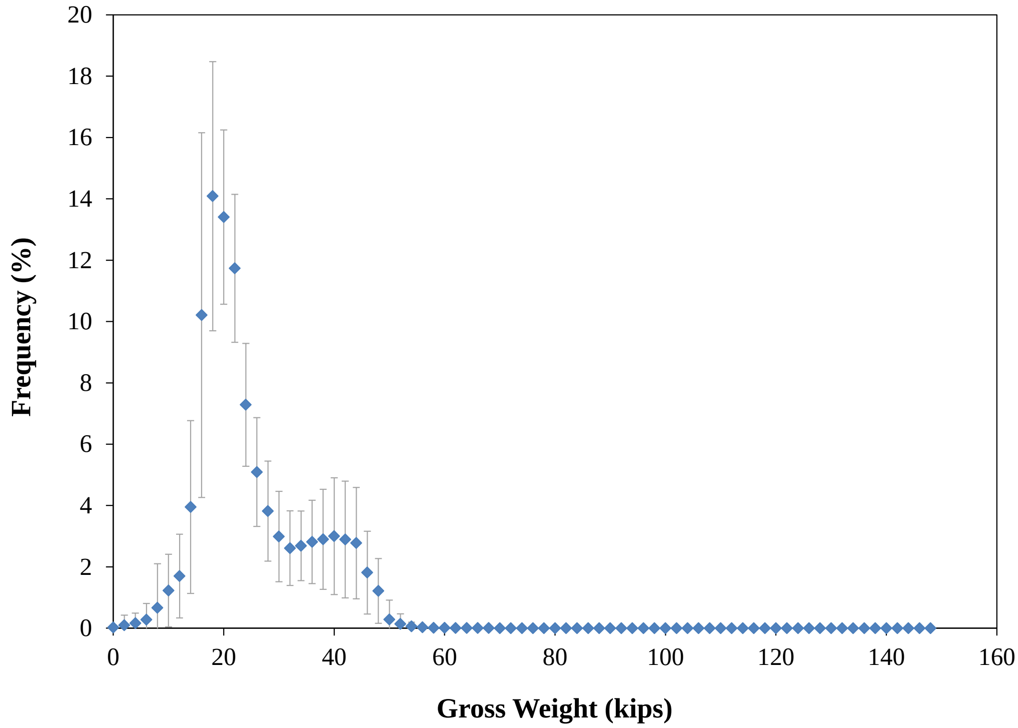


Figure 94: Statewide Average Class 4 Gross Weight Distribution

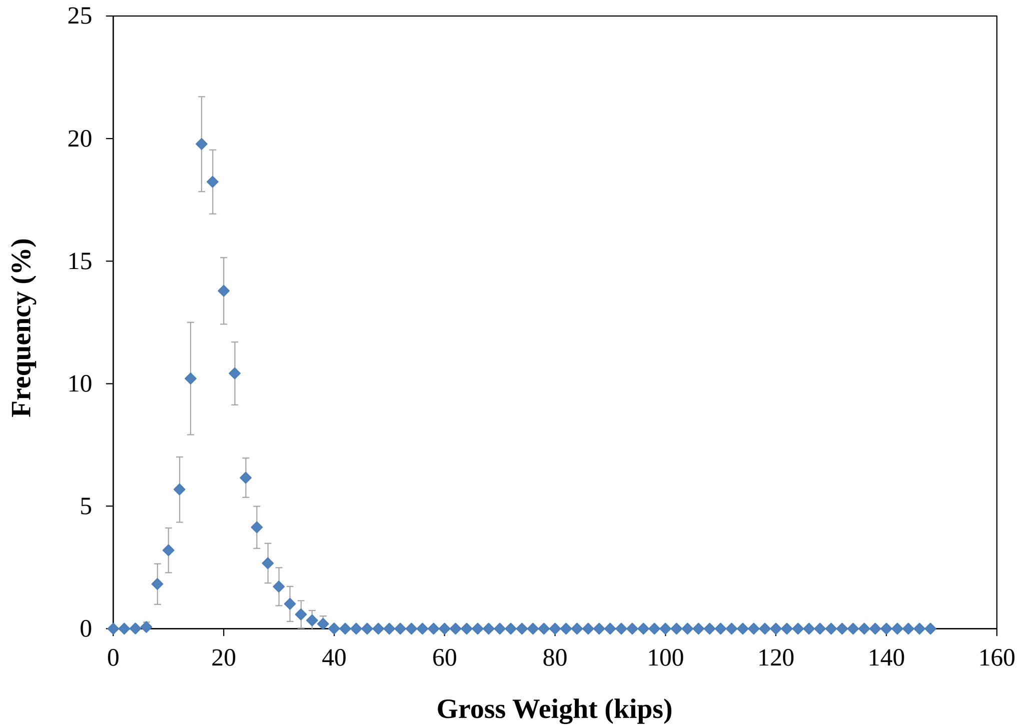


Figure 95: Statewide Average Class 5 Gross Weight Distribution

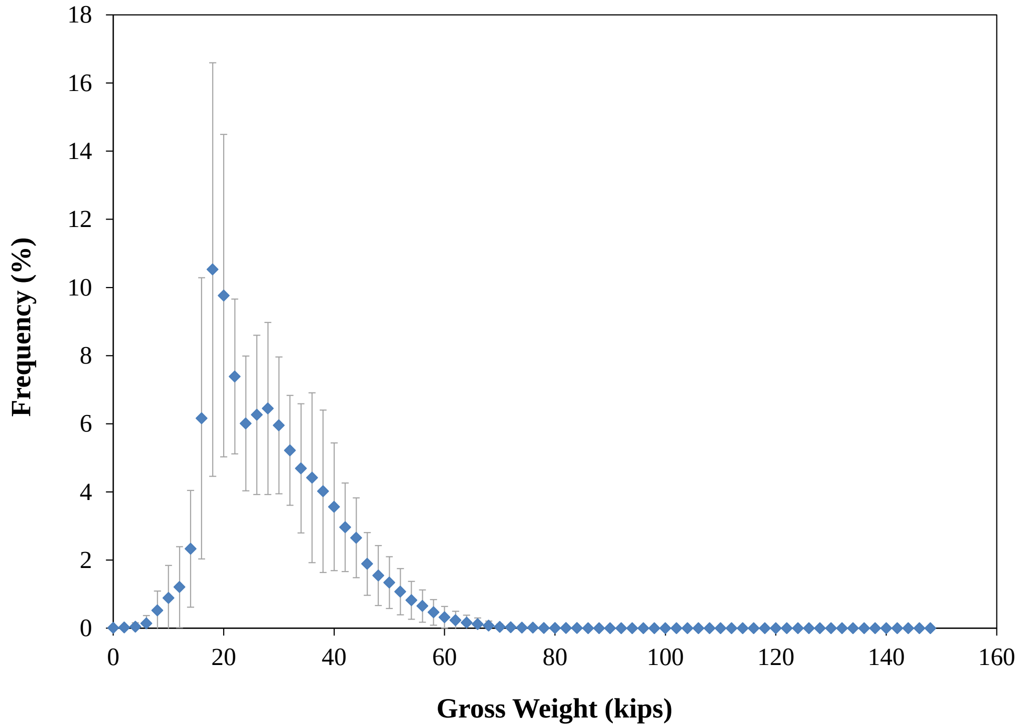


Figure 96: Statewide Average Class 6 Gross Weight Distribution

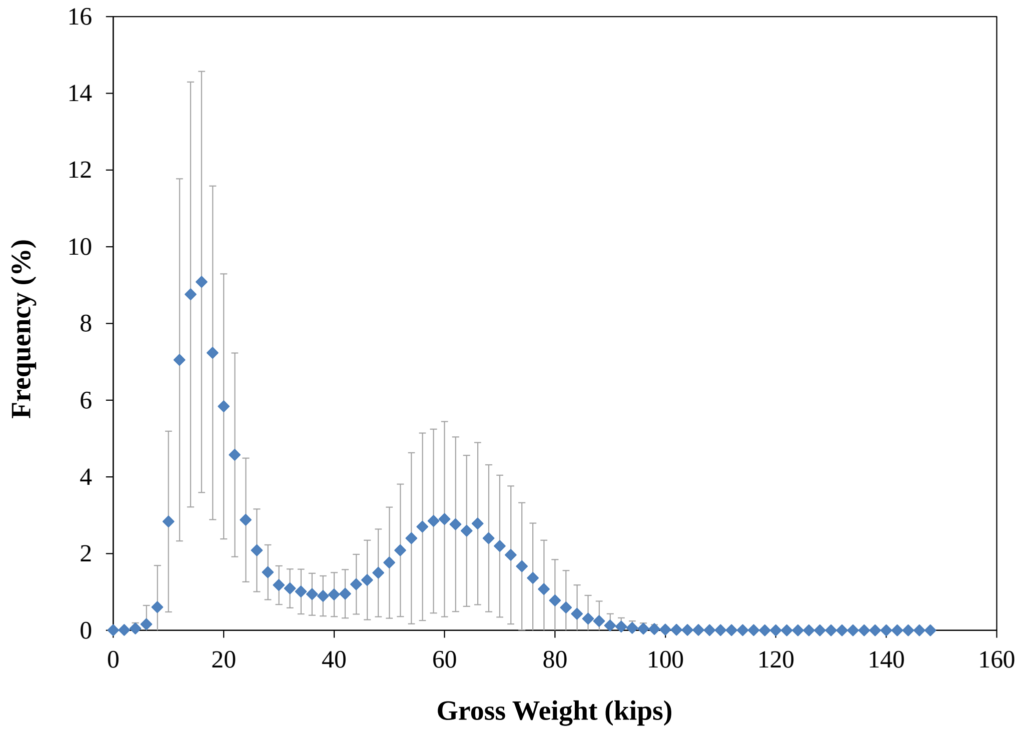


Figure 97: Statewide Average Class 7 Gross Weight Distribution

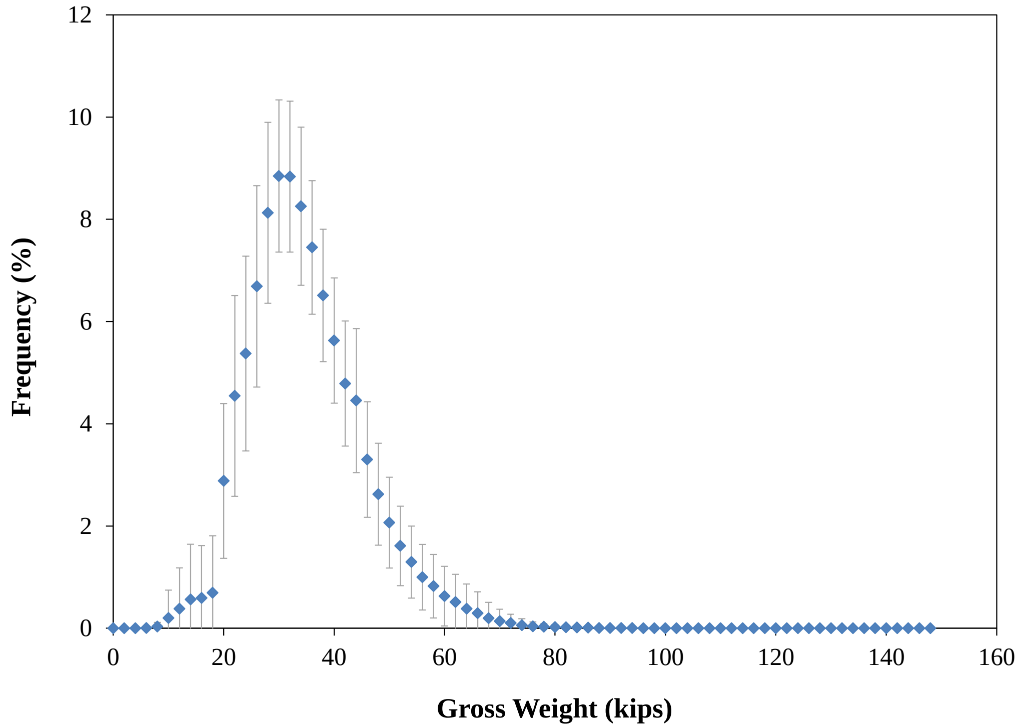


Figure 98: Statewide Average Class 8 Gross Weight Distribution

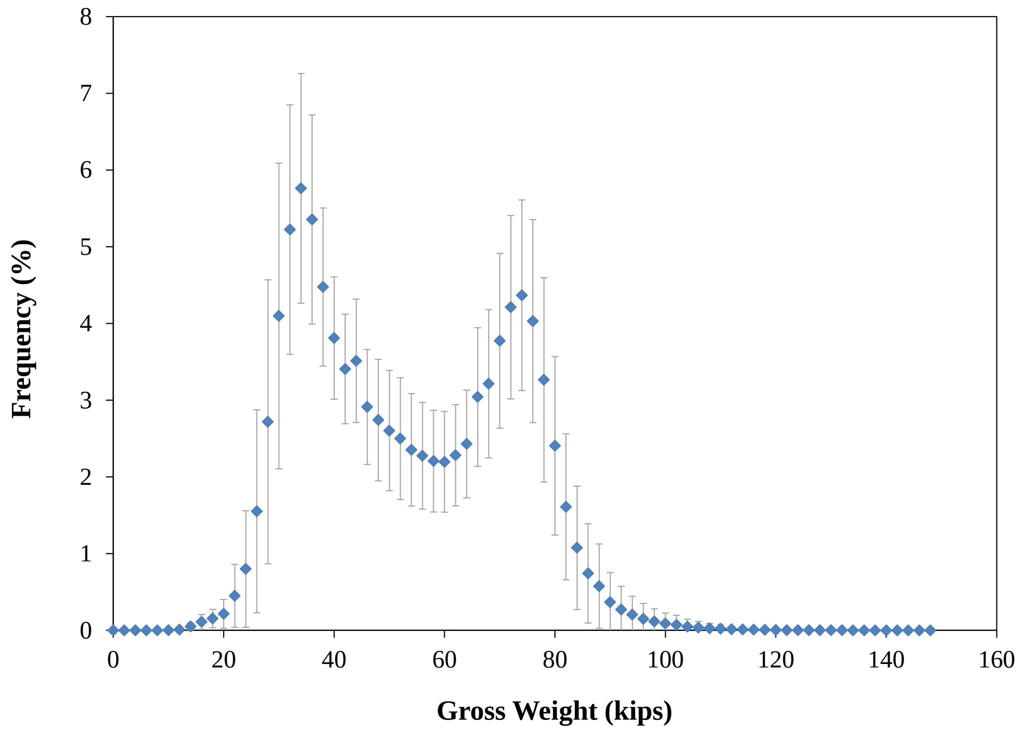


Figure 99: Statewide Average Class 9 Gross Weight Distribution

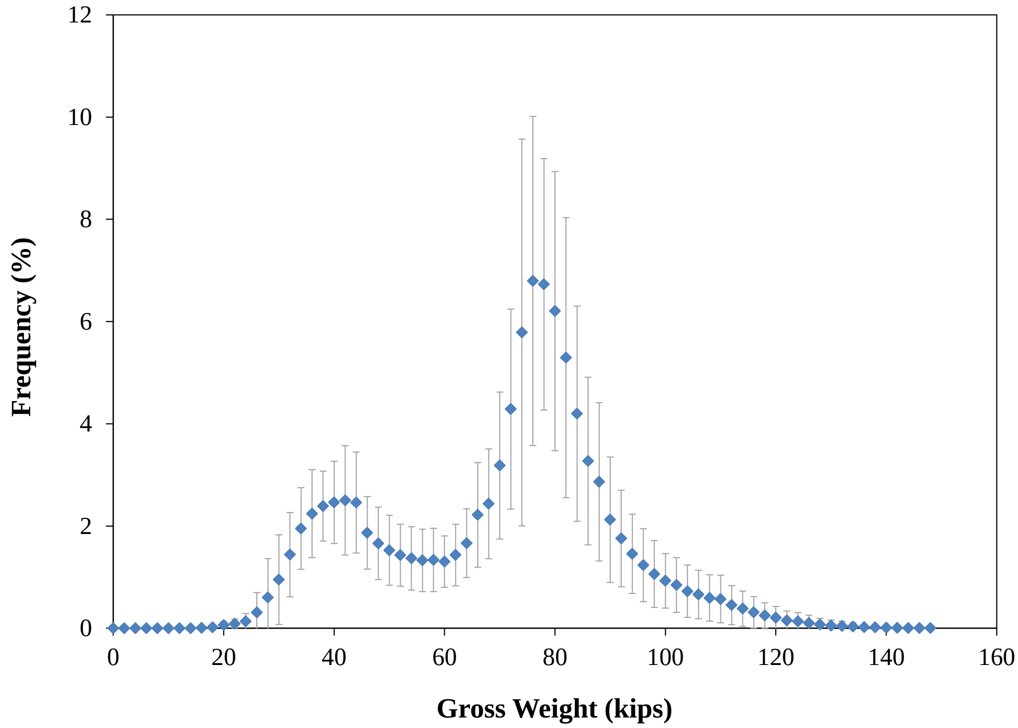


Figure 100: Statewide Average Class 10 Gross Weight Distribution

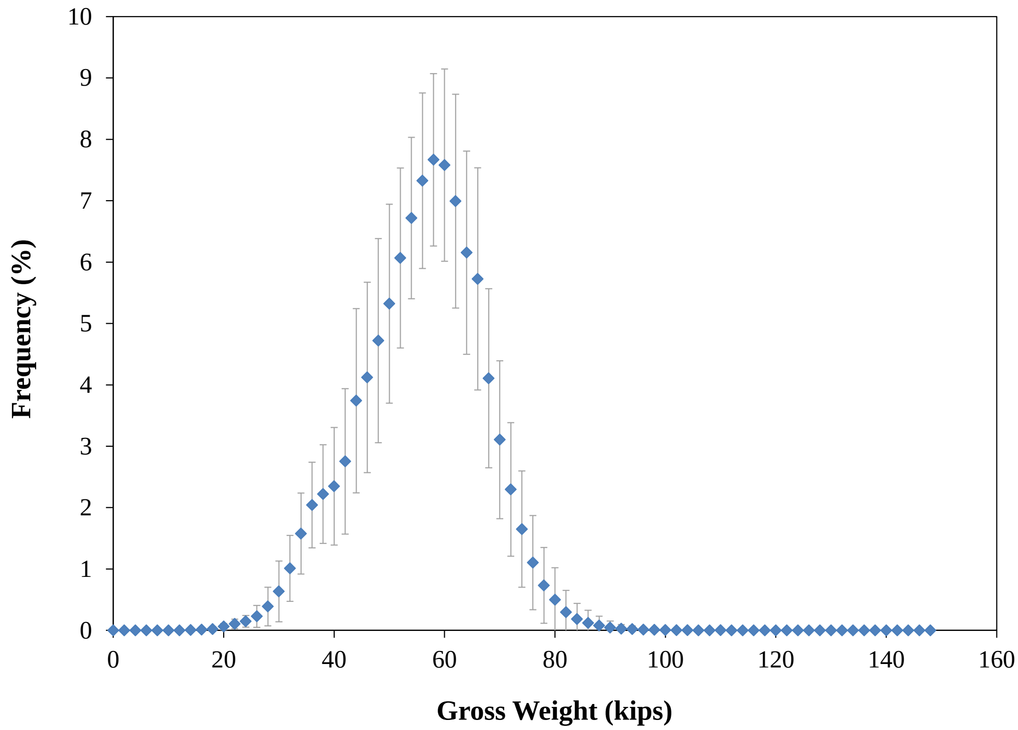


Figure 101: Statewide Average Class 11 Gross Weight Distribution

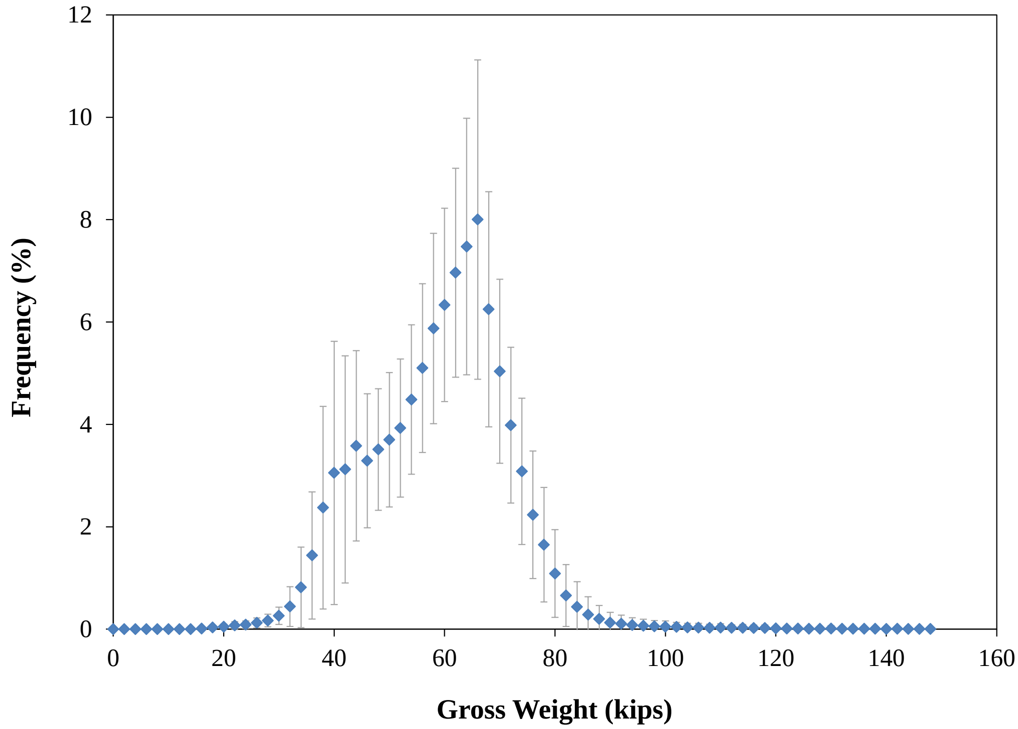


Figure 102: Statewide Average Class 12 Gross Weight Distribution

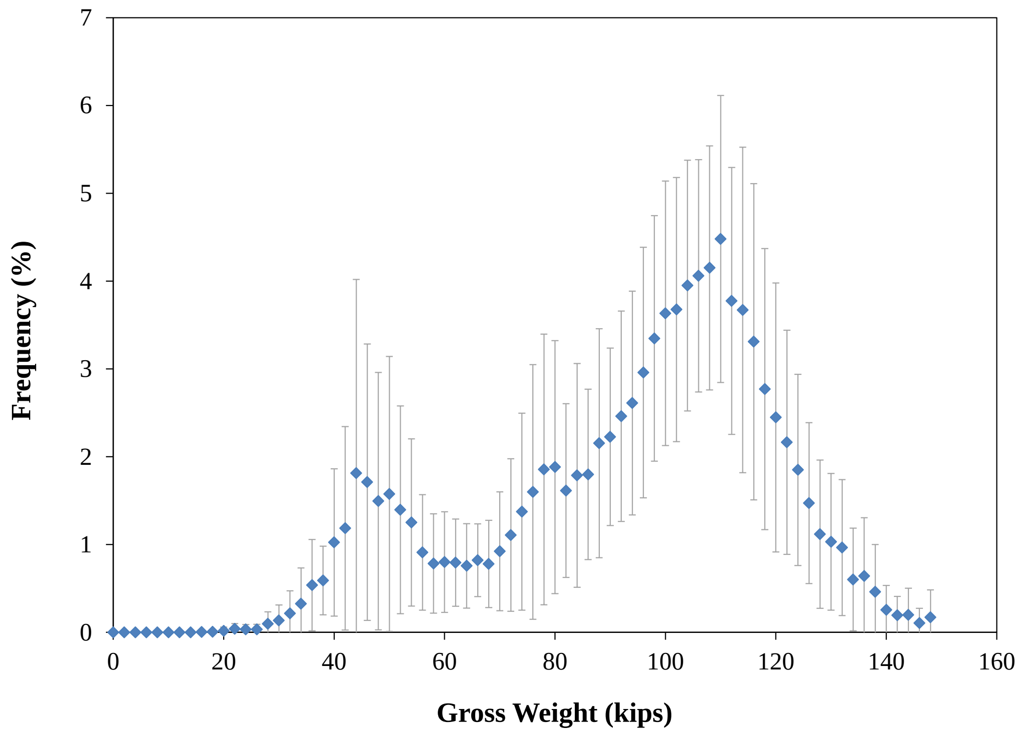


Figure 103: Statewide Average Class 13 Gross Weight Distribution

Table 48: List of Sites used in Development of Statewide Axle Load Spectra

Truck Class	Site List
Class 4	50 (2010, 2011), 65 (2006, 2007, 2008), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 706 (2006, 2007, 2008, 2009, 2010), 710 (2006, 2007, 2008, 2009, 2010, 2011), 711 (2006, 2007, 2008, 2009, 2010, 2011), 714 (2006, 2007, 2008), 716 (2006, 2007, 2008, 2009, 2010), 717 (2006, 2007, 2008, 2009, 2010, 2011), 718 (2006), 719 (2006, 2007, 2008, 2009, 2010, 2011), 721 (2006, 2007, 2008, 2009, 2010), 725 (2006, 2007, 2008, 2009, 2010, 2011), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2007, 2008), 760 (2006, 2007, 2008, 2009, 2010, 2011), 762 (2006), 763 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 770 (2008, 2009, 2010, 2011), 774 (2006, 2007, 2008, 2011), 775 (2009, 2010, 2011), 776 (2006), 779 (2010), 781 (2009), 782 (2011), 783 (2011)
Class 5	50 (2009, 2010), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2010), 721 (2008), 725 (2006, 2009, 2010, 2011), 745 (2008, 2009, 2010), 752 (2008, 2009), 754 (2007), 755 (2010), 760 (2009, 2010, 2011), 764 (2006, 2010), 768 (2006, 2007, 2008, 2009, 2010, 2011), 769 (2011), 770 (2008, 2009, 2010), 771 (2006), 773 (2007, 2008, 2009, 2011), 775 (2009, 2010), 779 (2006, 2007, 2008), 780 (2008, 2009, 2010, 2011), 781 (2008, 2009, 2010), 782 (2011), 783 (2011)
Class 6	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 706 (2006, 2007, 2008, 2009, 2010), 709 (2007, 2008, 2009, 2010, 2011), 710 (2009, 2010, 2011), 711 (2006, 2007, 2008, 2009, 2010, 2011), 714 (2006, 2007, 2008), 715 (2006, 2007, 2009, 2010), 716 (2006, 2009, 2010), 717 (2007, 2009, 2010, 2011), 719 (2006, 2007, 2008, 2009, 2010, 2011), 721 (2006, 2008, 2009, 2010, 2011), 725 (2006, 2007, 2008, 2009, 2010, 2011), 738 (2009, 2010), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2007, 2008, 2009, 2010), 760 (2006, 2007, 2008, 2009, 2010, 2011), 762 (2006), 763 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 768 (2006, 2007, 2008, 2009, 2010, 2011), 769 (2011), 770 (2008, 2009, 2010, 2011), 773 (2007, 2008, 2009, 2011), 774 (2006, 2007, 2008, 2011), 775 (2010, 2011), 779 (2006, 2007, 2008, 2009, 2010, 2011), 780 (2007, 2008, 2009, 2010, 2011), 781 (2009, 2010), 782 (2011), 783 (2011)

Table 48: List of Sites used in Development of Statewide Axle Load Spectra (Cont.)

Truck Class	Site List
Class 7	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 706 (2006, 2007), 709 (2007, 2008, 2009, 2010, 2011), 710 (2007, 2008, 2010, 2011), 723 (2006), 725 (2011), 738 (2009, 2010), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2007, 2008, 2009, 2010), 760 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 768 (2006, 2007, 2008, 2009, 2010, 2011), 770 (2008, 2009, 2010, 2011), 773 (2007, 2008, 2009, 2011), 774 (2006, 2007, 2008, 2011), 775 (2009, 2010, 2011), 776 (2006), 779 (2006, 2007, 2008, 2009, 2011), 780 (2007, 2008, 2009, 2010, 2011), 781 (2008, 2009, 2010), 782 (2011)
Class 8	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 706 (2006, 2007, 2008, 2009, 2010), 709 (2007, 2008), 710 (2006), 711 (2006), 714 (2006, 2007), 715 (2006, 2009), 716 (2006), 717 (2006), 718 (2006), 719 (2006), 721 (2006, 2007, 2008), 723 (2006), 725 (2006), 738 (2009, 2010), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2009, 2010), 760 (2006, 2007, 2008, 2009, 2010, 2011), 762 (2006), 763 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 768 (2006, 2007, 2008, 2009, 2010, 2011), 770 (2008, 2010, 2011), 771 (2006), 774 (2006, 2011), 775 (2009, 2010, 2011), 779 (2006), 781 (2008, 2009, 2010), 782 (2011), 783 (2011)
Class 9	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 706 (2006, 2007, 2008, 2009), 709 (2007, 2008, 2009, 2010, 2011), 710 (2006, 2007, 2008, 2009, 2010, 2011), 711 (2006, 2007, 2008, 2009, 2010, 2011), 714 (2006, 2007, 2008), 715 (2006, 2007, 2009, 2010), 716 (2006, 2007, 2008, 2009, 2010), 717 (2006, 2007, 2008, 2009, 2010, 2011), 718 (2006), 719 (2006, 2007, 2008, 2009, 2010, 2011), 721 (2006, 2007, 2008, 2009, 2010, 2011), 723 (2006), 725 (2006, 2007, 2008, 2009, 2010, 2011), 738 (2009, 2010), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2007, 2008, 2009, 2010), 760 (2006, 2007, 2008, 2009, 2010, 2011), 762 (2006), 763 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 768 (2006, 2007, 2008, 2009, 2010, 2011), 769 (2011), 770 (2008, 2009, 2010, 2011), 771 (2006, 2007, 2008), 773 (2007, 2008, 2009, 2011), 774 (2006, 2007, 2008, 2011), 775 (2009, 2010, 2011), 776 (2006), 779 (2006, 2007, 2008, 2009, 2010, 2011), 780 (2007, 2008, 2009, 2010, 2011), 781 (2008, 2009, 2010), 782 (2011), 783 (2011)

Table 48: List of Sites used in Development of Statewide Axle Load Spectra (Cont.)

Truck Class	Site List
Class 10	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 518 (2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 706 (2006, 2007, 2008, 2009, 2010), 709 (2007, 2008, 2009, 2010, 2011), 711 (2006, 2007, 2008, 2009, 2010, 2011), 715 (2006, 2007), 716 (2006, 2007, 2008, 2009, 2010), 719 (2006, 2007, 2009, 2010, 2011), 721 (2006, 2007, 2008, 2009, 2010, 2011), 723 (2006), 725 (2006, 2007, 2008, 2009, 2010, 2011), 738 (2009, 2010), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008), 754 (2006, 2007), 755 (2006, 2007, 2008, 2009, 2010), 763 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 770 (2008, 2009, 2010, 2011), 773 (2007, 2008, 2009, 2011), 774 (2006, 2007, 2008, 2011), 775 (2009, 2010), 779 (2006, 2007, 2008, 2009, 2010, 2011), 781 (2008, 2009), 783 (2011)
Class 11	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 518 (2008, 2009, 2010, 2011), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 711 (2006, 2007, 2008, 2009, 2010, 2011), 714 (2006, 2007, 2008), 715 (2006, 2007, 2009, 2010), 716 (2006, 2007, 2008, 2009, 2010), 717 (2006, 2007, 2008, 2009, 2010, 2011), 718 (2006), 719 (2006, 2007, 2008, 2009, 2010, 2011), 721 (2006, 2007, 2008, 2009, 2010, 2011), 723 (2006), 725 (2006, 2007), 738 (2009, 2010), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2007, 2008, 2009), 762 (2006), 764 (2006, 2007, 2008, 2009, 2010, 2011), 770 (2008, 2009, 2010, 2011), 775 (2009, 2010, 2011), 779 (2007, 2008, 2009, 2010, 2011), 781 (2008, 2009, 2010), 782 (2011)
Class 12	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 535 (2009, 2010, 2011), 613 (2008, 2009, 2010), 711 (2006, 2007, 2008, 2009, 2010, 2011), 715 (2006, 2007, 2009, 2010), 716 (2006, 2007, 2008, 2009, 2010), 717 (2006, 2007, 2008, 2009, 2010, 2011), 718 (2006), 719 (2006, 2007, 2008, 2009, 2010, 2011), 721 (2008, 2009, 2010, 2011), 723 (2006), 725 (2006, 2007), 743 (2007, 2008, 2009), 745 (2008, 2009, 2010, 2011), 752 (2008, 2009), 754 (2006, 2007), 755 (2006, 2007), 762 (2006), 770 (2008, 2009, 2010, 2011), 775 (2009, 2010, 2011), 779 (2006, 2007, 2008, 2009, 2010, 2011), 781 (2008, 2009, 2010), 782 (2011)
Class 13	50 (2009, 2010, 2011), 65 (2006, 2007, 2008), 535 (2009, 2010, 2011), 706 (2006, 2007, 2008), 711 (2011), 717 (2011), 719 (2006, 2007, 2008, 2009, 2010, 2011), 725 (2006, 2007, 2009, 2010, 2011), 745 (2009, 2010, 2011), 754 (2006), 783 (2011)

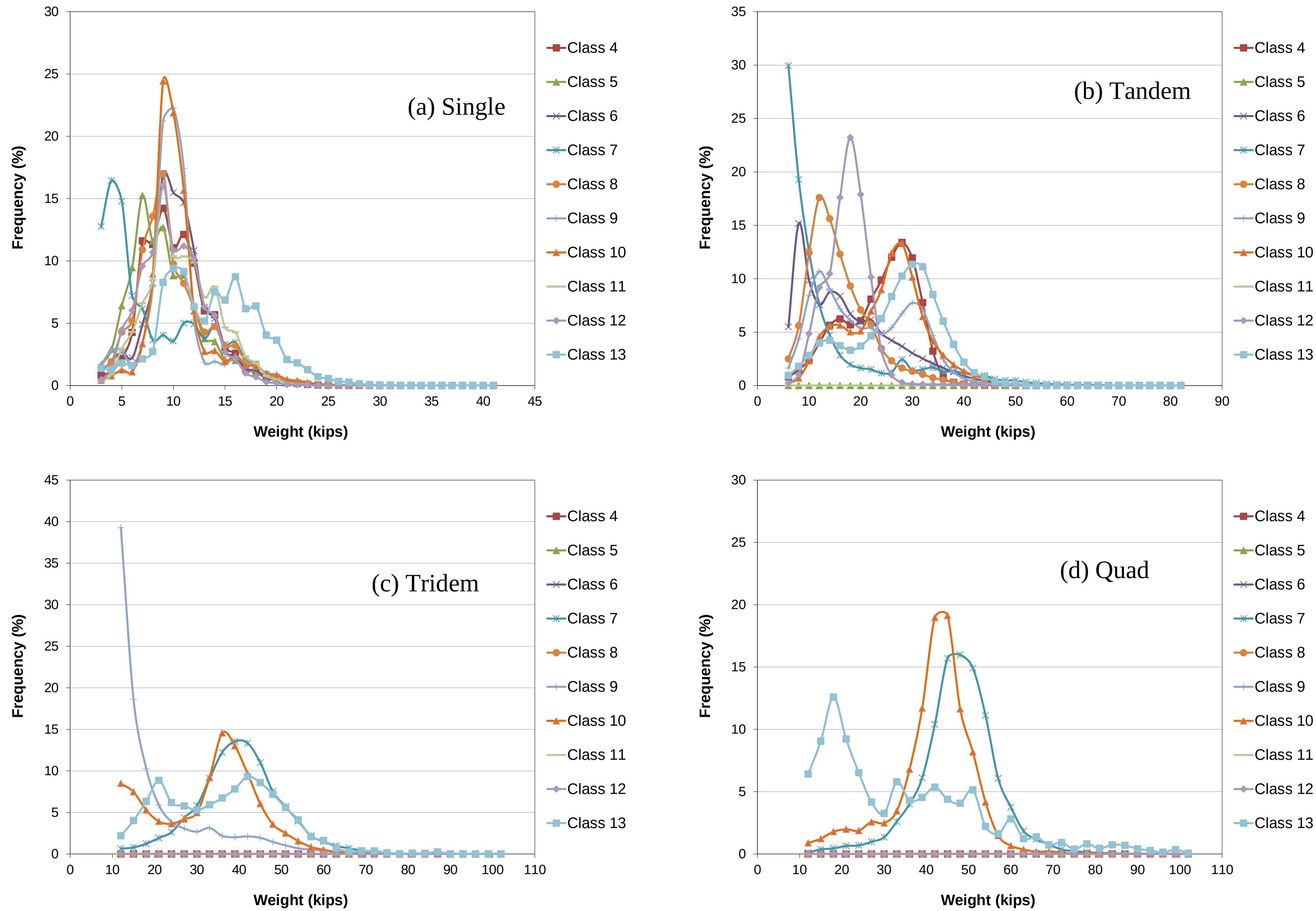


Figure 104: Statewide Average (a) Single, (b) Tandem, (c) Tridem, and (d) Quad Axle Load Distributions

8.10 Number of Axles Per Truck

As discussed in Section 2.3.4.4, the MEPDG requires defining the number of axles (single, tandem, tridem, and quad) per truck for each truck class (4 through 13). State highway agencies typically follow a standard procedure to classify their vehicles (refer to Table 45 for ODOT vehicle classification tree). Therefore, it is reasonable to use statewide average number of axles per truck in the design of pavement structures. Table 49 presents the statewide average number of single, tandem, tridem, and quad axles per truck for truck Classes 4 through 13. As noticed from this table, the number of axles per truck reflects the axle configurations presented in Table 45. For instance, Class 5 trucks contain only single axles, while truck Classes 7, 10, and 13 may have a combination of single, tandem, tridem, or quad axles. By comparing the statewide average number of axles for Ohio to the MEPDG defaults in Table 5, it can be noticed that the MEPDG defaults do not contain any quad axles. Since these axles are identified in the State of Ohio, the statewide average should provide a better estimate of the number of axles per truck than the MEPDG default values.

Table 49: Statewide Average Number of Axles Per Truck

	Axle Configuration			
Class	Single	Tandem	Tridem	Quad
4	1.695	0.304	0.000	0.000
5	2.000	0.000	0.000	0.000
6	1.000	1.000	0.000	0.000
7	1.635	0.570	0.224	0.226
8	2.394	0.669	0.000	0.000
9	1.293	1.846	0.004	0.000
10	1.241	1.019	0.844	0.068
11	5.000	0.000	0.000	0.000
12	4.000	1.000	0.000	0.000
13	2.374	1.243	0.236	0.360

Chapter 9
Effect of Traffic Inputs on Pavement Design

9.1 Introduction

The previous chapters outline the efforts made to analyze the traffic monitoring data provided by ODOT and the development of the statewide averages for the various MEPDG traffic inputs. Since some traffic inputs are expected to have more impact on pavement design, it is critical to identify and quantify the effect of these inputs on the outcome of the MEPDG. In order to assess the sensitivity of the mechanistic-empirical pavement design to the various traffic inputs, a set of baseline designs were defined in the MEPDG and the traffic inputs were varied to determine their impact on the performance of the pavement structure.

9.2 Baseline MEPDG Pavement Designs

The baseline designs used in this study are based on a research project recently funded by ODOT to develop guidelines for the implementation of the NCHRP 1-37A mechanistic-empirical design procedures in Ohio (*12*). As part of that project, the researchers used the MEPDG to examine the sensitivity of two ODOT baseline pavement designs, one for a new flexible pavement and one for a new rigid pavement, to various design parameters including material properties, layer thicknesses, and regional weather data. The baseline pavement structures were developed using information obtained from ODOT pavement design manual, ODOT construction and material specifications, ODOT research reports, and the long-term pavement performance (LTPP) database. The following subsections detail these baseline designs and further evaluate their sensitivity to the three levels of the MEPDG traffic inputs.

9.2.1 Baseline New Flexible Pavement

The baseline new flexible pavement section was assumed to be located in the City of Newark in central Ohio. A design life of 20 years was used in the analysis with an initial international roughness index (IRI) of 63 inch/mile. Default roughness and distress limits were used for the performance criteria and the reliability was set to 90% for all performance parameters. Key performance parameters included longitudinal (top-down) fatigue cracking, alligator (bottom-up) fatigue cracking, transverse (low-temperature) cracking, rutting (HMA rutting and total rutting), and smoothness expressed using IRI.

The baseline new flexible pavement structure is presented in Figure 105. As can be noticed from this figure, the pavement structure consisted of a 1.5-inch (38.1-mm) Superpave HMA surface course (ODOT Item 442, Type A, 12.5 mm), a 1.75-inch (44.5-mm) Superpave HMA intermediate course (ODOT Item 442, Type A, 19 mm), a 9-inch (228.6-mm) Marshall mix bituminous base course (ODOT Item 302), and a 6-inch (152.4-mm) dense graded aggregate base course (ODOT Item 304) placed over 12 inches (304.8 mm) of compacted AASHTO A-6 (clayey soil) subgrade. Figure 106 shows a screen shot of the baseline new flexible pavement structure as defined in the MEPDG, and Figures 107 through 111 show screen shots of the material properties used for the various layers of the pavement structure. Additional information about this baseline design and material properties is available in Mallela et al. (*12*).

The baseline new flexible pavement structure was used to conduct a sensitivity analysis to determine the impact of the various traffic inputs on pavement performance. Climatic data from the Newark-Heath Airport was adopted for all pavement designs. Site 715 was used to obtain site-specific traffic data for Level 1 analysis. This site is located along interstate 71 between Columbus and Cincinnati. The interstate at that location has two lanes per direction and is classified as a rural interstate (FC 1). Each traffic input (base-year AADTT, growth rate, monthly adjustment factors, hourly distribution factors, vehicle (truck) class distribution, axle load spectra, and axles per truck) was then varied to determine the influence of using Level 2 (statewide average) or Level 3 (MEPDG default – national average) analysis on pavement performance. Table 50 presents the traffic information for the Level 1 baseline pavement design and the alternative traffic inputs. As can be seen from this table, each traffic input was individually varied over a wide range of values to determine its impact on pavement performance. It should be noted that Site 715 is located along a major interstate with relatively high truck traffic. Therefore, the sensitivity analysis results may not be representative of highways with lower truck traffic. The following subsections present the performance predictions obtained using the MEPDG for the baseline design and the considered traffic alternatives.

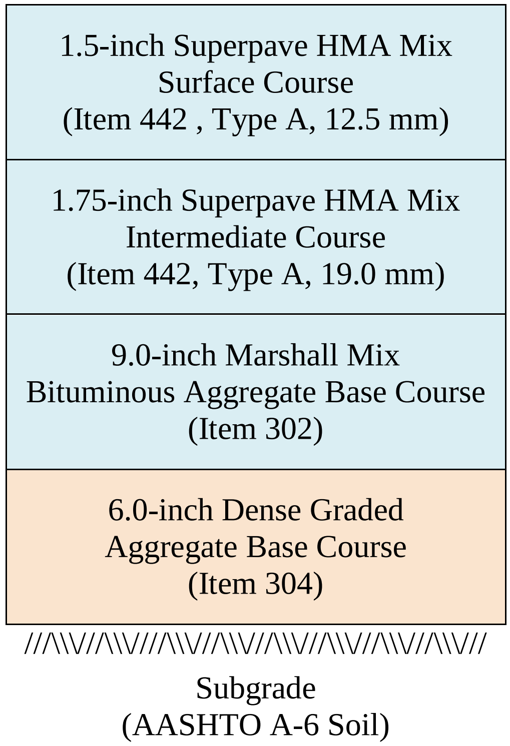


Figure 105: Baseline New Flexible Pavement Structure

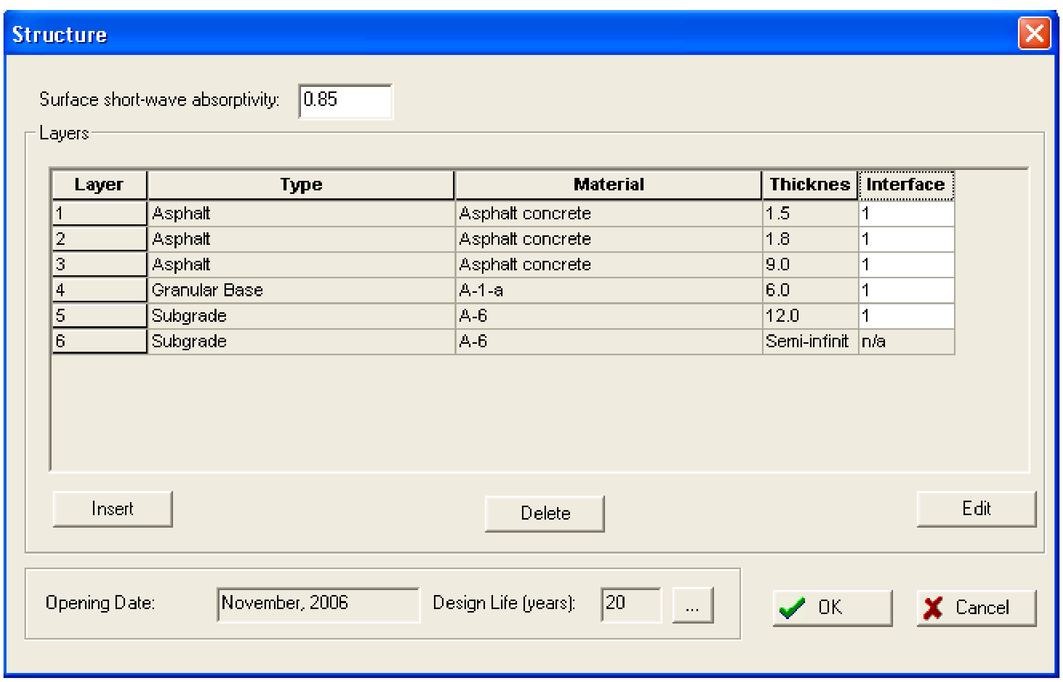
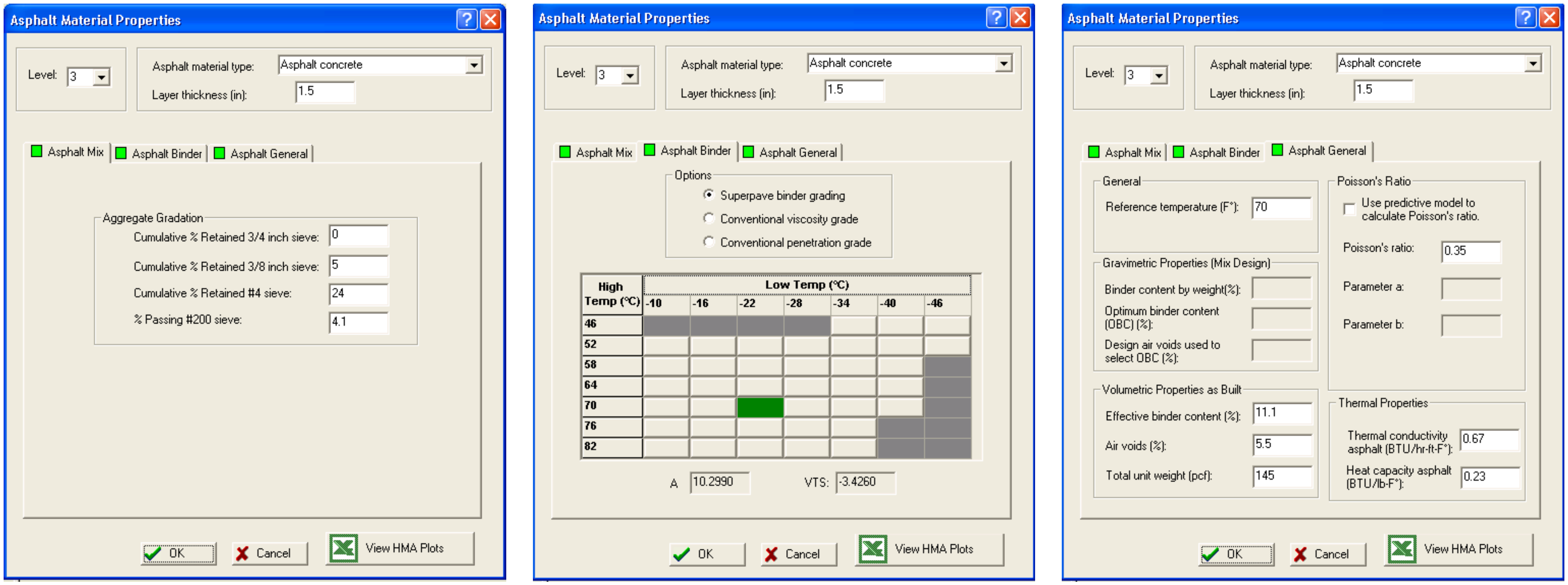
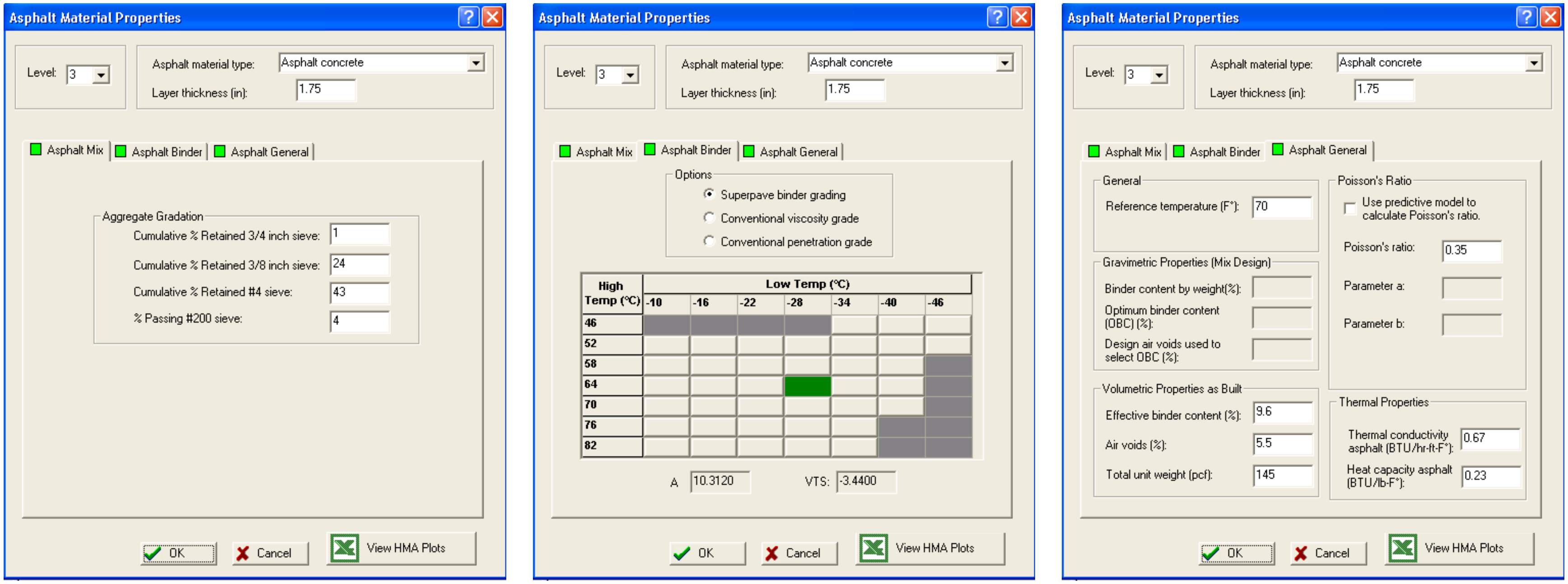


Figure 106: Baseline New Flexible Pavement Structure in the MEPDG



(a) (b) (c)

Figure 107: Material Properties (1.5-inch Superpave HMA Surface Course)



(a) (b) (c)

Figure 108: Material Properties (1.75-inch Superpave HMA Intermediate Course)

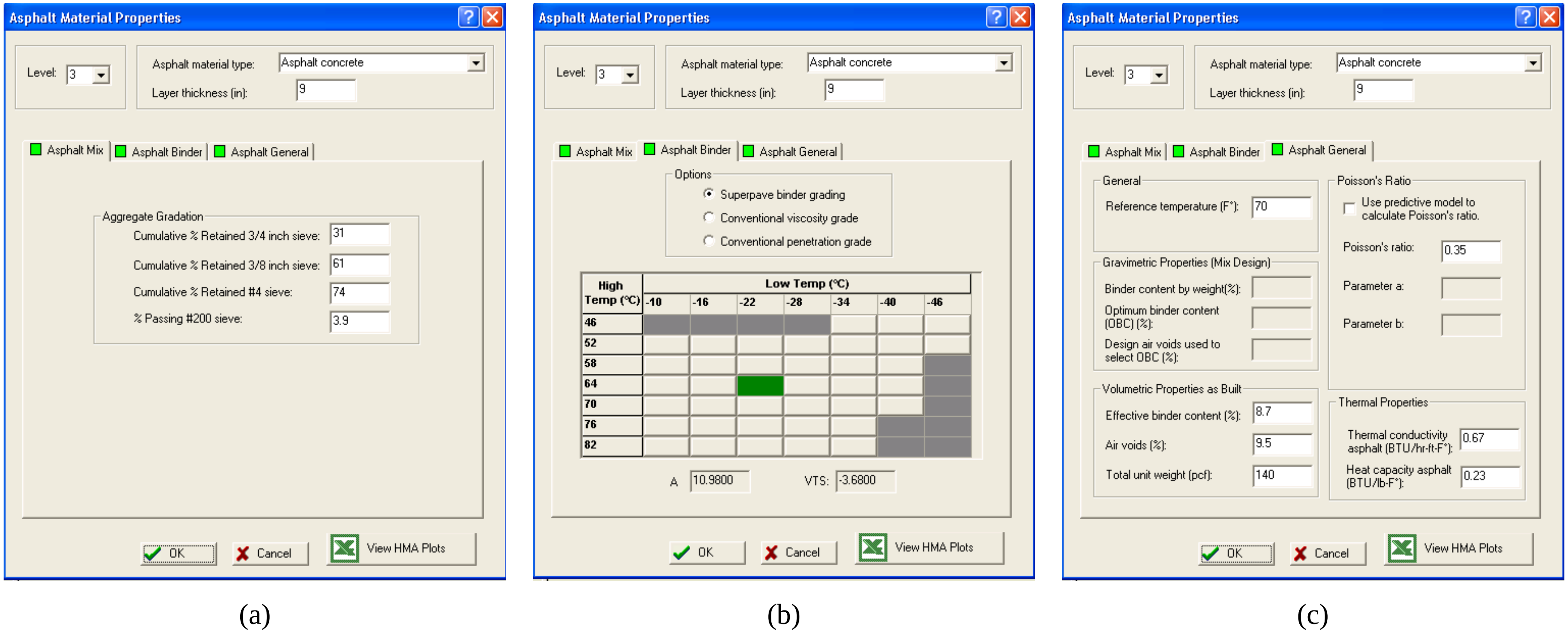
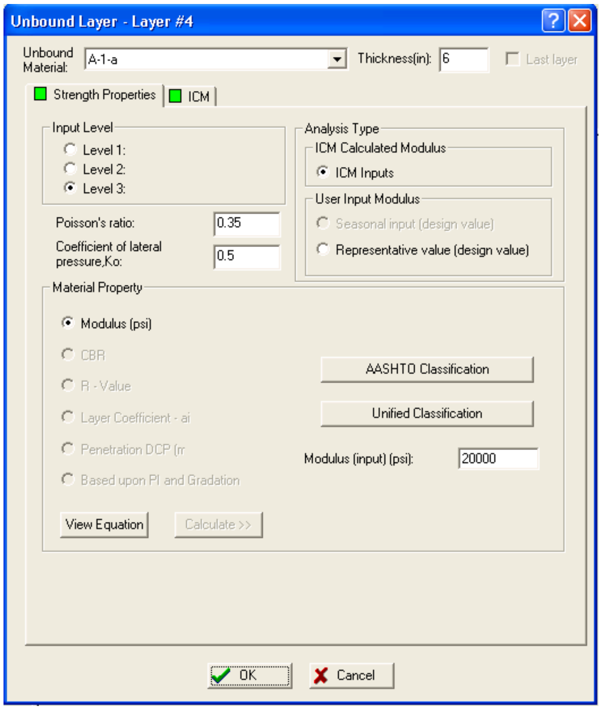
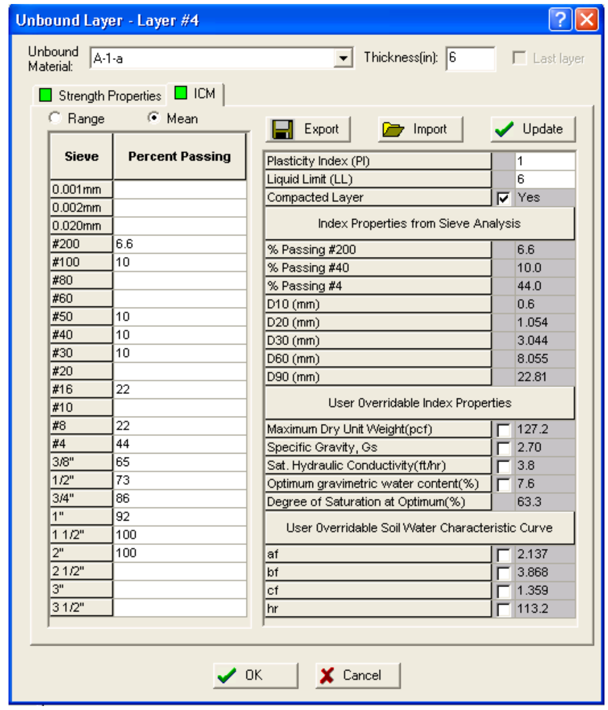


Figure 109: Material Properties (9-inch Marshall Mix Bituminous Base Course)

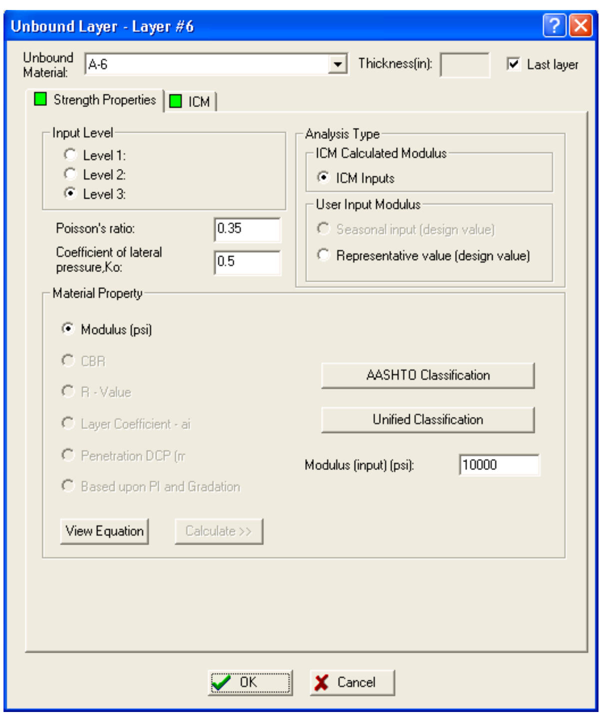


(a)

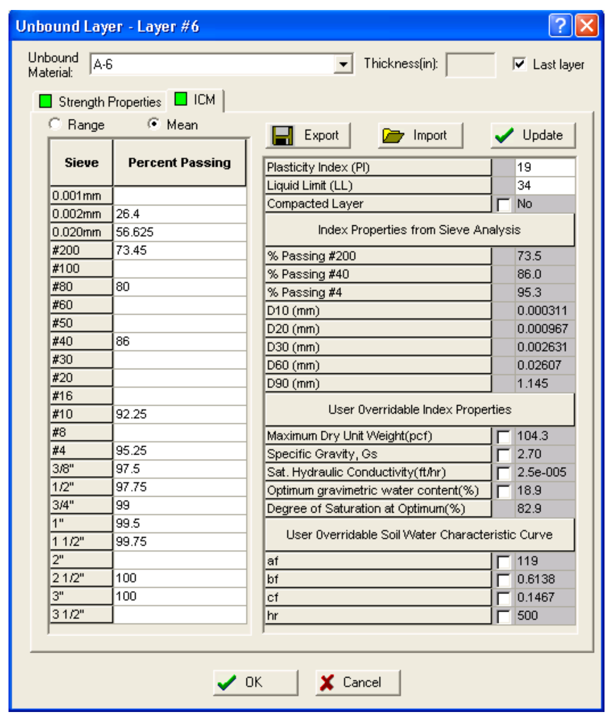


(b)

Figure 110: Material Properties (6-inch Dense Graded Aggregate Base Course)



(a)



(b)

Figure 111: Material Properties (AASHTO A-6 Subgrade Soil)

Table 50: Traffic Inputs for Sensitivity Analysis

MEPDG Traffic Input	Baseline	Alternative Traffic Inputs
AADTT	10000	7000, 8000, 9000, 11000, 12000, and 13000
Growth Rate (%)	3	1, 1.5, 2, 2.5, 3.5, 4, 4.5, 5
MAF	Site 715	FC1, FC2, FC6, FC7, FC8, FC11, FC12, FC14, FC16, and MEPDG Default
HDF	Site 715	FC1, FC2, FC6, FC7, FC8, FC11, FC12, FC14, FC16, and MEPDG Default
VCD	Site 715	FC1, FC2, FC6, FC7, FC8, FC11, FC12, FC14, FC16, TTC1, TTC2, TTC3, TTC4, TTC5, TTC6, TTC7, TTC8, TTC9, TTC10, TTC11, TTC12, TTC13, TTC14, TTC15, TTC16, and TTC17
ALS	Site 715	Cluster 1, Cluster 2, Cluster 3, Cluster 4, Statewide Average, and MEPDG Default
Axles Per Truck	Site 715	Statewide Average and MEPDG Default

9.2.1.1 MEPDG Results for Baseline New Flexible Pavement

Figures 112 to 116 present the MEPDG results for the baseline new flexible pavement structure. As can be seen from these figures, the MEPDG predictions seem to be reasonable with the exception of total rutting, which is expected since a local calibration has not been conducted on the MEPDG for the State of Ohio. This, however, is not expected to affect the results of the sensitivity analysis because the focus is on the change in performance due to the use of different traffic inputs and not on the predicted distresses.

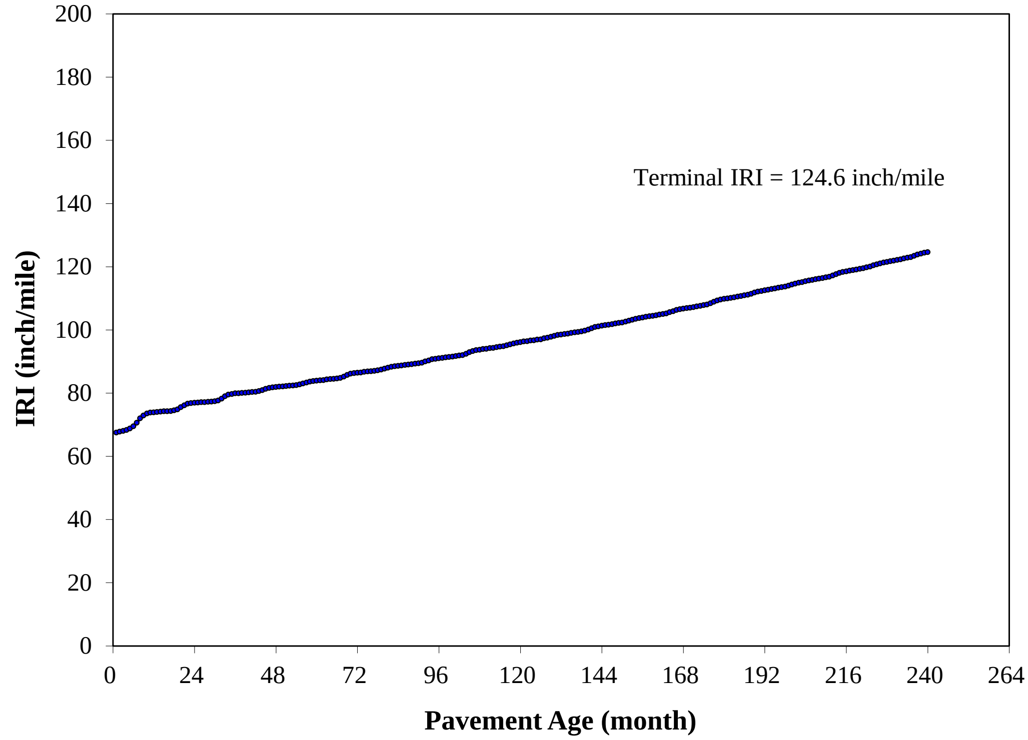


Figure 112: Predicted Mean IRI versus Flexible Pavement Age

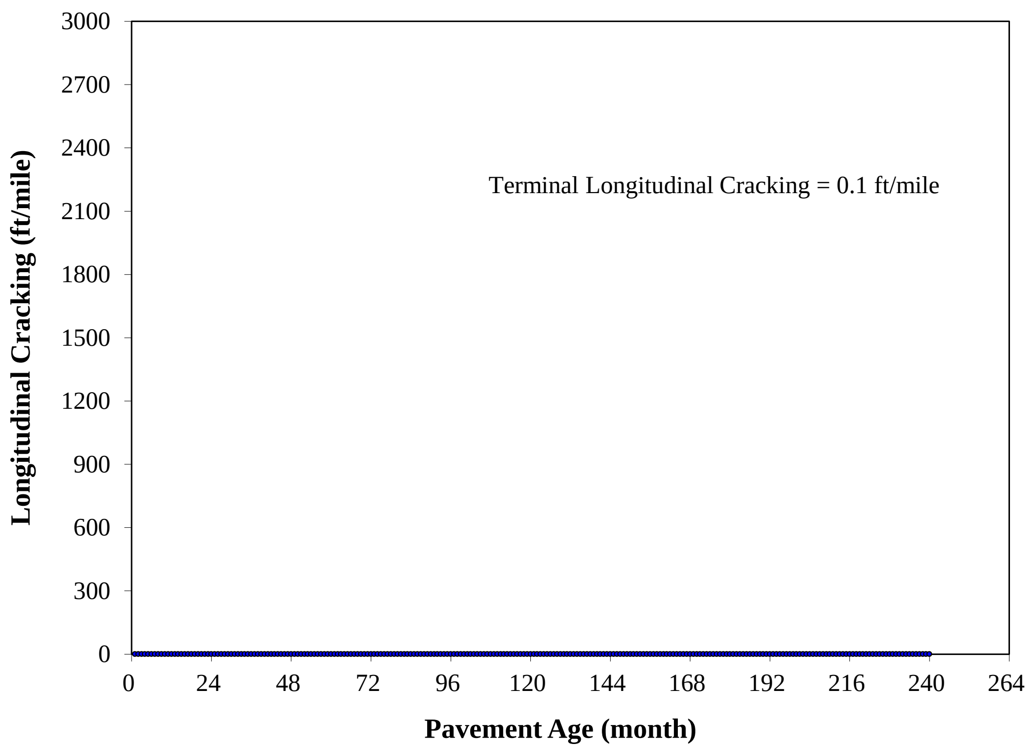


Figure 113: Predicted Mean Longitudinal Cracking versus Flexible Pavement Age

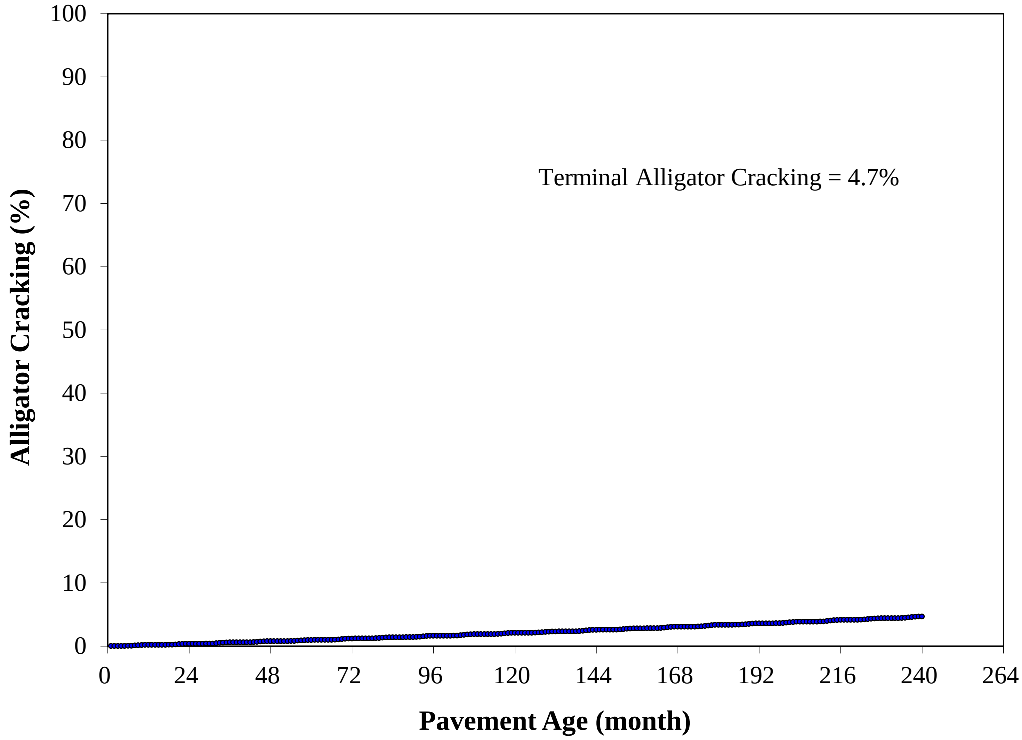


Figure 114: Predicted Mean Alligator Cracking versus Flexible Pavement Age

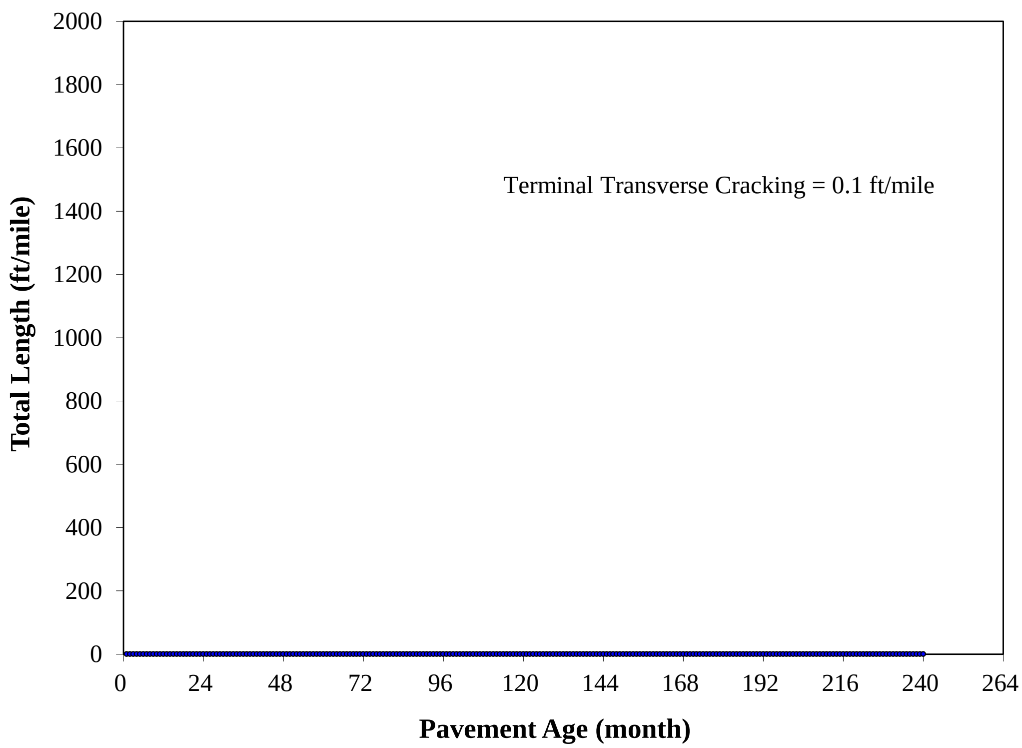


Figure 115: Predicted Mean Transverse Cracking versus Flexible Pavement Age

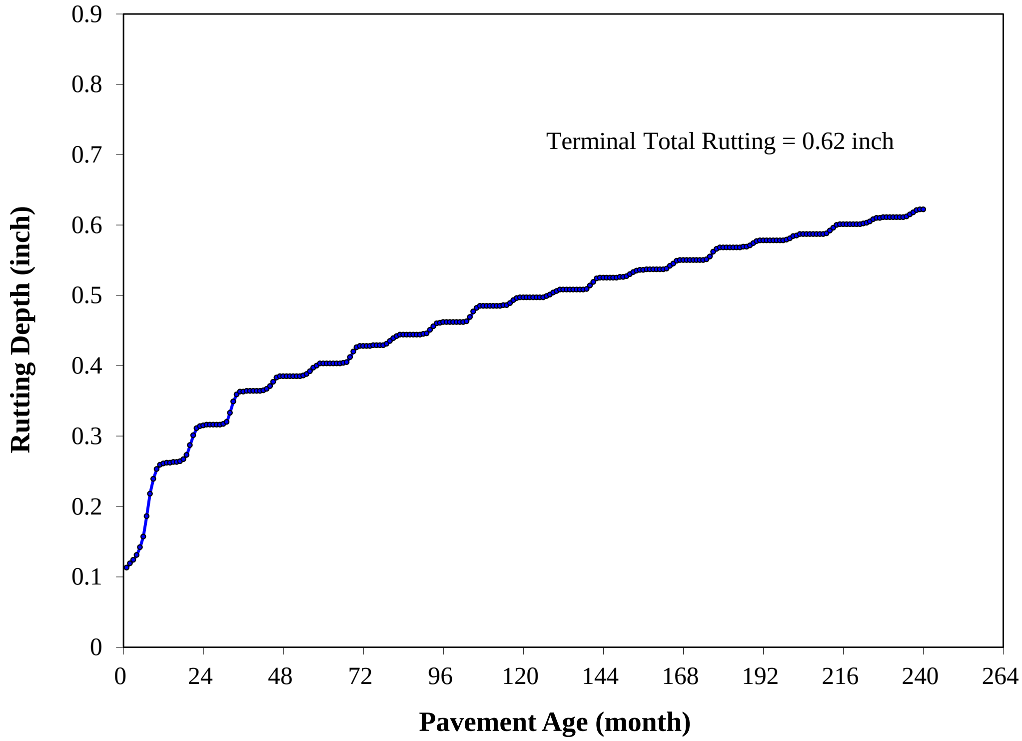


Figure 116: Predicted Mean Total Rutting versus Flexible Pavement Age

9.2.1.2 Sensitivity Analysis Results for New Flexible Pavement

Table 51 shows the performance results obtained for the various AADTT levels. As can be noticed from this table, the IRI ranged from 121.4 to 127.4 inch/mile with a prediction of 124.6 inch/mile for the baseline design. The longitudinal cracking was close to zero for all AADTT levels. The alligator cracking ranged from 3.3% to 6.1% with a prediction of 4.7% for the baseline design. It can also be observed that the transverse cracking was close to zero for all AADTT levels. Furthermore, the total rutting ranged from 0.56 to 0.67 inch with a total rutting of 0.62 inch for the baseline design. Based on these observations, the AADTT seems to have a negligible impact on longitudinal and transverse cracking, and a moderate impact on IRI, alligator cracking, and total rutting.

Table 51: Sensitivity of Baseline New Flexible Pavement to AADTT

AADTT	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
7000	121.4	0.0	3.3	0.1	0.56
8000	122.6	0.1	3.7	0.1	0.58
9000	123.6	0.1	4.2	0.1	0.60
10000	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
11000	125.6	0.1	5.1	0.1	0.64
12000	126.5	0.1	5.6	0.1	0.66
13000	127.4	0.1	6.1	0.1	0.67

Table 52 shows the performance results obtained for the various growth rates. As can be seen from this table, the IRI ranged from 123.2 to 126.0 inch/mile with a prediction of 124.6 inch/mile for the baseline design. The longitudinal cracking was close to zero for all growth rates. The alligator cracking ranged from 4.0% to 5.3% with a prediction of 4.7% for the baseline design. It can also be observed that the transverse cracking was close to zero for all growth rates. Furthermore, the total rutting ranged from 0.59 to 0.65 inch with a total rutting of 0.62 inch for the baseline design. Based on these observations, the growth rate seems to have a negligible impact on longitudinal and transverse cracking, and a moderate impact on IRI, alligator cracking, and total rutting.

Table 52: Sensitivity of Baseline New Flexible Pavement to Growth Rate

Growth Rate (%)	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
1.0	123.2	0.1	4.0	0.1	0.59
1.5	123.5	0.1	4.2	0.1	0.60
2.0	123.9	0.1	4.3	0.1	0.61
2.5	124.3	0.1	4.5	0.1	0.62
3.0	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
3.5	125.0	0.1	4.8	0.1	0.63
4.0	125.3	0.1	5.0	0.1	0.64
4.5	125.7	0.1	5.2	0.1	0.64
5.0	126.0	0.1	5.3	0.1	0.65

Table 53 shows the performance results obtained for Levels 1, 2 (based on functional classification), and 3 (MEPDG default) hourly distribution factors. As can be seen from this table, the MEPDG predictions were the same for all three levels. Therefore, it may be reasonable to use Level 2 or Level 3 for this traffic input.

Table 53: Sensitivity of Baseline New Flexible Pavement to Hourly Distribution Factors

HDF	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
Level 1	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
FC 1	124.6	0.1	4.7	0.1	0.62
FC 2	124.6	0.1	4.7	0.1	0.62
FC 6	124.6	0.1	4.7	0.1	0.62
FC 7	124.6	0.1	4.7	0.1	0.62
FC 8	124.6	0.1	4.7	0.1	0.62
FC 11	124.6	0.1	4.7	0.1	0.62
FC 12	124.6	0.1	4.7	0.1	0.62
FC 14	124.6	0.1	4.7	0.1	0.62
FC 16	124.6	0.1	4.7	0.1	0.62
MEPDG Default	124.6	0.1	4.7	0.1	0.62

Table 54 shows the performance results obtained for Levels 1, 2 (based on functional classification), and 3 (MEPDG default) monthly adjustment factors. As can be seen from this table, the MEPDG predictions were similar for all three levels. Therefore, it may be reasonable to use Level 2 or Level 3 for this traffic input.

Table 54: Sensitivity of Baseline New Flexible Pavement to Monthly Adjustment Factors

MAF	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
Level 1	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
FC 1	124.6	0.1	4.7	0.1	0.62
FC 2	124.8	0.1	4.8	0.1	0.62
FC 6	124.6	0.1	4.6	0.1	0.62

Table 54: Sensitivity of Baseline New Flexible Pavement to Monthly Adjustment Factors (Cont.)

FC 7	124.7	0.1	4.7	0.1	0.62
FC 8	125.3	0.1	5.0	0.1	0.63
FC 11	124.7	0.1	4.7	0.1	0.62
FC 12	124.7	0.1	4.7	0.1	0.62
FC 14	125.2	0.1	4.9	0.1	0.63
FC 16	125.1	0.1	4.8	0.1	0.63
MEPDG Default	124.5	0.1	4.6	0.1	0.62

Table 55 shows the performance results obtained for Levels 1, 2 (based on functional classification), and 3 (based on MEPDG default TTC groups) vehicle (truck) class distributions. As can be seen from this table, the IRI ranged from 118.3 to 124.9 inch/mile for Level 3 analysis based on truck traffic classification and from 119.0 to 125.0 inch/mile for Level 2 analysis based on functional classification, while the predicted IRI was 124.6 inch/mile for the baseline design. The longitudinal cracking was less than 0.4 ft/mile for all functional classifications and ranged from 0.0 to 1.2 ft/mile for the different truck traffic classifications, while the predicted longitudinal cracking was 0.1 ft/mile for the baseline design. The predicted alligator cracking ranged from 2.3 to 4.8% based on functional classification and from 2.1 to 4.6% based on truck traffic classification, while the predicted alligator cracking was 4.7% for the baseline design. The transverse cracking was close to zero for all vehicle (truck) class distributions. As for the total rutting, it ranged from 0.51 to 0.63 inch and 0.53 to 0.63 inch based on functional classification and truck traffic classification, respectively, with a total rutting of 0.62 inch for the baseline design. It can also be noticed that the predicted longitudinal cracking was higher for the TTC groups that contain high percentages of Class 13. As for IRI, alligator cracking, and total rutting, lower terminal performance values were obtained for non-interstate highways (FCs 2, 6, 7, 8, 12, 14, and 16) than interstate highways (FCs 1 and 11) and for TTC groups containing higher percentages of multi-trailer trucks (Class 8-13). From these observations, the vehicle (truck) class distribution seems to have a negligible impact on longitudinal and transverse cracking, and a moderate impact on IRI, alligator cracking, and total rutting. Given its impact on pavement design, it is recommended to estimate the vehicle (truck) class distribution from site-specific short-term counts as discussed in Chapter 8. It is noted that Site 715 is located along interstate 71 at a location where the interstate is classified as a rural interstate (FC 1) with a TTC 1 vehicle (truck) class distribution, resulting in similar distress levels for Level 1, Level 2 (FC 1), and Level 3 (TTC 1).

Table 55: Sensitivity of Baseline New Flexible Pavement to Vehicle (Truck) Class Distribution

VCD	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
Level 1	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
FC 1	125.0	0.1	4.8	0.1	0.63
FC 2	124.2	0.1	4.3	0.1	0.62
FC 6	122.6	0.4	3.5	0.1	0.58
FC 7	123.0	0.3	3.7	0.1	0.59
FC 8	122.6	0.1	3.6	0.1	0.58
FC 11	124.2	0.0	4.4	0.1	0.61
FC 12	122.8	0.2	3.7	0.1	0.59
FC 14	121.6	0.2	3.2	0.1	0.56
FC 16	119.0	0.1	2.3	0.1	0.51
TTC 1	124.5	0.0	4.6	0.1	0.62
TTC 2	123.8	0.0	4.2	0.1	0.61
TTC 3	124.8	0.3	4.5	0.1	0.63
TTC 4	122.9	0.1	3.8	0.1	0.59
TTC 5	124.9	0.7	4.5	0.1	0.63
TTC 6	121.7	0.0	3.3	0.1	0.56
TTC 7	123.6	0.5	3.9	0.1	0.60
TTC 8	124.3	0.8	4.2	0.1	0.62
TTC 9	120.9	0.1	3.1	0.1	0.55
TTC 10	122.5	0.3	3.5	0.1	0.58
TTC 11	123.9	1.2	3.9	0.1	0.61
TTC 12	120.0	0.1	2.7	0.1	0.53
TTC 13	122.7	0.7	3.5	0.1	0.59
TTC 14	118.3	0.2	2.1	0.1	0.49
TTC 15	119.5	0.4	2.3	0.1	0.52
TTC 16	120.8	1.0	2.6	0.1	0.55
TTC 17	120.3	0.0	3.1	0.1	0.53

Table 56 shows the performance results obtained for Levels 1, 2 (based on Clusters 1 through 4 and statewide average), and 3 (MEPDG default) axle load spectra. As can be noticed from this table, the predicted IRI was 124.6 inch/mile for the baseline design, 126.2 inch/mile for the statewide average, 130.3 inch/mile for the MEPDG default, and ranged from 125.4 to 128.5 inch/mile for Clusters 1 through 4. The predicted longitudinal cracking was less than 0.3 ft/mile for all combinations. The alligator cracking was 4.7% for the baseline design, 5.2% for the statewide average, 7.5% for the MEPDG default, and 4.8% to 6.4% for Clusters 1 through 4. The transverse cracking was close to zero for all axle load spectra. As for the total rutting, 0.62 inch was obtained for the baseline design, 0.65 inch was obtained for the statewide average, 0.73 inch was obtained for the MEPDG default, and 0.64 to 0.70 inch was obtained for Clusters 1 through 4. In addition, it can be noticed that the MEPDG default axle load spectra resulted in the highest terminal IRI values and distress predictions. Therefore, using the MEPDG default axle load spectra will result in a more conservative pavement design. It can also be noticed that the statewide average axle load spectra resulted in predictions between Clusters 1 through 3 and Cluster 4. Based on these observations, the axle load spectra seem to have a negligible impact on longitudinal and transverse cracking, and a moderate impact on IRI, alligator cracking, and total rutting. The results also suggest that it may be reasonable to use the statewide average axle load spectra instead of the four weight clusters for locations where site-specific WIM data is not available.

Table 56: Sensitivity of Baseline New Flexible Pavement to Axle Load Spectra

ALS	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
Level 1	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
Cluster 1	125.6	0.1	4.9	0.1	0.64
Cluster 2	125.6	0.2	5.0	0.1	0.64
Cluster 3	125.4	0.2	4.8	0.1	0.64
Cluster 4	128.5	0.3	6.4	0.1	0.70
Statewide Average	126.2	0.2	5.2	0.1	0.65
MEPDG Default	130.3	0.2	7.5	0.1	0.73

Table 57 shows the performance results obtained for Levels 1 (site-specific), 2 (statewide average), and 3 (MEPDG default) number of axles per truck. As can be seen from this table, the MEPDG predictions were similar for all three levels. Therefore, it may be reasonable to use Level 2 or Level 3 for this traffic input.

Table 57: Sensitivity of Baseline New Flexible Pavement to Number of Axles per Truck

Axles Per Truck	IRI (inch/mile)	Longitudinal Cracking (ft/mile)	Alligator Cracking (%)	Transverse Cracking (ft/mile)	Total Rutting (inch)
Level 1	*124.6*	*0.1*	*4.7*	*0.1*	*0.62*
Statewide Average	124.5	0.0	4.7	0.1	0.62
MEPDG Default	124.3	0.0	4.5	0.1	0.62

9.2.2 Baseline New Rigid Pavement

The baseline new rigid pavement section was designed as a jointed plain concrete pavement (JPCP). The pavement section was assumed to be located in the City of Newark in central Ohio. A design life of 20 years was used in the analysis with an initial international roughness index (IRI) of 63 inch/mile. Default roughness and distress limits were used for the performance criteria and the reliability was set to 90% for all performance parameters. Key performance parameters included transverse cracking (% slabs cracked), joint faulting, and smoothness expressed using IRI.

The baseline new rigid pavement structure is presented in Figure 117. As can be noticed from this figure, the pavement structure consisted of a 10-inch (254-mm) Portland cement concrete (PCC) layer placed over a 6-inch (152.4-mm) aggregate base course (AASHTO A-1-a) constructed on top of 12 inches (304.8 mm) of compacted AASHTO A-6 (clayey soil) subgrade. Figure 118 and 119 show a screen shot of the baseline new rigid pavement structure as defined in the MEPDG, and Figures 20 through 22 show screen shots of the material properties used for the various layers of the pavement structure. Additional information about this baseline design and material properties is available in Mallela et al. (*12*).

The baseline new rigid pavement structure was used to conduct a sensitivity analysis to determine the impact of the various traffic inputs on pavement performance. The traffic inputs and climatic data used for the sensitivity analysis were the same as those used for the new flexible pavement (Section 9.2.1).

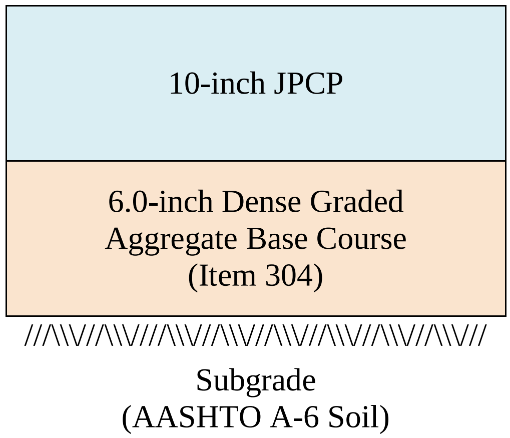


Figure 117: Baseline New Rigid Pavement Structure

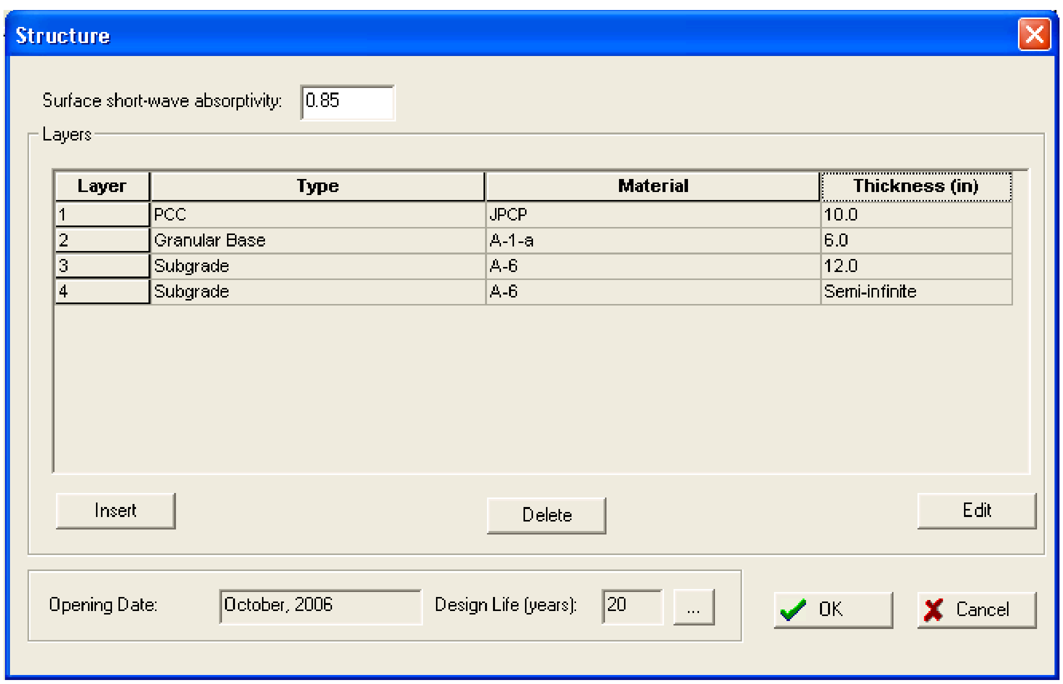


Figure 118: Baseline New Rigid Pavement Structure in the MEPDG

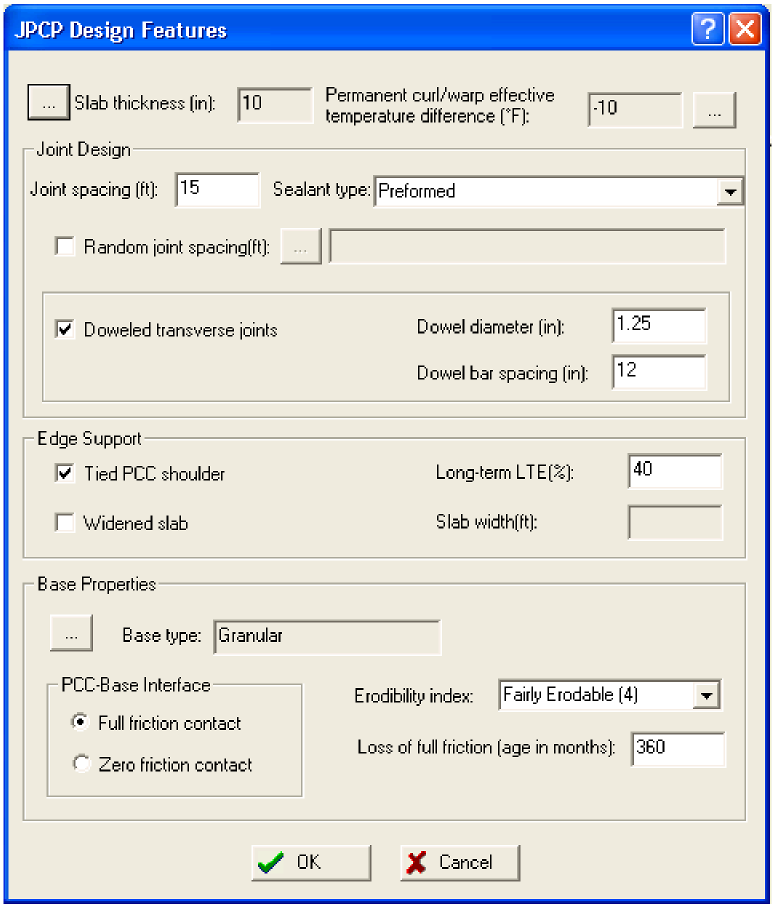


Figure 119: Design Features of the Baseline New Rigid Pavement

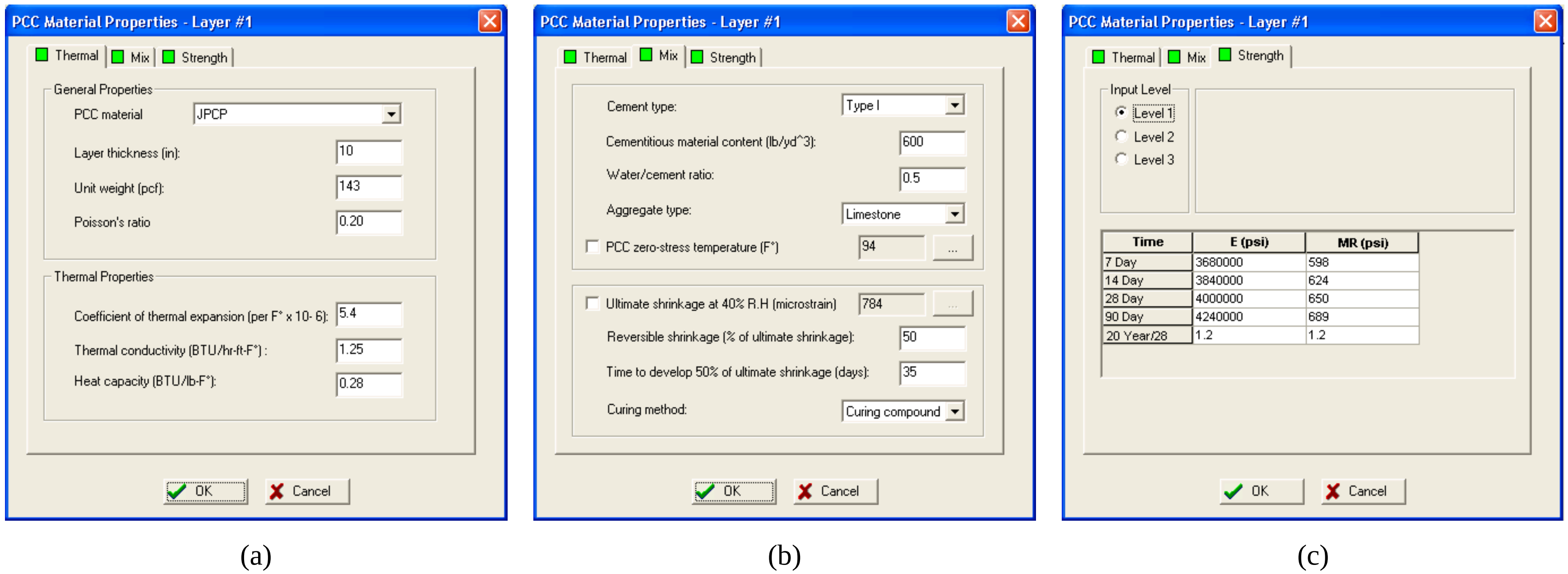
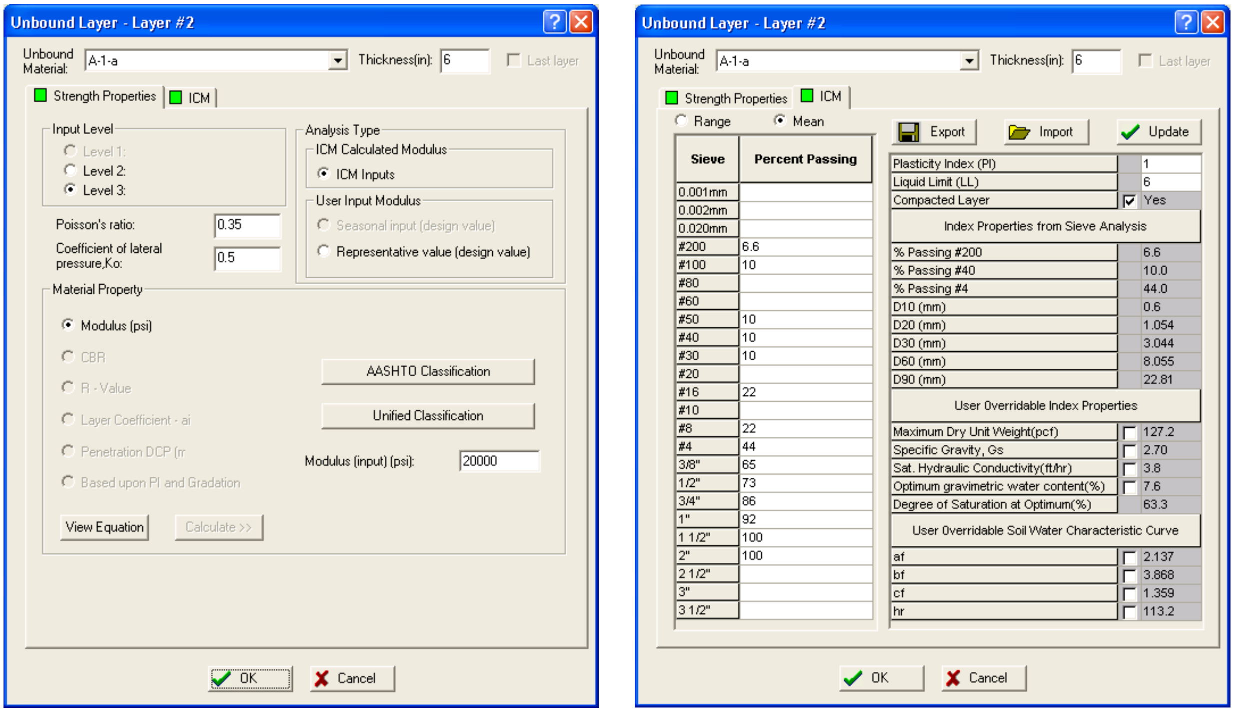
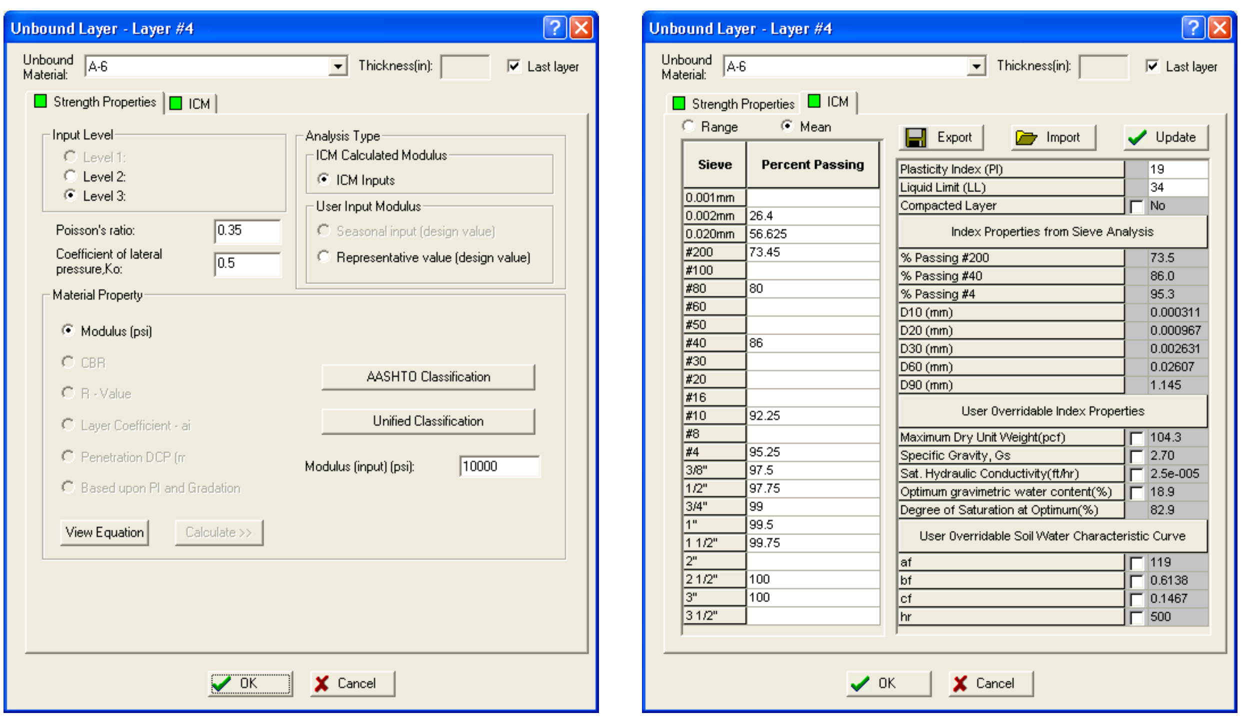


Figure 120: Material Properties (10-inch Portland Cement Concrete Layer)



(a) (b)

Figure 121: Material Properties (6-inch Dense Graded Aggregate Base Course)



(a) (b)

Figure 122: Material Properties (AASHTO A-6 Subgrade Soil)

9.2.2.1 MEPDG Results for Baseline New Rigid Pavement

Figures 123 to 125 present the MEPDG results for the baseline new rigid pavement structure. As can be seen from these figures, the MEPDG predicted reasonable pavement distresses and IRI values indicating that the baseline design is suitable for the sensitivity analysis. As previously discussed, the MEPDG has not been locally calibrated for the State of Ohio. Nonetheless, this is not expected to affect the results of the sensitivity analysis because the focus is on the change in performance due to the use of different traffic inputs and not on the predicted distresses.

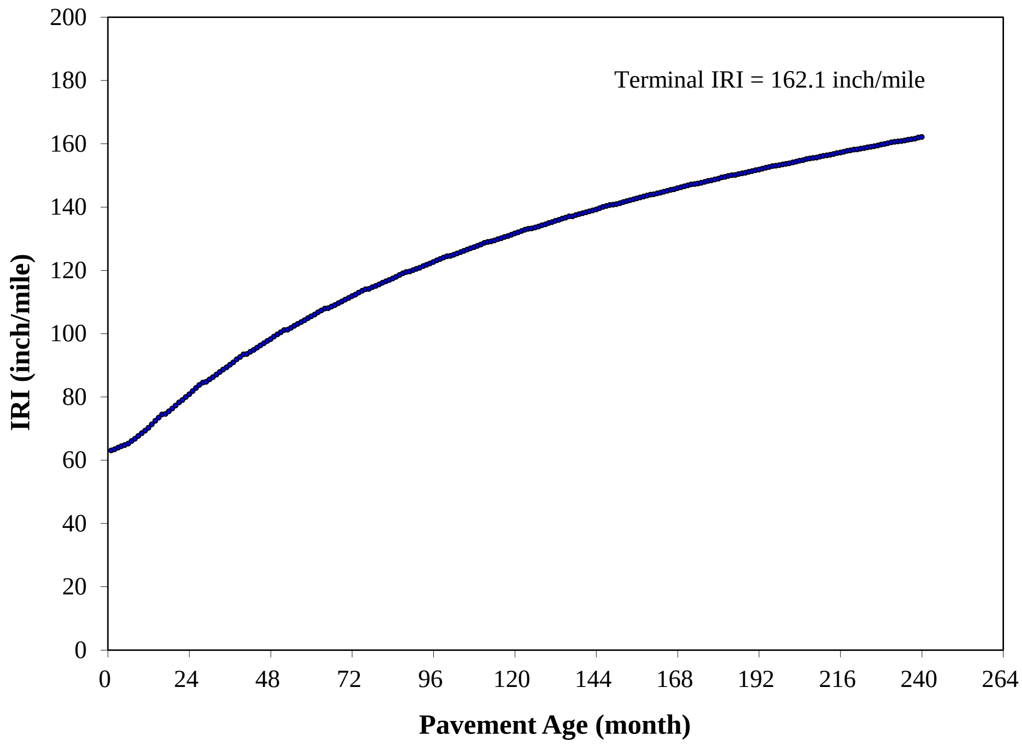


Figure 123: Predicted Mean IRI versus Rigid Pavement Age

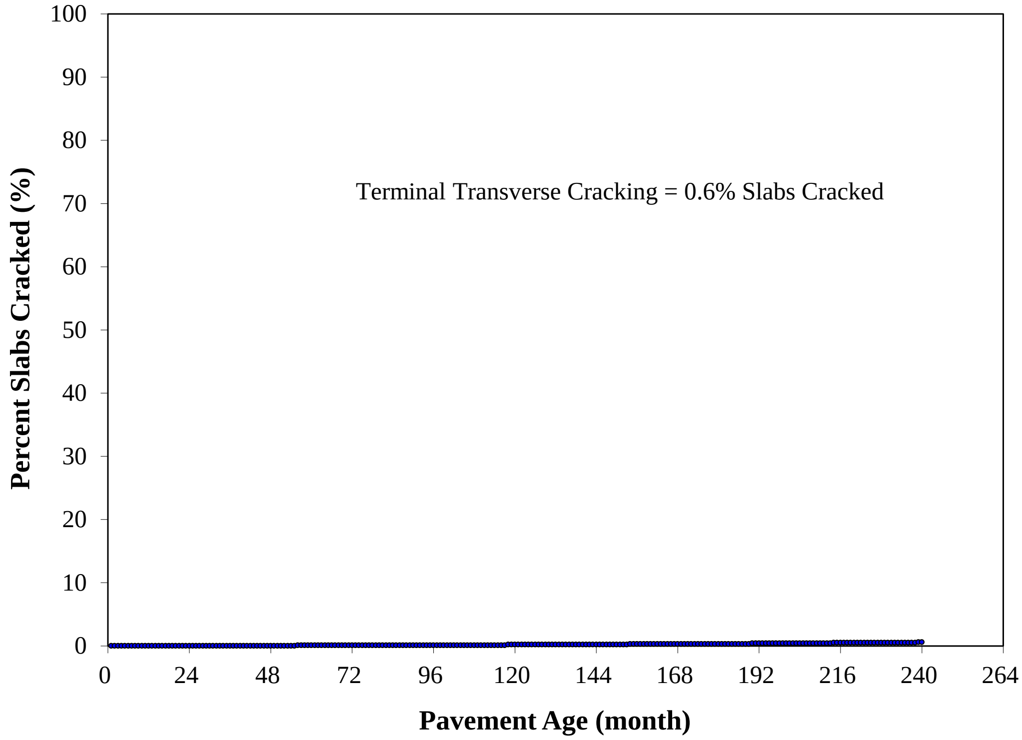


Figure 124: Predicted Mean Transverse Cracking versus Rigid Pavement Age

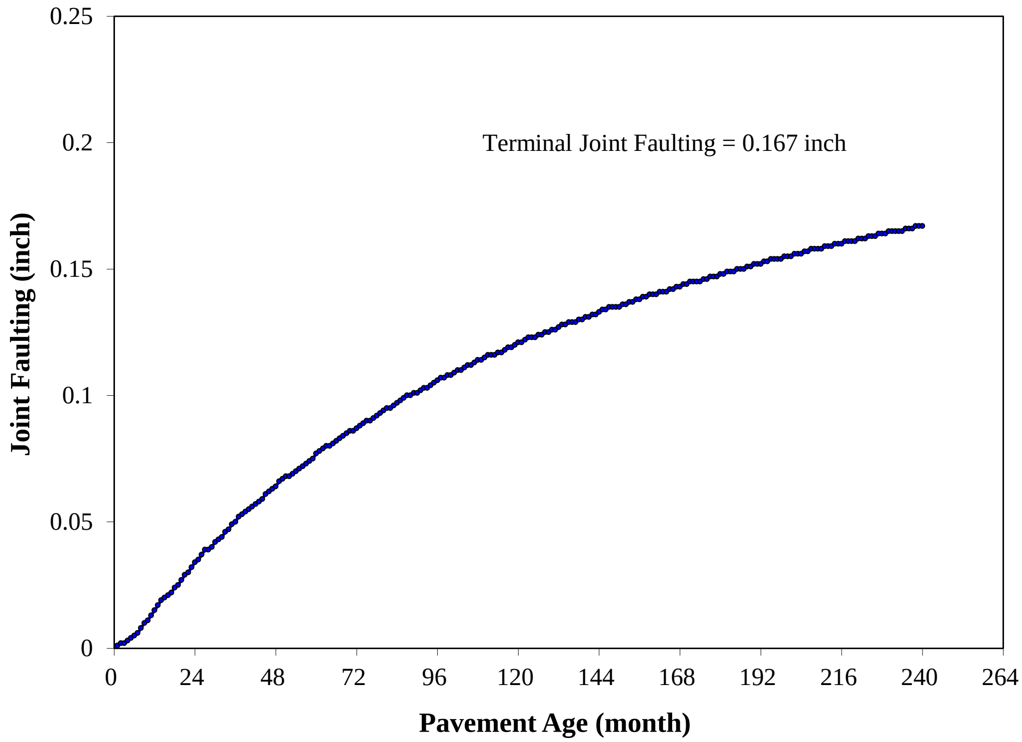


Figure 125: Predicted Mean Joint Faulting versus Rigid Pavement Age

9.2.2.2 Sensitivity of Baseline New Rigid Pavement to Traffic

Table 58 shows the performance results obtained for the various AADTT levels. As can be noticed from this table, the predicted IRI ranged from 151.4 to 169.7 inch/mile with a prediction of 162.1 inch/mile for the baseline design. The predicted transverse cracking ranged from 0.3 to 0.9% for the various AADTT levels. The joint faulting ranged from 0.147 to 0.181 inch with a prediction of 0.167 inch for the baseline design. Based on these observations, it seems that the AADTT has a moderate effect on IRI, transverse cracking, and joint faulting.

Table 58: Sensitivity of Baseline New Rigid Pavement to AADTT

AADTT	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
7000	151.4	0.3	0.147
8000	155.4	0.4	0.155
9000	158.9	0.5	0.162
10000	*162.1*	*0.6*	*0.167*
11000	164.8	0.7	0.172
12000	167.4	0.8	0.177
13000	169.7	0.9	0.181

Table 59 shows the performance results obtained for the various growth rates. As can be seen from this table, the IRI ranged from 157.4 to 166.1 inch/mile with a prediction of 162.1 inch/mile for the baseline design. The transverse cracking ranged from 0.4 to 0.7% with a prediction of 0.6% for the baseline design. The mean joint faulting ranged from 0.159 to 0.175 inch with a prediction of 0.167 inch for the baseline design. Based on these observations, the growth rate seems to have a moderate effect on IRI, transverse cracking, and joint faulting.

Table 59: Sensitivity of Baseline New Rigid Pavement to Growth Rate

GR (%)	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
1.0	157.4	0.4	0.159
1.5	158.6	0.5	0.161
2.0	159.8	0.5	0.163

Table 59: Sensitivity of Baseline New Rigid Pavement to Growth Rate (Cont.)

2.5	160.9	0.5	0.165
3.0	*162.1*	*0.6*	*0.167*
3.5	163.1	0.6	0.169
4.0	164.1	0.6	0.171
4.5	165.1	0.7	0.173
5.0	166.1	0.7	0.175

Table 60 shows the performance results obtained for Levels 1, 2 (based on functional classification), and 3 (MEPDG default) hourly distribution factors. As can be seen from this table, the IRI ranged from 162.0 to 161.9 inch/mile with a prediction of 162.1 inch/mile for the baseline design. The transverse cracking ranged from 0.1 to 0.6% with a prediction of 0.6% for the baseline design. The predicted joint faulting was 0.167 inch for all three levels. Based on these observations, the hourly distribution factors had a negligible effect on IRI and joint faulting and a moderate effect on transverse cracking.

Table 60: Sensitivity of Baseline New Rigid Pavement to Hourly Distribution Factors

HDF	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
Level 1	*162.1*	*0.6*	*0.167*
FC 1	162.0	0.5	0.167
FC 2	161.8	0.3	0.167
FC 6	161.7	0.1	0.167
FC 7	161.7	0.1	0.167
FC 8	161.7	0.1	0.167
FC 11	161.9	0.3	0.167
FC 12	161.7	0.1	0.167
FC 14	161.7	0.1	0.167
FC16	161.7	0.1	0.167
MEPDG Default	161.9	0.4	0.167

Table 61 shows the performance results obtained for Levels 1, 2 (based on functional classification), and 3 (MEPDG default) monthly adjustment factors. As can be seen from this table, the MEPDG predictions were similar for all three levels. Therefore, it may be reasonable to use Level 2 or Level 3 for this traffic input.

Table 61: Sensitivity of Baseline New Rigid Pavement to Monthly Adjustment Factors

MAF	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
Level 1	*162.1*	*0.6*	*0.167*
FC 1	162.1	0.6	0.167
FC 2	162.1	0.6	0.167
FC 6	162.2	0.6	0.167
FC 7	162.0	0.6	0.167
FC 8	162.4	0.6	0.168
FC 11	162.1	0.6	0.167
FC 12	162.1	0.6	0.167
FC 14	162.3	0.6	0.168
FC16	162.5	0.7	0.168
MEPDG Default	161.9	0.6	0.167

Table 62 shows the performance results obtained for Levels 1, 2 (based on functional classification), and 3 (MEPDG default TTC groups) vehicle (truck) class distributions. As can be seen from this table, the IRI ranged from 137.6 to 162.2 inch/mile for Level 3 analysis based on truck traffic classification and from 141.1 to 163.2 inch/mile for Level 2 analysis based on functional classification, while the predicted IRI was 162.1 inch/mile for the baseline design. The transverse cracking was less than 0.6 ft/mile for all functional classifications and truck traffic classifications, while the predicted transverse cracking was 0.6 ft/mile for the baseline design. The predicted joint faulting ranged from 0.128 to 0.169 inch based on functional classification and from 0.121 to 0.168 inch based on truck traffic classification, while the predicted joint faulting was 0.167 inch for the baseline design. From these observations, the vehicle (truck) class distribution seems to have a negligible impact on transverse cracking and joint faulting, and a moderate impact on the IRI. Similar to flexible pavements, it is recommended to estimate the vehicle (truck) class distribution from site-specific short-term counts as discussed in Chapter 8. It is noted that Site 715 is located along interstate 71 at a location where the interstate is classified as a rural interstate (FC 1) with a TTC 1 vehicle (truck) class distribution, resulting in similar distress levels for Level 1, Level 2 (FC 1), and Level 3 (TTC 1).

Table 62: Sensitivity of Baseline New Rigid Pavement to Vehicle (Truck) Class Distribution

VCD	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
Level 1	*162.1*	*0.6*	*0.167*
FC 1	163.2	0.6	0.169
FC 2	160.6	0.6	0.164
FC 6	153.5	0.3	0.151
FC 7	155.1	0.4	0.154
FC 8	155.1	0.4	0.154
FC 11	160.9	0.6	0.165
FC 12	155.5	0.4	0.155
FC 14	150.9	0.3	0.146
FC 16	141.1	0.2	0.128
TTC 1	162.2	0.6	0.168
TTC 2	159.8	0.5	0.163
TTC 3	161.1	0.6	0.165
TTC 4	156.6	0.4	0.157
TTC 5	160.1	0.5	0.164
TTC 6	152.7	0.3	0.150
TTC 7	156.3	0.4	0.157
TTC 8	158.1	0.4	0.160
TTC 9	149.7	0.3	0.144
TTC 10	153.7	0.3	0.152
TTC 11	155.6	0.3	0.155
TTC 12	145.5	0.2	0.136
TTC 13	152.5	0.3	0.149
TTC 14	137.6	0.1	0.121
TTC 15	140.1	0.1	0.126
TTC 16	143.4	0.1	0.133
TTC 17	148.3	0.4	0.141

Table 63 shows the performance results obtained for Levels 1, 2 (based on Clusters 1 through 4 and statewide average), and 3 (MEPDG default) axle load spectra. As can be noticed from this table, the predicted IRI was 162.1 inch/mile for the baseline design, 162.3 inch/mile for the statewide average, 167.5 inch/mile for the MEPDG default, and ranged from 160.5 to 163.3 inch/mile for Clusters 1 through 4. The transverse cracking was 0.6% for the baseline design, 0.7% for the statewide average, 2.6% for the MEPDG default, and 0.6% to 1.4% for Clusters 1 through 4. As for the joint faulting, 0.167 inch was obtained for the baseline design, 0.168 inch was obtained for the statewide average, 0.174 inch was obtained for the MEPDG default, and 0.164 to 0.169 inch was obtained for Clusters 1 through 4. In addition, it can be noticed that the MEPDG default axle load spectra resulted in the highest terminal IRI values and distress predictions. Therefore, using the MEPDG default axle load spectra will result in a more conservative pavement design. It can also be noticed that the statewide average axle load spectra resulted in predictions between Clusters 1 through 3 and Cluster 4. Based on these observations, the axle load spectra seem to have a negligible impact on transverse cracking and joint faulting, and a moderate impact on IRI. The results also suggest that it may be reasonable to use the statewide average axle load spectra instead of the four weight clusters for locations where site-specific WIM data is not available.

Table 63: Sensitivity of Baseline New Rigid Pavement to Axle Load Spectra

ALS	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
Level 1	*162.1*	*0.6*	*0.167*
Cluster 1	163.3	0.7	0.169
Cluster 2	161.8	0.6	0.167
Cluster 3	160.5	0.6	0.164
Cluster 4	163.1	1.4	0.168
Statewide Average	162.3	0.7	0.168
MEPDG Default	167.5	2.6	0.174

Table 64 shows the performance results obtained for Levels 1 (site-specific), 2 (statewide average), and 3 (MEPDG default) number of axles per truck. As can be seen from this table, the MEPDG predictions were similar for all three levels. Therefore, it may be reasonable to use Level 2 or Level 3 for this traffic input.

Table 64: Sensitivity of Baseline New Rigid Pavement to Number of Axles per Truck

Axles Per Truck	IRI (inch/mile)	Transverse Cracking (% Slabs Cracked)	Joint Faulting (inch)
Level 1	*162.1*	*0.6*	*0.167*
Statewide Average	162.1	0.6	0.167
MEPDG Default	161.5	0.6	0.166

9.3 Sensitivity Analysis Results

In summary, the MEPDG was found to be moderately sensitive to some of the traffic inputs and not sensitive to others. Table 65 summarizes the sensitivity analysis results for both baseline pavement designs and highlights the impact of the various traffic inputs on the pavement performance.

Table 65: Sensitivity of Baseline Pavement Designs to MEPDG Traffic Inputs

	Impact on Pavement Performance	
Traffic Input	Flexible	Rigid
AADTT	Moderate	Moderate
GR (%)	Moderate	Moderate
HDF	Negligible	Moderate
MAF	Negligible	Negligible
VCD	Moderate	Moderate
ALS	Moderate	Moderate
No. of Axles Per Truck	Negligible	Negligible

Chapter 10
Summary and Conclusions

10.1 Summary

This study included a thorough review of literature on topics related to the analysis of traffic data for use in the MEPDG. The hierarchical approach and the various traffic inputs used in the MEPDG were summarized to highlight their importance in pavement design. Additionally, the ESAL approach used by ODOT to characterize traffic for pavement design was summarized to provide a comparison between the MEPDG and the AASHTO design method. Furthermore, the traffic monitoring practices used in Ohio were evaluated to provide insight into the type and quality of data that is obtained by ODOT.

The data set used in this study was provided by ODOT Traffic Monitoring Section. The data was collected using permanent traffic monitoring sites distributed throughout the State of Ohio from 2006 to 2011. The total number of sites was 143 (93 AVC and 50 WIM systems) with the majority of these sites located along roadways classified as FC 1 (rural interstate), FC 2 (rural principal arterial), FC 11 (urban interstate), and FC 12 (urban freeway). Prior to analyzing the traffic data to obtain the required MEPDG traffic inputs, considerable efforts were made to identify and exclude erroneous data. This quality control process was used to detect invalid data entries, outliers, and trends that would otherwise be unrecognizable due to the large amount of data and the variations that occur over the collection period. This process was critical in ensuring that the generated traffic inputs accurately portrayed the traffic characteristics at each AVC and WIM location.

This study also included the development of a Visual Basic for Application (VBA) code to analyze the traffic monitoring data. VBA is an event-driven programming language that is available in several Microsoft Office applications including Microsoft Excel. The VBA code was used to generate statewide traffic inputs based on functional classification and truck traffic classification. Furthermore, cluster analysis was used to group sites based on the axle load spectra of Class 9 tandem axles in order to obtain the statewide axle load spectra. The analysis was performed based on Class 9 tandem axles because they are the most common types of axles, and their axle load spectra consistently fall within expected weight ranges. The cluster analysis results were incorporated into the VBA code, thus allowing the user to generate Level 1 (site-specific), 2 (statewide averages), and 3 (MEPDG default) traffic inputs. The generated traffic inputs are created in a standard text format that can be directly imported into the MEPDG.

Finally, the sensitivity of the MEPDG to the various traffic inputs was evaluated using two baseline pavement designs, one for a new flexible pavement and one for a new rigid pavement. The baseline pavement structures were developed using information obtained from ODOT pavement design manual, ODOT construction and material specifications, ODOT research reports, and the long-term pavement performance (LTPP) database. Site 715 was used to obtain site-specific traffic data (Level 1) for both baseline flexible and rigid pavements. This site is located along interstate 71 between Columbus and Cincinnati. The interstate at that location has two lanes per direction and is classified as a rural interstate (FC 1). The key performance parameters for the flexible pavement included longitudinal (top-down) fatigue cracking, alligator (bottom-up) fatigue cracking, transverse (low-temperature) cracking, rutting (HMA rutting and total rutting), and smoothness expressed using IRI, while the key performance parameters for the rigid pavement included transverse cracking (% slabs cracked), joint faulting, and smoothness expressed using IRI. Each individual traffic input was then varied to determine the impact of using Level 2 (statewide average) or Level 3 (MEPDG default – national average) analysis on pavement performance. This comprehensive sensitivity analysis was used to the influence of each traffic input on pavement design.

10.2 Conclusions

The following is a summary of the key findings and conclusions of this study:

- ODOT has an extensive traffic monitoring program that includes more than two hundred continuous (permanent) monitoring sites supplemented with a large number of short-term counts conducted by ODOT personnel on a periodic basis. The locations of these sites are dispersed across the State of Ohio to represent a large number of regions and roadways. ODOT’s traffic monitoring program is more comprehensive than other DOT’s and state highway agencies. Additionally, ODOT utilizes a quality control procedure to remove various data errors including entries that are duplicates or contain empty lines or spaces. The quality and accuracy of the traffic analysis and the resulting statewide averages developed in this study reflects the efforts taken by ODOT to ensure the data obtained from the traffic monitoring sites is accurate and representative of the actual traffic characteristics in Ohio.

Furthermore, ODOT provides a large amount of data including AADT and AADTT online at its (website) that is suitable for use in the MEPDG.

- To calculate the AADT from short-term counts, ODOT uses a series of seasonal adjustment factors to account for the variations in traffic during the year. All permanent sites within the same functional classification are combined to determine the seasonal adjustment factors for each day of the week and month of the year. Although ODOT did not apply any seasonal adjustment factors to truck data in the past, it has recently implemented truck factoring to estimate AADTT from short-term counts.
- Currently ODOT uses a directional distribution of 50% for all roadways. The directional distribution determined from the traffic data for truck Classes 4 through 13 was found to be between 50% and 55% for the majority of the sites. Therefore, the current ODOT procedure provides a slightly less conservative estimate of the actual directional distribution throughout Ohio.
- ODOT currently uses a lane distribution factor of 100% for two-lane roads, 90% for four-lane roads, and 80% for six or more lane roads. The average lane distribution factors determined from the traffic data set are 100% for two-lane roadways, 95% for four-lane roadways, 80% for six-lane roadways, and 70% for eight or more lane roadways. Therefore, the current ODOT values are less conservative for four-lane roadways and more conservative for eight or more lane roadways.
- The monthly adjustment factors for the majority of the functional classifications with sufficient data availability are close to 1.00 for all months and truck classes. This indicates that truck traffic is relatively constant throughout the year with little variation between months. Significantly higher variations in truck traffic were observed during the week. However, such variations are not accounted for in the MEPDG.
- The hourly distribution factors determined from the traffic data set showed that truck traffic is more uniformly distributed during the day on major highways (FCs 1, 2, 11, and 12) with a peak between 10:00 am and 2:00 pm, while other functional classifications show wide variations between daytime and nighttime truck traffic and have clear peaks during the morning and evening rush hours.
- By analyzing the historical traffic data at a large number of sites in Ohio, it was determined that the growth rate for AADT is not necessarily indicative of the growth rate for AADTT.

Additionally, the growth rate was found to be significantly influenced by the traffic monitoring period over which the growth rate is estimated. It was also found that a minimum traffic monitoring period of 20 years (with ideally 25 years) was sufficient in predicting the overall truck traffic growth.

- ODOT currently uses the B:C ratio to describe the vehicle (truck) class distribution for different functional classifications. Based on the findings in this study, it was determined that vehicle (truck) class distribution cannot be accurately estimated from the B:C ratio due to a lack of correlation between the B:C ratio and functional classification. Similar observations were made regarding the development of statewide vehicle (truck) class distributions based on functional classification. This study also investigated the use of the MEPDG TTC grouping system to represent the truck class distribution observed in the State of Ohio. The MEPDG TTC groups were found to be significantly biased towards Class 9 trucks with little consideration towards the other truck classes. A more accurate method of calculating the vehicle (truck) class distribution was the use of short-term counts and seasonal adjustment factors for each truck class. The application of these seasonal adjustment factors reduced the difference between the daily truck class distributions and the annual truck class distributions, especially for truck Classes 5, 6, and 11.
- The axle load distribution factors were calculated for each axle group (single, tandem, tridem and quad) and truck class (4 through 13). Cluster analysis was utilized to group sites based on the axle load spectra of Class 9 tandem axles because they are the most common types of axles, and their axle load spectra consistently fall within expected weight ranges. Four weight clusters were identified in the State of Ohio. The cluster analysis results revealed a larger number of full Class 9 trucks than empty Class 9 trucks along major interstates, with a noticeable presence of partially full Class 9 trucks. Other roadways primarily showed axle load spectra with either full or empty Class 9 trucks, and the number of empty Class 9 trucks was either approximately equal to or greater than the number of full trucks. By comparing the axle load spectra for the four weight clusters, it was observed that they were close to each other. Therefore, statewide average axle load spectra were developed based on information from all sites. Additionally, it was observed that most clusters were affected by the presence of inconsistent axle load spectra for certain truck classes, which can be partially explained by the presence of a small number of trucks from that truck class at that site. As a result, sites

that showed inconsistent gross vehicle weight distribution for a particular truck class were excluded from the calculation of the statewide average. The resulting statewide average axle load spectra were found to have similar overall trends that were more consistent than those defined for the four weight clusters.

- The number of axles per truck determined from the traffic data set was based on the axle configurations defined by ODOT. As a result, little variations were observed among traffic monitoring sites based on number of axles per truck supporting the development of a statewide average for this traffic input. Additionally, the number of axles per truck was found to be slightly different than the default values used in the MEPDG primarily for tridem and quad axles.
- Finally, this study evaluated the sensitivity of the MEPDG to the various traffic inputs. Two baseline pavement designs, one for a new flexible pavement and one for a new rigid pavement, were used for this purpose. In general, the MEPDG was found to be moderately sensitive to some of the traffic inputs and not sensitive to others. Table 65 summarizes the sensitivity analysis results for both baseline pavement designs and highlights the impact of the various traffic inputs on the pavement performance.

Chapter 11
Recommendations for Implementation

11.1 Summary of Recommendations

The MEPDG requires a multitude of project-specific input data need to be defined including the proposed pavement structure, material properties, traffic information, and environmental conditions. The traffic inputs required by the MEPDG include: (a) base-year traffic data such as the initial two-way annual average daily truck traffic (AADTT), (b) traffic volume adjustment factors (directional and lane distribution factors, vehicle class distribution, monthly adjustment factors, hourly truck distribution factors, and traffic growth factors), (c) axle load spectra by truck class (Class 4 to Class 13) and axle type (single, tandem, tridem, and quad), and (d) general traffic inputs (lateral truck traffic wander, number of axles per truck, axle and wheel base configurations, and tire characteristics and inflation pressure).

In order to ensure an accurate pavement design, it is recommended to use site-specific traffic data whenever possible. However, since it is not always practical to obtain site-specific data, the MEPDG assimilates a hierarchal level concept upon which data may be input. The hierarchical approach allows pavements to be designed using both statewide averages and MEPDG default values. To guarantee that pavement designs throughout the State of Ohio are consistent, a standard procedure must be followed in the selection MEPDG traffic inputs. This procedure must include recommendations in which MEPDG inputs yield reliable results when using Level 2 (statewide average) or Level 3 (MEPDG default) analyses. These values must accurately represent the traffic characteristics throughout Ohio.

The following table presents a summary of recommendations pertaining to the selection of the traffic inputs for mechanistic-empirical pavement design using the MEPDG in Ohio. While Level 1 is expected to provide the most accurate pavement design, these recommendations allow for the use Level 2 or Level 3 analyses for some inputs without compromising the quality or accuracy of the pavement design. These recommendations allow for a seamless transition from the current traffic analysis procedure used by ODOT for pavement design to the new MEPDG.

Table 66: MEPDG Traffic Inputs Recommendations

Traffic Input	Recommendation
AADTT	This traffic input shall be obtained from ODOT Traffic Monitoring Section.
D(%)	Use 50% (current ODOT value) for all roadways.
LF(%)	Level 2 (statewide average). Recommended values: 100% for 2-lane roadways, 95% for 4-lane roadways, 80% for 6-lane roadways, and 70% for 8 or more lane roadways.
Operational Speed	This traffic input shall be obtained from ODOT Traffic Monitoring Section.
MAF	Level 3 (MEPDG default).
VCD	This traffic input shall be estimated from a combination of site-specific short-term counts (Level 1) and seasonal adjustment factors for each truck class. The short-term counts shall be obtained from ODOT Traffic Monitoring Section. Level 2 (statewide average based on functional classification) analysis can be used for locations where site-specific data is not available.
HDF	Level 3 (MEPDG default) for flexible pavements and Level 2 (statewide average based on functional classification) for rigid pavements.
Growth Rate	This traffic input shall be obtained from ODOT Modeling and Forecasting Section (Certified Traffic).
ALS (Single, Tandem, Tridem, and Quad)	Level 2 (statewide average based on information from all sites)
No. of Axles per Truck	Level 2 (statewide average based on information from all sites)
Lateral Wander	Level 3 (MEPDG default)
Axle Configuration	Level 3 (MEPDG default)
Wheelbase Distribution	Level 3 (MEPDG default)

11.2 Recommendations for Further Study

The sensitivity analysis results presented in this study are based on Version 1.100 of the MEPDG. This program is the predecessor to a new pavement design program called DarWIN-ME. ODOT is currently in the process of acquiring this new program. However, it was not available at the disposal of the research team at the time of the study. Therefore, the results of the Visual Basic for Application (VBA) code may need to be modified in order to be directly imported into DarWIN-ME. Furthermore, DarWIN-ME would need to be locally calibrated before being used for pavement design in Ohio. Once calibrated, it is recommended to repeat the sensitivity analysis to confirm the results obtained in this study. Finally, even though ODOT is in the early phases of transitioning to DarWIN-ME, the axle load spectra developed in this study can be used to better estimate the ESAL conversion factors that are currently being used by ODOT for pavement design.

References

1. American Association of State Highway and Transportation Officials (AASHTO), *Guide for Design of Pavement Structures*, 1993 Edition.
2. National Cooperative Highway Research Program (NCHRP), *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, NCHRP 1-37A Final Report, Transportation Research Board, National Research Council, Washington, D.C., 2004.
3. Federal Highway Administration (FHWA), *Traffic Monitoring Guide*, 2001 Edition.
4. National Report 538, *Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design*, NCHRP Study 1-39, Transportation Research Board, National Research Council, Washington, D.C., 2005.
5. Lu, Q., Zhang, Y., and J. T. Harvey (2007). "Analysis of Truck Traffic Growth for the Mechanistic Empirical Pavement Design Guide," *Proceedings of the 86th Annual Transportation Research Board Meeting*, Washington, D.C., January 21-25.
6. Federal Highway Administration (FHWA), *Vehicle Travel Information System (VTRIS) Users' Guide*, 2008. http://www.fhwa.dot.gov/ohim/ohimvtis.cfm.
7. Ohio Department of Transportation (ODOT) *Pavement Design Manual*, 2008 Edition.
8. Roth, J. (2010). *A Time Series Approach to Removing Outlying Data Points from Bluetooth Vehicle Speed Data*, Master's Thesis, University of Akron.
9. Basu, S. and M. Meckesheimer (2007). "Automatic Outlier Detection for Time Series: An Application to Sensor Data," *Knowledge and Information Systems*, Vol. 11(2), pp. 137-154.
10. Stone, J. R., Kim, Y. R., List, G. F., Rasdorf, W., Sayyady, F., Jadoun, F., and A. N. Ramachandran (2011). *Development of Traffic Data Input Resources for the Mechanistic Empirical Pavement Design Process*, North Carolina Department of Transportation (NCDOT), Report No. FHWA/NC/2008-11.
11. Ohio Department of Transportation (ODOT) *Certified Traffic Manual*, 2007 Edition.
12. Mallela, J., Glover, L. T., Darter, M. I., Von Quintus, H., Gotlif, A., and M. Stanley (2009). *Guidelines for Implementing NCHRP 1-37A M-E Design Procedures in Ohio: Volume 3 – Sensitivity Analysis*, Ohio Department of Transportation (ODOT), Report No. FHWA/OH-2009/9C.

Appendix A

Manual for the MEPDG Traffic Inputs VBA Code (Version 0.9)

Manual for the MEPDG Traffic Inputs VBA Code (Version 0.9)

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Table of Contents

A.1 Introduction

This manual is intended for instructional purposes and to serve as a guide for using the VBA Code to generate the required MEPDG traffic inputs. This manual highlights the various components of the VBA Code and describes the information required to operate this program. In addition, it provides a description of the database and files created by the program.

A.1.1 Conventions

The following conventions are used in the manual:

- *Italics* are used to refer to menus and sub-menus as well as sections in the program windows
- “Quotes” are used to refer to buttons

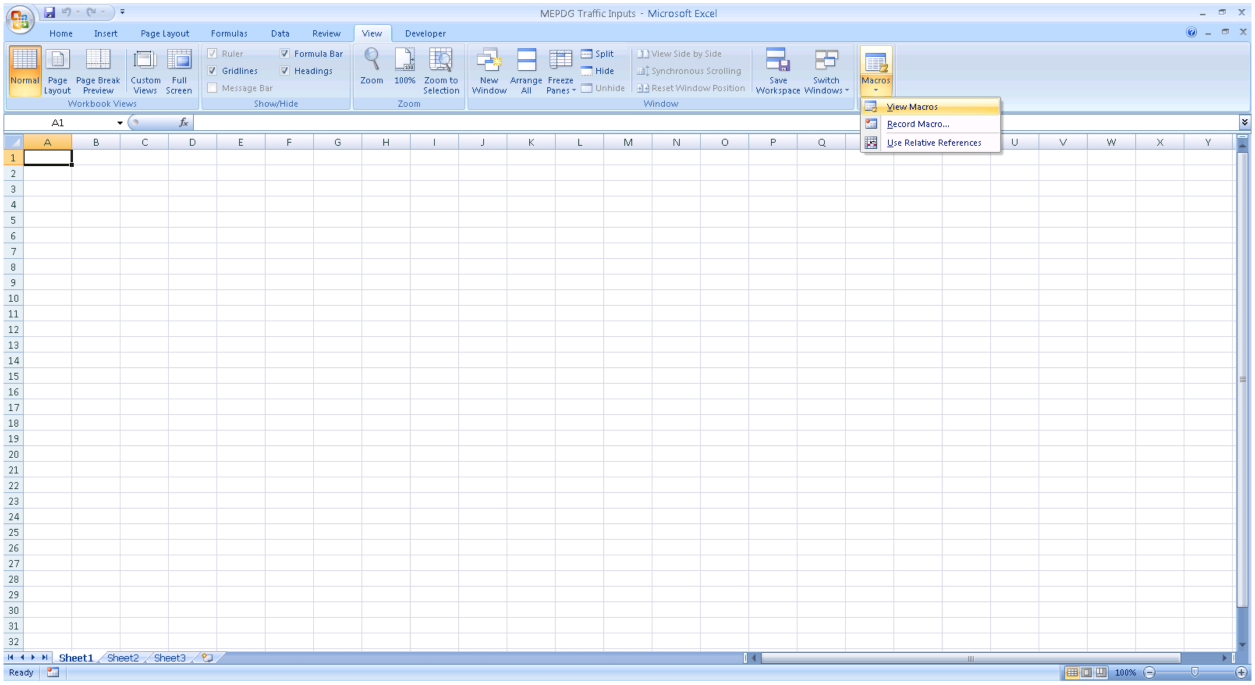
A.1.2 Installation

This program is operated from within Microsoft Excel. No installation is required to use this program.

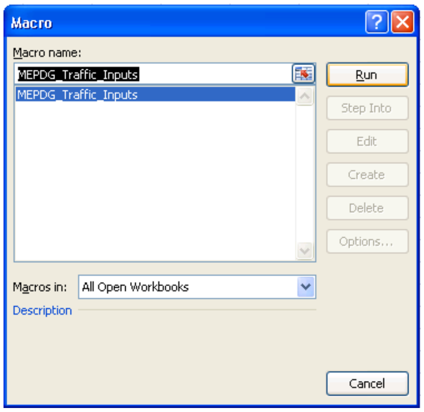
A.1.3 Opening the Program

This program operates as a Macro in Microsoft Excel. To open the program:

- Open the Excel file containing the code
    - Navigate to the *View* tab
    - Click “Macro”

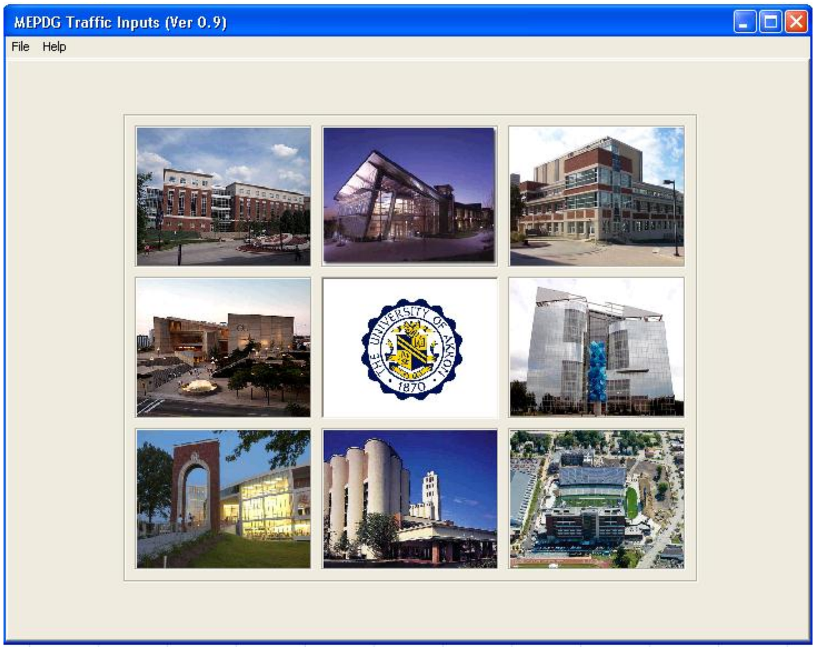


- The Macro window will open and the VBA Code should be shown in the table
    - Select the VBA Code
    - Click “Run”



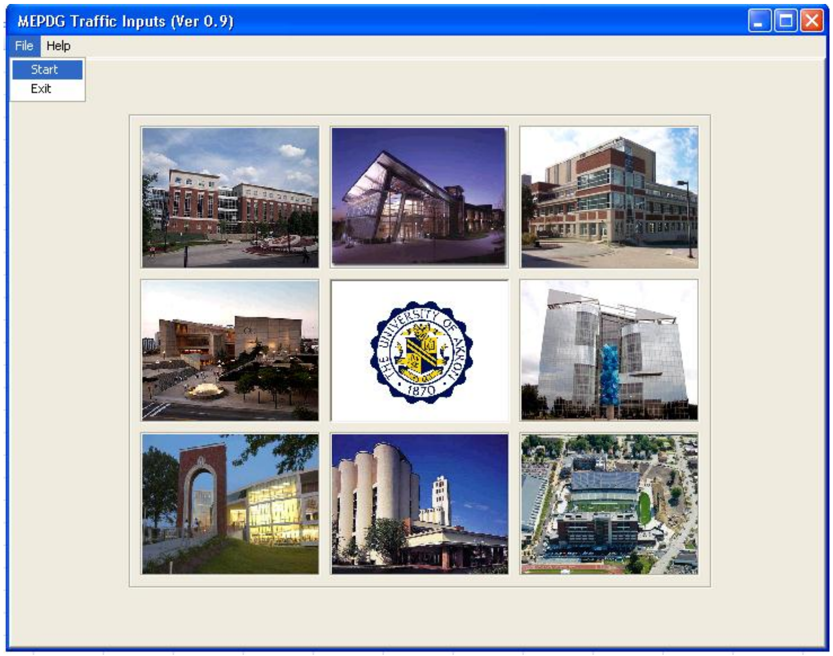
A.1.3.1 Welcome Screen

The Welcome Screen of the program depicts images of The University of Akron surrounding the official university seal.



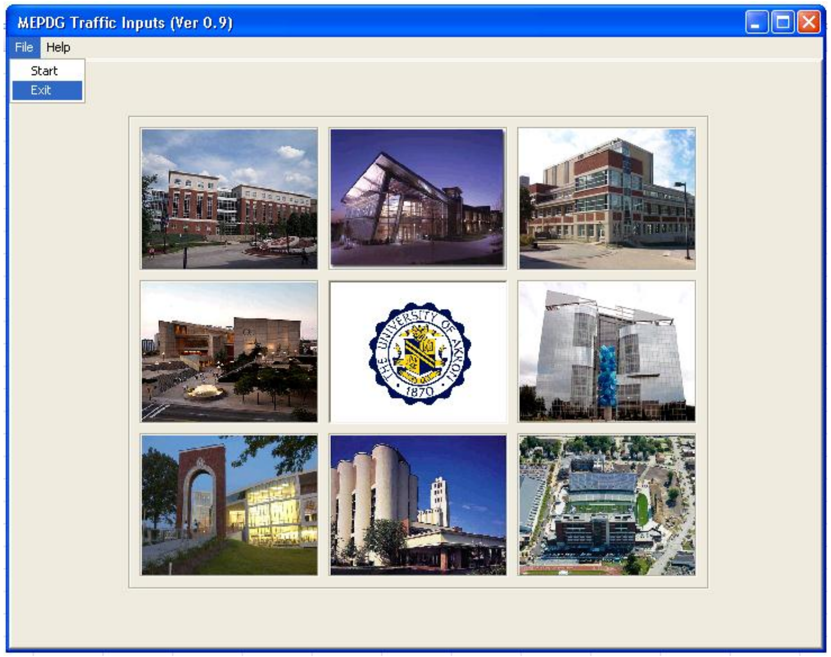
A.1.3.2 Starting a New Project

- To start a new project:
    - Navigate to the *File* menu
    - Click “Start”



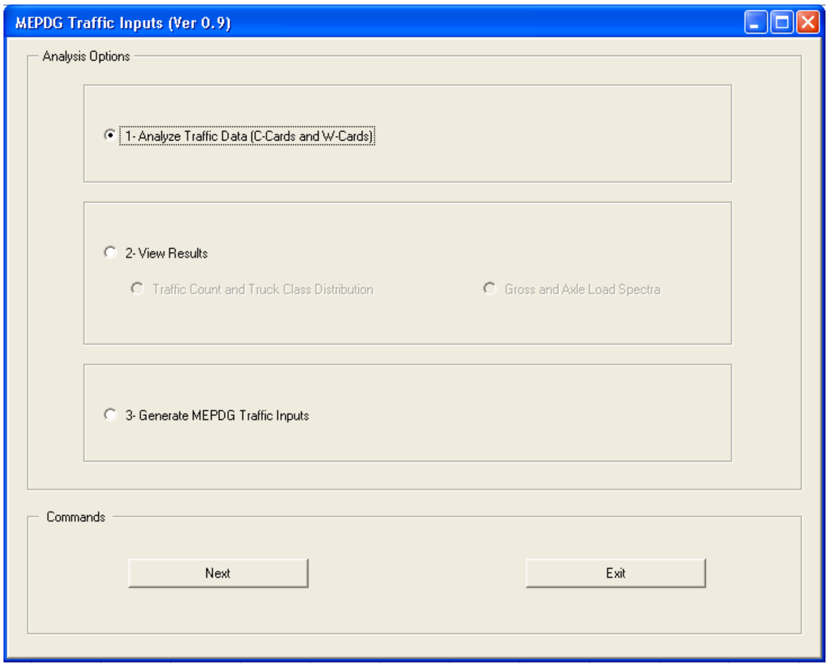
A.1.3.3 Exiting the Program

- To exit the Program:
    - Navigate to the *File* menu
    - Click "Exit"



A.2 Analysis Options

- When a new project is started, the main window of the VBA Code opens depicting three analysis options:
    1. Analyze Traffic Data (C-Cards and W-Cards)
    2. View Results
        a. Traffic Count and Truck Class Distribution
        b. Gross and Axle Load Spectra
    3. Generate MEPDG Traffic Inputs



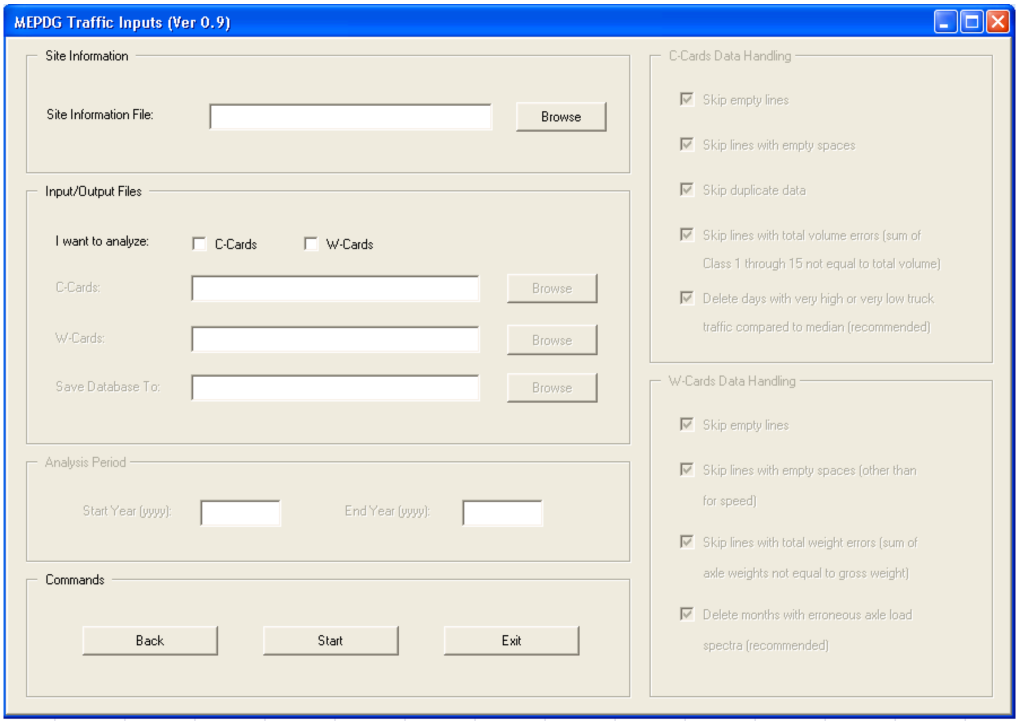
A.2.1 Analyze Traffic Data

This option can be used to analyze C-Cards only, W-Cards only, or both C-Cards and W-Cards.

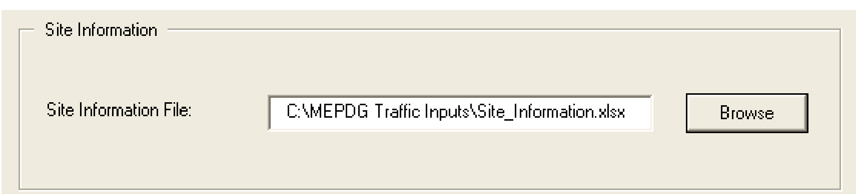
A.2.1.1 Analyze C-Cards

- To analyze C-Cards:
  - Select the option button next to *1- Analyze Traffic Data (C-Cards and W-Cards)* of the *Analysis Options* window
  - Click "Next" under the *Commands* section of the *Analysis Options* window

- A new window opens displaying a number of sections



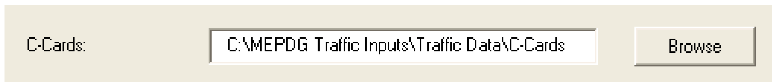
- To begin the analysis:
  - Click "Browse" under the *Site Information* section
    - Navigate and select the site information file (an .xlsx file)



Note: The site information file contains basic information about the traffic monitoring sites including: site ID, route, functional classification, district, county, direction, number of lanes, and type of program. This file must be updated annually to include information for new sites. This information can be obtained from ODOT Traffic Monitoring Section.

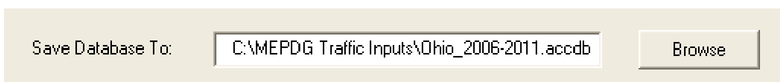
- Select the *C-Cards* check box next to *I want to analyze:* under the *Input/Output Files* section

- Click “Browse” next to *C-Cards:*
  - Navigate and select the folder containing the C-Cards

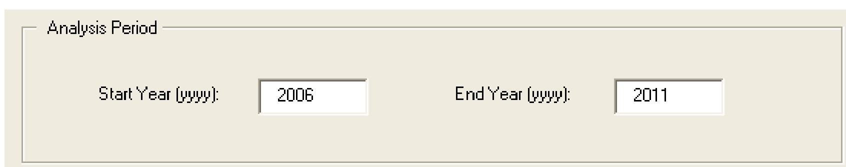


Note: The VBA Code will search the selected folder and all subfolders for C-Cards.

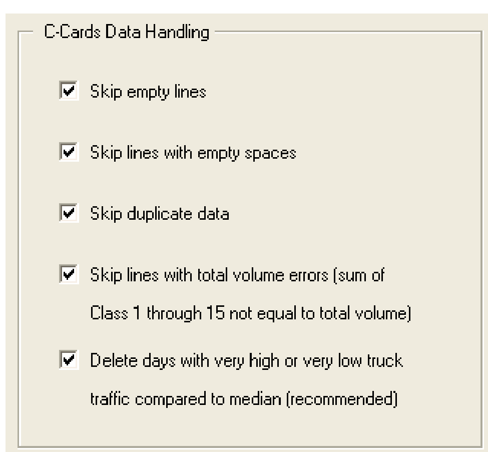
- Click “Browse” next to *Save Database To:*
  - Select the appropriate location to save the results database in Microsoft Access .accdb format



- Specify the *Start Year* and *End Year* of the analysis under the *Analysis Period* section

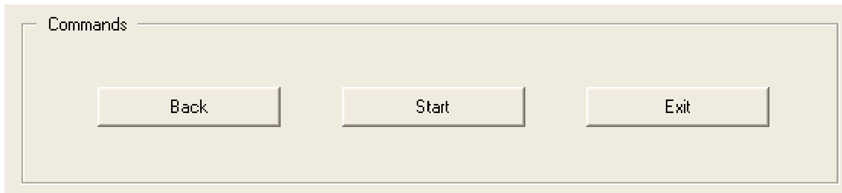


- The VBA Code allows the user to specify the quality control measures applied to the analysis
  - Select the desired quality control measures under the *Data Handling* section



Note: By selecting *Delete days with very high or very low truck traffic compared to median (recommended)*, the VBA Code will remove any outliers from the analysis (refer to Chapter 6 in the report).

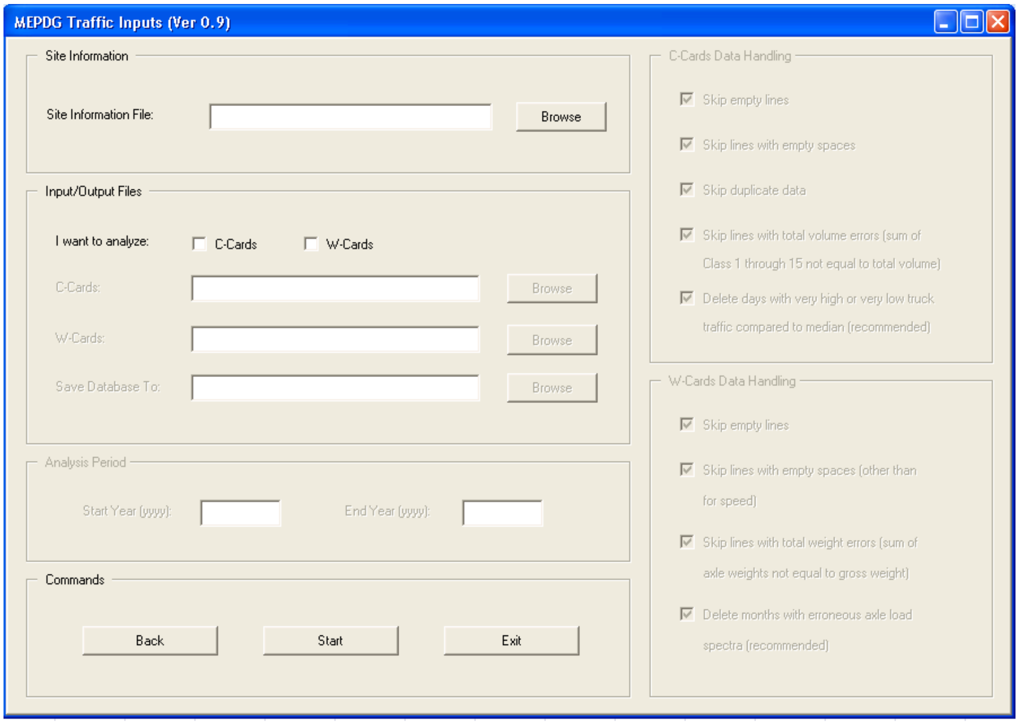
- To start the analysis:
  - Click "Start" under the *Commands* section
  - Upon the completion of the analysis, a results database is created (for more information about the results database, refer to Section 3 in this manual)



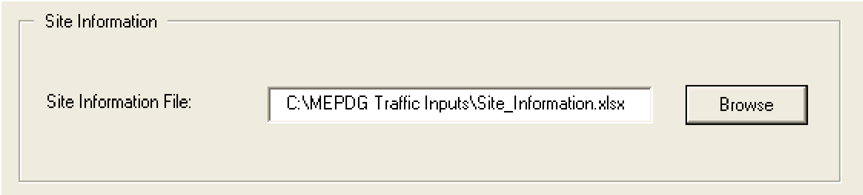
A.2.1.2 Analyze W-Cards

- To analyze W-Cards:
  - Select the option button next to *1- Analyze Traffic Data (C-Cards and W-Cards)* of the *Analysis Options* window
  - Click "Next" under the *Commands* section of the *Analysis Options* window

- A new window opens displaying a number of sections



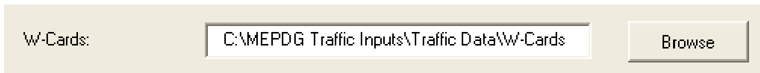
- To begin the analysis:
  - Click "Browse" under the *Site Information* section
    - Navigate and select the site information file (an .xlsx file)



Note: The site information file contains basic information about the traffic monitoring sites including: site ID, route, functional classification, district, county, direction, number of lanes, and type of program. This file must be updated annually to include information for new sites. This information can be obtained from ODOT Traffic Monitoring Section.

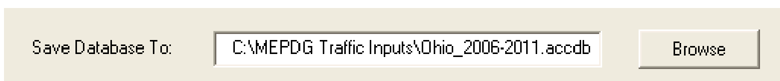
- Select the *W-Cards* check box next to *I want to analyze:* under the *Input/Output Files* section

- Click "Browse" next to *W-Cards:*
  - Navigate and select the folder containing the W-Cards

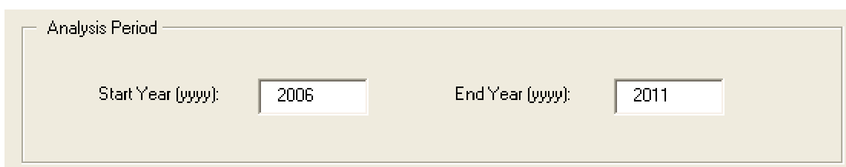


Note: The VBA Code will search the selected folder and all subfolders for W-Cards.

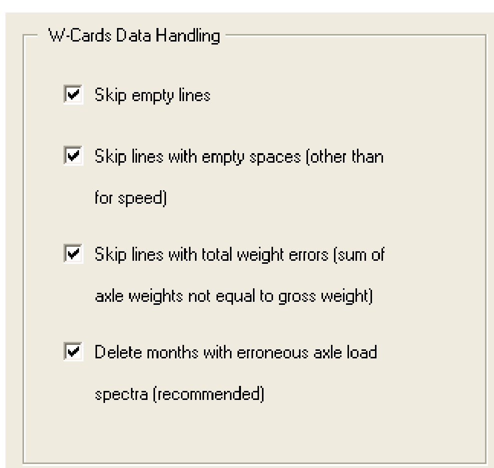
- Click "Browse" next to *Save Database To:*
  - Select the appropriate location to save the results database in Microsoft Access .accdb format



- Specify the *Start Year* and *End Year* of the analysis under the *Analysis Period* section

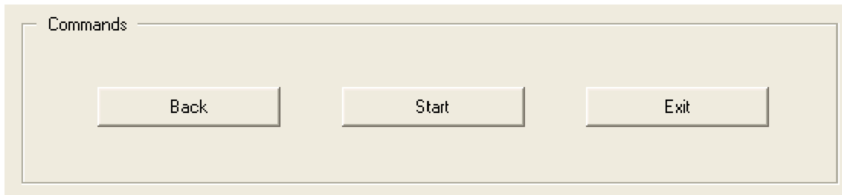


- The VBA Code allows the user to specify the quality control measures applied to the analysis
  - Select the desired quality control measures under the *Data Handling* section



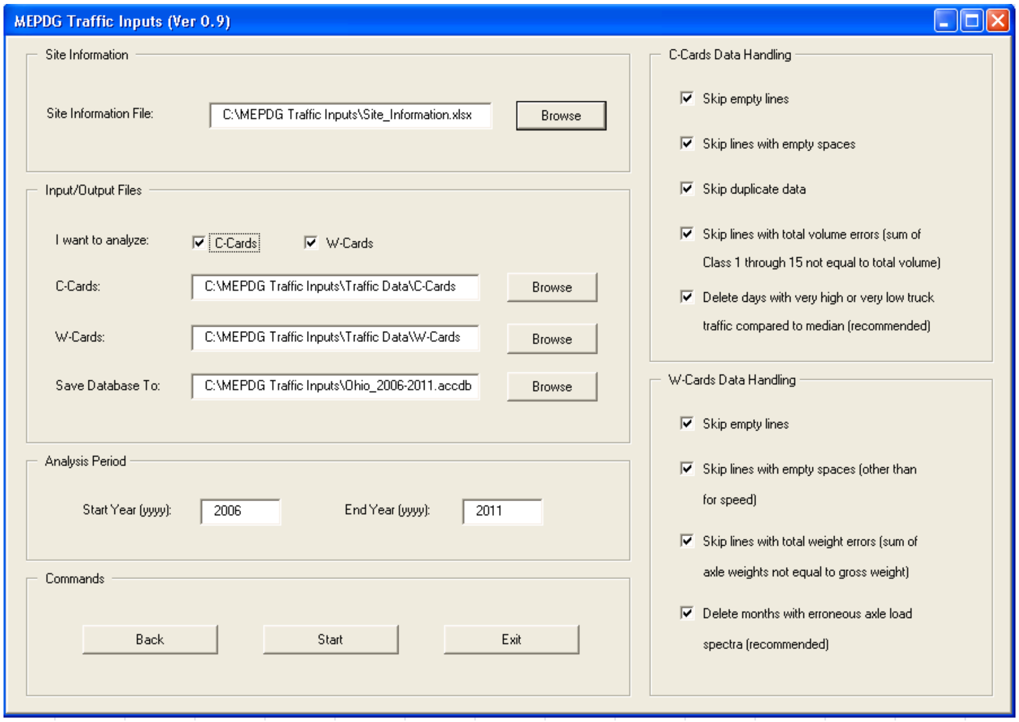
Note: By selecting *Delete months with erroneous axle load spectra (recommended)*, the VBA Code will remove any outliers from the analysis (refer to Chapter 6 in the report).

- To start the analysis:
    - Click “Start” under the *Commands* section
    - Upon the completion of the analysis, a results database is created (for more information about the results database, refer to Section 3 in this manual)



A.2.1.3 Analyze C-Cards and W-Cards

- To analyze C-Cards and W-Cards:
  - Follow the procedure outlined in Sections 2.1.1 and 2.1.2 and select both *C-Cards* and *W-Cards* check boxes next to *I want to analyze:* under the *Input/Output Files* section



Note: If the C-Cards and W-Cards are analyzed separately, the user cannot save the results to the same database. The analysis must be repeated using both C-Cards and W-Cards selected in order to save the results to the same database.

- Upon the completion of the analysis, a results database is created and saved at the selected location. The database consists of 53 tables organized into five main categories:

  1- Site General:
  - Site_General_Information
  - Site_General_FC_TTC

  2- Site Traffic:
  - Site_Traffic_Data_Availability
  - Site_Traffic_Annual_ADT_ADTT_Percent_Truck
  - Site_Traffic_Annual_DOW_Truck_Class_Count
  - Site_Traffic_Annual_Hourly_Distribution
  - Site_Traffic_Annual_Truck_Class_Distribution
  - Site_Traffic_Directional_And_Lane_Distributions
  - Site_Traffic_Monthly_ADT_ADTT_Percent_Truck
  - Site_Traffic_Monthly_DOW_Truck_Class_Count

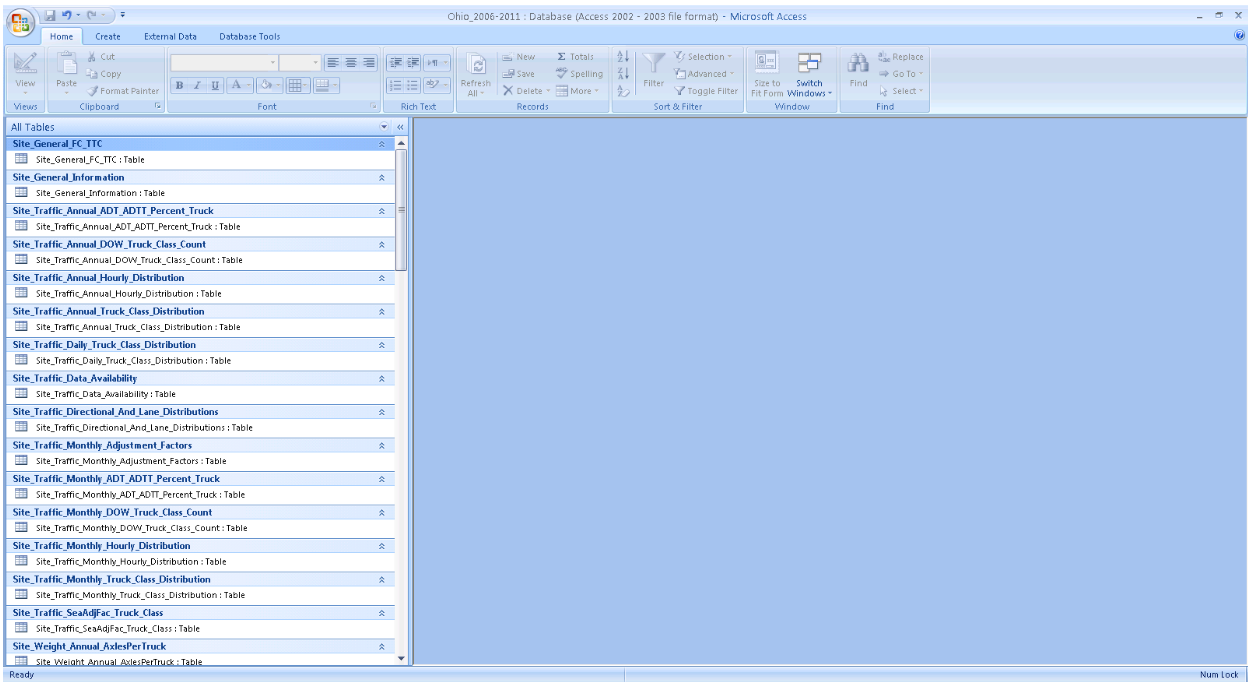
- Site_Traffic_Monthly_Hourly_Distribution
- Site_Traffic_Monthly_Truck_Class_Distribution
- Site_Traffic_Monthly_Adjustment_Factors
- Site_Traffic_Daily_Truck_Class_Distribution
- Site_Traffic_SeaAdjFac_Truck_Class

3- Site Weight:
- Site_Weight_Data_Availability
- Site_Weight_Annual_Gross
- Site_Weight_Annual_Single
- Site_Weight_Annual_Tandem
- Site_Weight_Annual_Tridem
- Site_Weight_Annual_Quad
- Site_Weight_Annual_Class_9_Error_Checks
- Site_Weight_Annual_Class_9_Front_Axle
- Site_Weight_Annual_Class_9_Drive_Tandem
- Site_Weight_Annual_AxlesPerTruck
- Site_Weight_Monthly_Gross
- Site_Weight_Monthly_Single
- Site_Weight_Monthly_Tandem
- Site_Weight_Monthly_Tridem
- Site_Weight_Monthly_Quad
- Site_Weight_Monthly_Class_9_Error_Checks
- Site_Weight_Monthly_Class_9_Front_Axle
- Site_Weight_Monthly_Class_9_Drive_Tandem

4- Statewide Traffic:
- Statewide_Traffic_Hourly_Distribution_FC_Avg
- Statewide_Traffic_Hourly_Distribution_FC_Site_List
- Statewide_Traffic_Hourly_Distribution_FC_StDev
- Statewide_Traffic_Hourly_Distribution_TTC_Avg
- Statewide_Traffic_Hourly_Distribution_TTC_Site_List
- Statewide_Traffic_Hourly_Distribution_TTC_StDev
- Statewide_Traffic_MAF_FC_Avg
- Statewide_Traffic_MAF_FC_Cont_Site_List
- Statewide_Traffic_MAF_FC_StDev
- Statewide_Traffic_MAF_TTC_Avg
- Statewide_Traffic_MAF_TTC_Cont_Site_List
- Statewide_Traffic_MAF_TTC_StDev
- Statewide_Traffic_SeaAdjFac_Avg_Truck_Class
- Statewide_Traffic_SeaAdjFac_Cont_Site_List_Truck_Class
- Statewide_Traffic_SeaAdjFac_StDev_Truck_Class
- Statewide_Traffic_VCD_FC_Avg
- Statewide_Traffic_VCD_FC_Site_List
- Statewide_Traffic_VCD_FC_StDev

5- Statewide Weight:
   - Statewide_Weight_AxlesPerTruck_Avg
   - Statewide_Weight_AxlesPerTruck_StDev

- To access the database, identify the location in which the file was stored and open the database.



- In addition to the results database, the VBA Code creates a log file with the selected site information file, input/output files, analysis period, and data handling options.

Ohio_2006-2011 - Notepad

File Edit Format View Help

```
Site Information File: "C:\MEPDG Traffic Inputs\Site_Information.xlsx"

Analyze C-Cards: True
C-Cards Folder: "C:\MEPDG Traffic Inputs\Traffic Data\C-Cards"
C-Cards Skip Empty Lines: True
C-Cards Skip Lines with Empty Spaces: True
C-Cards Skip Duplicate Data: True
C-Cards Skip Line with Total Volume Errors: True
C-Cards Delete Lines with Very High or Very Low Truck Traffic Compared to Median: True

Analyze W-Cards: True
W-Cards Folder: "C:\MEPDG Traffic Inputs\Traffic Data\W-Cards"
W-Cards Skip Empty Lines: True
W-Cards Skip Lines with Empty Spaces: True
W-Cards Skip Line with Total Weight Errors: True
W-Cards Delete Months with Erroneous Axle Load Spectra: True

Output Database: "C:\MEPDG Traffic Inputs\Ohio_2006-2011.accdb"

Start Year: 2006
End Year: 2011

---------------------------------------------------------------------------

Start C-Cards Analysis: 10/23/2012 3:16:35 PM

No. of C-Cards: 5911
C:\MEPDG Traffic Inputs\Traffic Data\C-Cards\2006\C06501xx.06
C:\MEPDG Traffic Inputs\Traffic Data\C-Cards\2006\C06502xx.06
C:\MEPDG Traffic Inputs\Traffic Data\C-Cards\2006\C06503xx.06
.
.
.

Start W-Cards Analysis: 10/23/2012 3:34:01 PM

No. of W-Cards: 2571
C:\MEPDG Traffic Inputs\Traffic Data\W-Cards\2006\W06505XX.Y06
C:\MEPDG Traffic Inputs\Traffic Data\W-Cards\2006\W06507XX.Y06
C:\MEPDG Traffic Inputs\Traffic Data\W-Cards\2006\W06508XX.Y06
.
.
.

End Analysis: 10/23/2012 5:18:32 PM

---------------------------------------------------------------------------
```

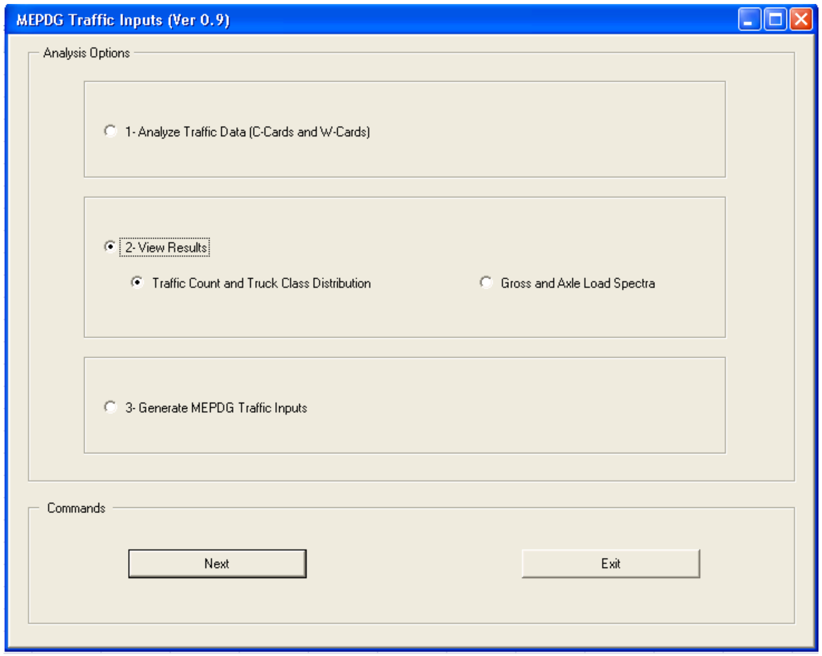
Note: While this program focuses on the generation of the MEPDG traffic inputs, the created database can be a vital tool in analyzing traffic data for alternative purposes.

A.2.2 View Results

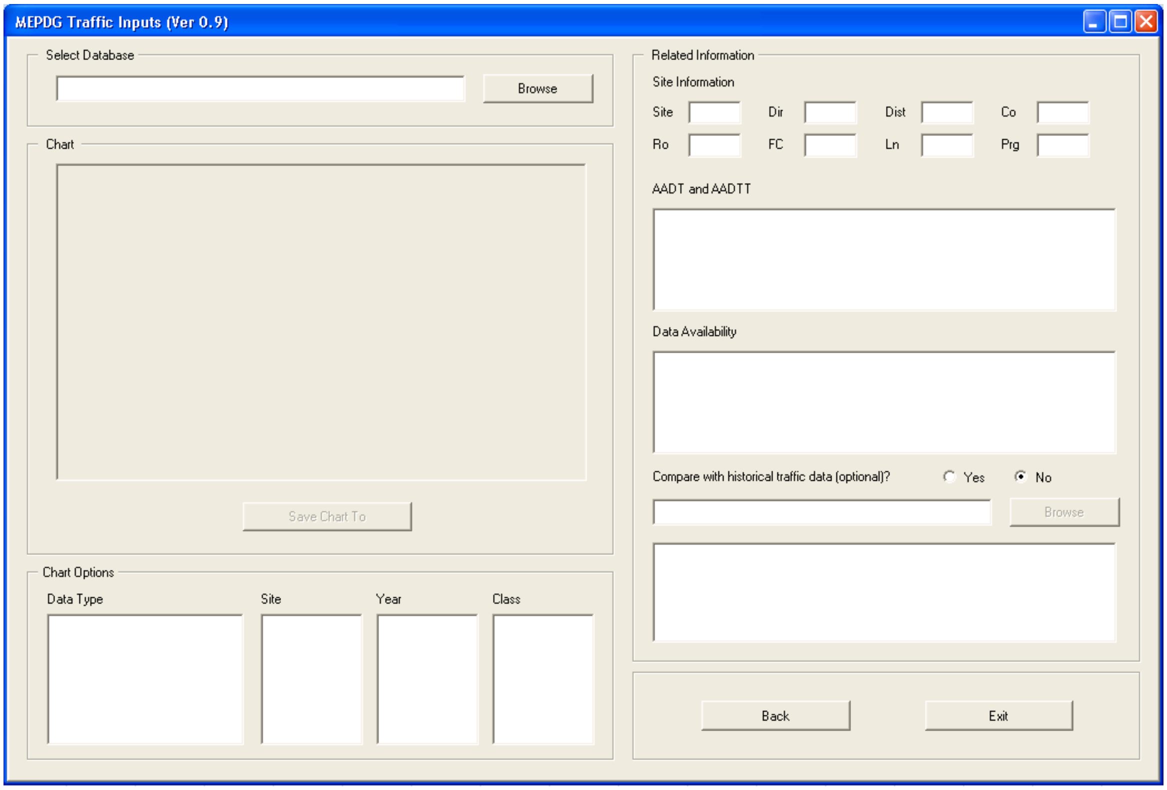
This option can be used to view the C-Cards or W-Cards analysis results.

A.2.2.1 Traffic Counts and Truck Class Distribution

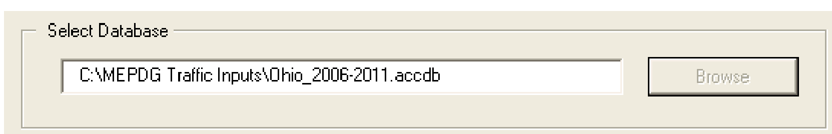
- To view the results of the Analyze Traffic Data (C-Cards)
  - Select the option button next to *View Results* on the *Analysis Options* window
    - Select the option button next to *Traffic Count and Truck Class Distribution*
  - Click "Next" under the *Commands* section



- A new window opens with several sections for viewing results

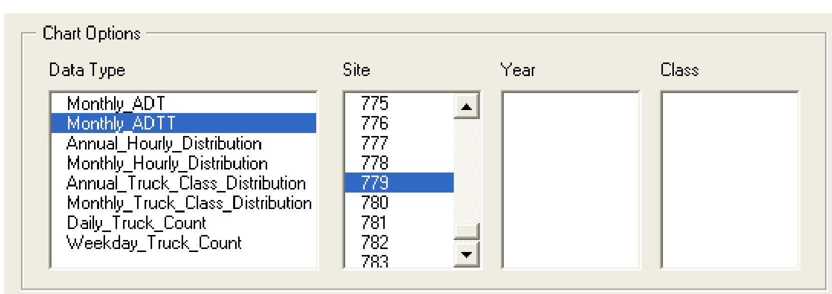


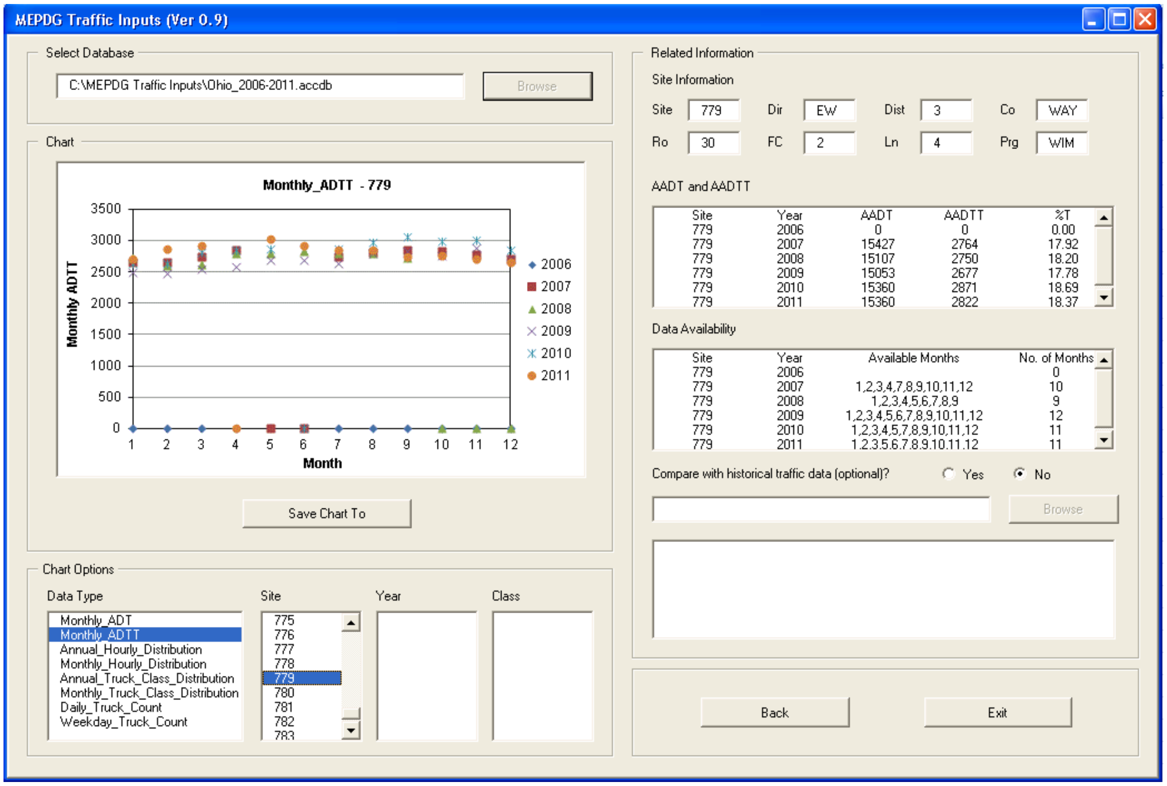
- To begin viewing the results:
  - Click “Browse” under the *Select Database* section
    - Navigate and select the results database



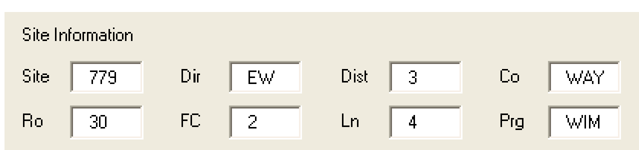
Note: The analyzed data will be displayed in the various sections of the *View Results* window upon the selection of the results database.

- The *Chart Options* section provides four tables titled: *Data Type*, *Site*, *Year*, and *Class*
  - By changing the selection in these tables, the chart area will update to show the corresponding results

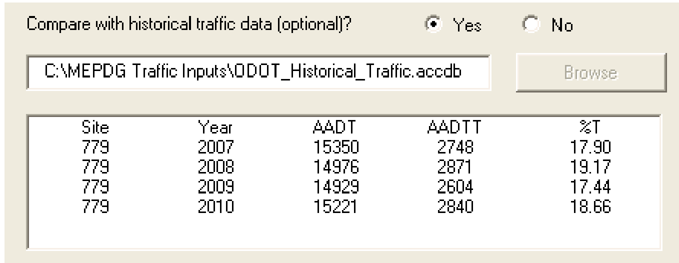




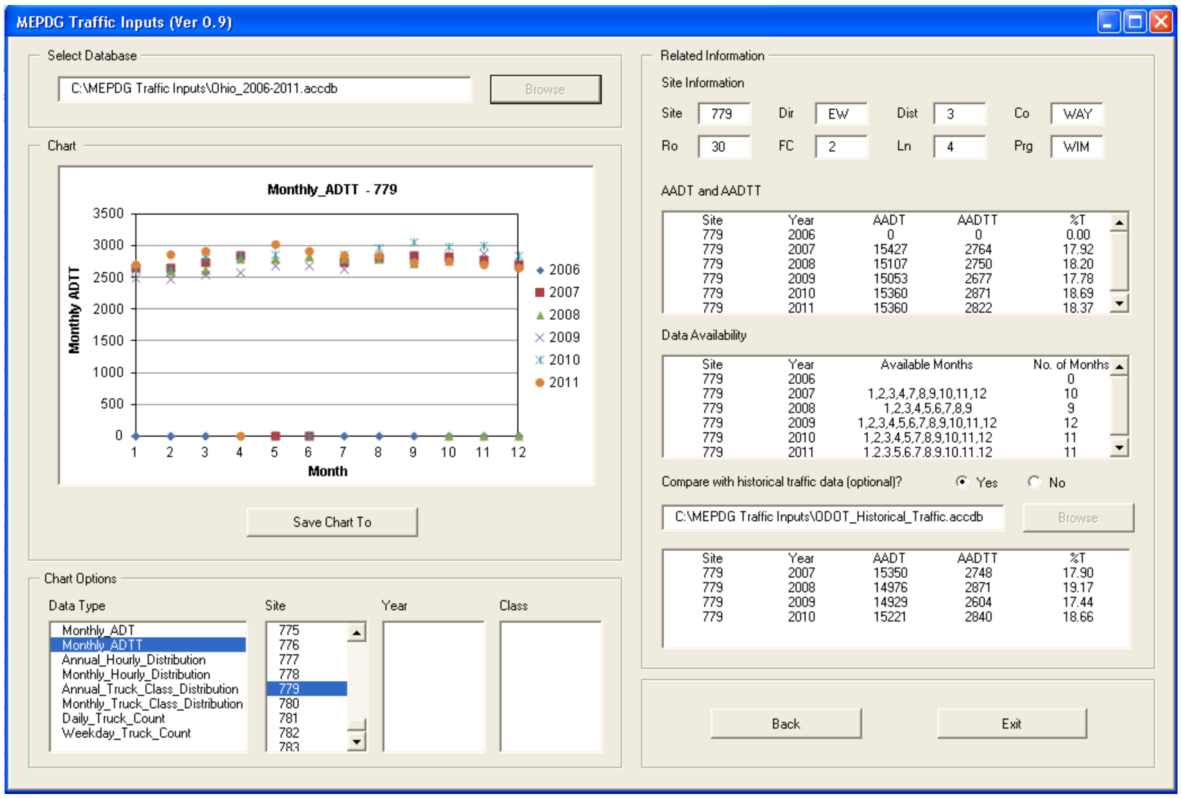
- The *Related Information* section provides additional information about each site to allow the user to determine the quality of the results. This section contains four subsections: *Site Information*, *AADT and AADTT*, *Data Availability*, and *Compare with Historical Traffic Data*
  - The *Site Information* subsection displays basic information about the selected site in the *Site* table under the *Chart Options* section: Site ID, Direction, District, County, Route, Functional Classification, Number of Lanes, and Type of Program (e.g., WIM for weigh-in-motion)



  - The vehicle and truck volumes are provided under the *AADT and AADTT* subsection and can be viewed simultaneously with the data displayed in the *Chart Area*
  - The *Data Availability* subsection lists the months for which data is available
  - The user can compare the data being viewed to historical traffic data from ODOT Traffic Monitoring Section by selecting "Yes" next to *Compare with historical traffic data (optional)?*
    - Click "Browse" to locate the Microsoft Access (.accdb) database containing the historic traffic data



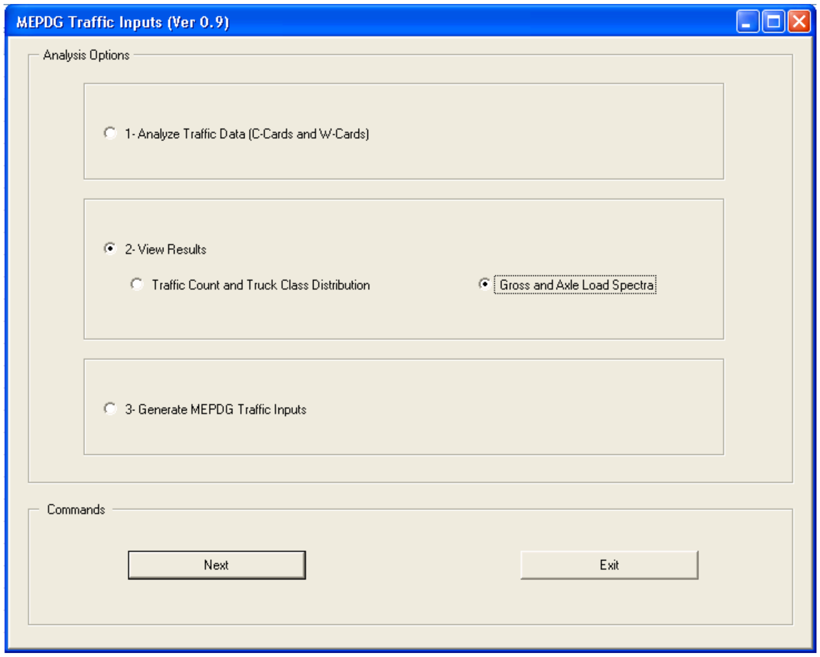
Note: This option allows the user to compare the AADT, AADTT and percent trucks (%T) from the analysis with historic traffic data.



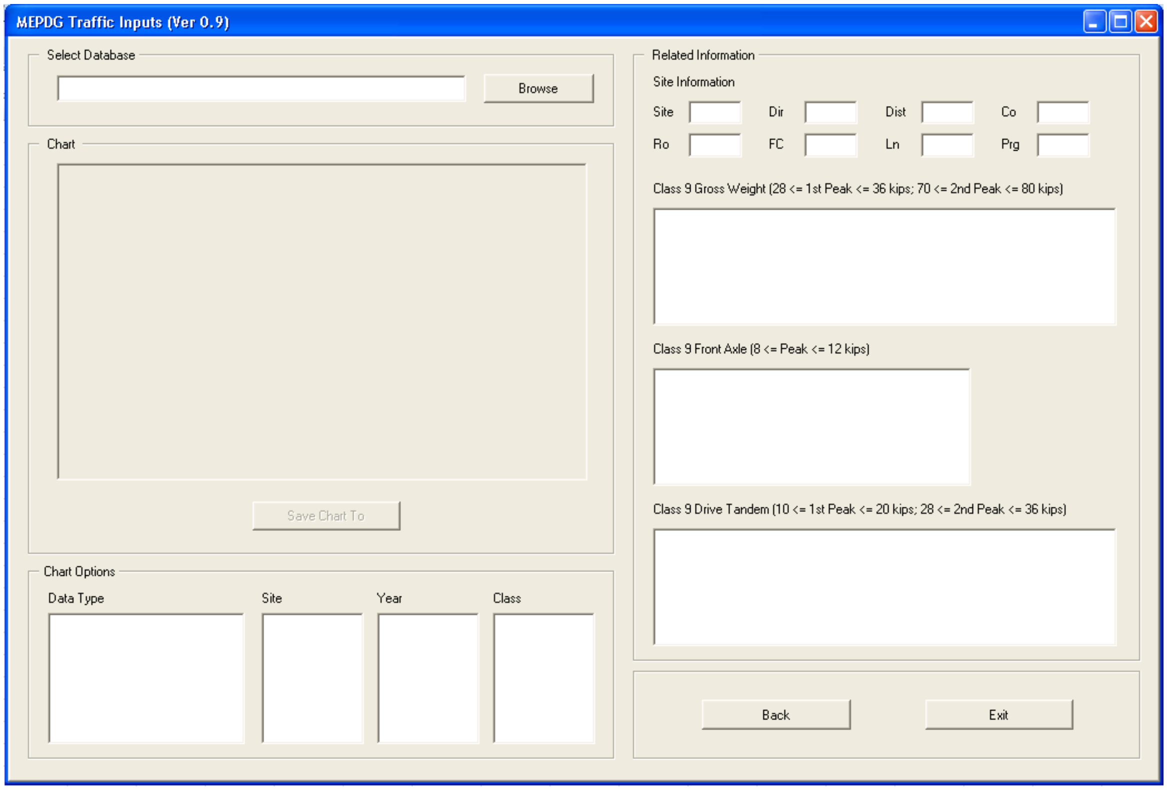
- Once the user has completed viewing the results, the user can return to the *Analysis Options* window by clicking the "Back" button or closing the program by clicking the "Exit" button

A.2.2.2 Gross and Axle Load Spectra

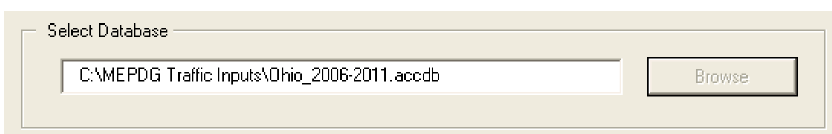
- To view the results of the Analyze Traffic Data (W-Cards)
    - Select the option button next to *View Results* on the *Analysis Options* window
        - Select the option button next to *Gross and Axle Load Spectra*
    - Click “Next” under the *Commands* section



- A new window opens with several sections for viewing results

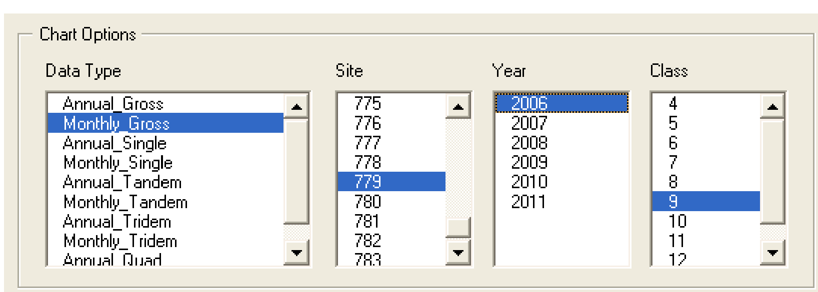


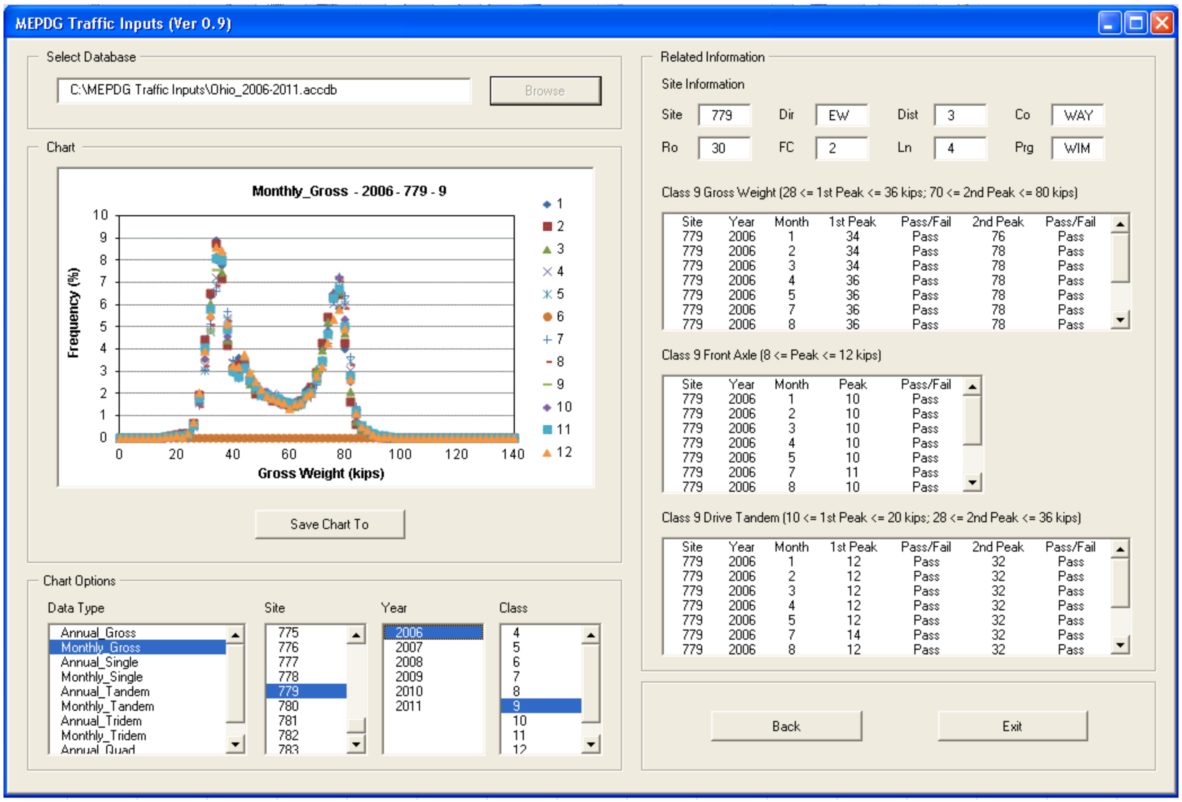
- To begin viewing the results:
  - Click “Browse” under the *Select Database* section
    - Navigate and select the results database



Note: The analyzed data will be displayed in the various sections of the *View Results* Window upon the selection of the results database.

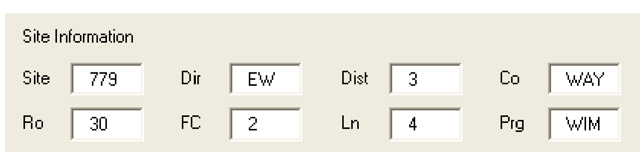
- The *Chart Options* section provides four tables titled: *Data Type*, *Site*, *Year*, and *Class*
  - By changing the selection in these tables, the chart area will update to show the corresponding results



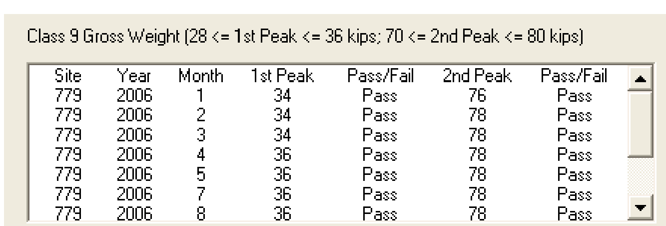


- The *Related Information* section provides additional information about each site to allow the user to determine the quality of the results. This section contains four subsections: *Site Information*, *Class 9 Gross Weight*, *Class 9 Front Axle*, and *Class 9 Drive Tandem Axle*

  - The *Site Information* subsection displays basic information about the selected site in the *Site* table under the *Chart Options* section: Site ID, Direction, District, County, Route, Functional Classification, Number of Lanes, and Type of Program (e.g., WIM for weigh-in-motion)



  - The *Class 9 Gross Weight* subsection shows whether the site has passed or failed the gross weight criteria for Class 9 trucks



Class 9 Gross Weight (28 <= 1st Peak <= 36 kips; 70 <= 2nd Peak <= 80 kips)

Site	Year	Month	1st Peak	Pass/Fail	2nd Peak	Pass/Fail
779	2006	1	34	Pass	76	Pass
779	2006	2	34	Pass	78	Pass
779	2006	3	34	Pass	78	Pass
779	2006	4	36	Pass	78	Pass
779	2006	5	36	Pass	78	Pass
779	2006	7	36	Pass	78	Pass
779	2006	8	36	Pass	78	Pass

- The *Class 9 Front Axle* subsection shows whether the site has passed or failed the front axle load criteria for Class 9 trucks

Class 9 Front Axle (8 <= Peak <= 12 kips)

Site	Year	Month	Peak	Pass/Fail
779	2006	1	10	Pass
779	2006	2	10	Pass
779	2006	3	10	Pass
779	2006	4	10	Pass
779	2006	5	10	Pass
779	2006	7	11	Pass
779	2006	8	10	Pass

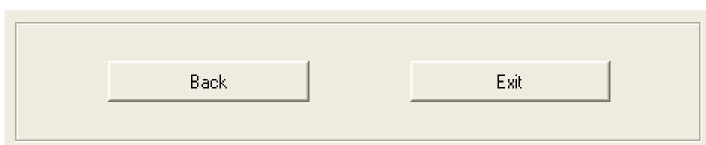
- The *Class 9 Drive Tandem* subsection shows whether the site has passed or failed the drive tandem axle load criteria for Class 9 trucks

Class 9 Drive Tandem (10 <= 1st Peak <= 20 kips; 28 <= 2nd Peak <= 36 kips)

Site	Year	Month	1st Peak	Pass/Fail	2nd Peak	Pass/Fail
779	2006	1	12	Pass	32	Pass
779	2006	2	12	Pass	32	Pass
779	2006	3	12	Pass	32	Pass
779	2006	4	12	Pass	32	Pass
779	2006	5	12	Pass	32	Pass
779	2006	7	14	Pass	32	Pass
779	2006	8	12	Pass	32	Pass

Note: The information displayed in the previous tables will change to show monthly or annual peak values based on the selection in the *Data Type* table under the *Chart Options* section.

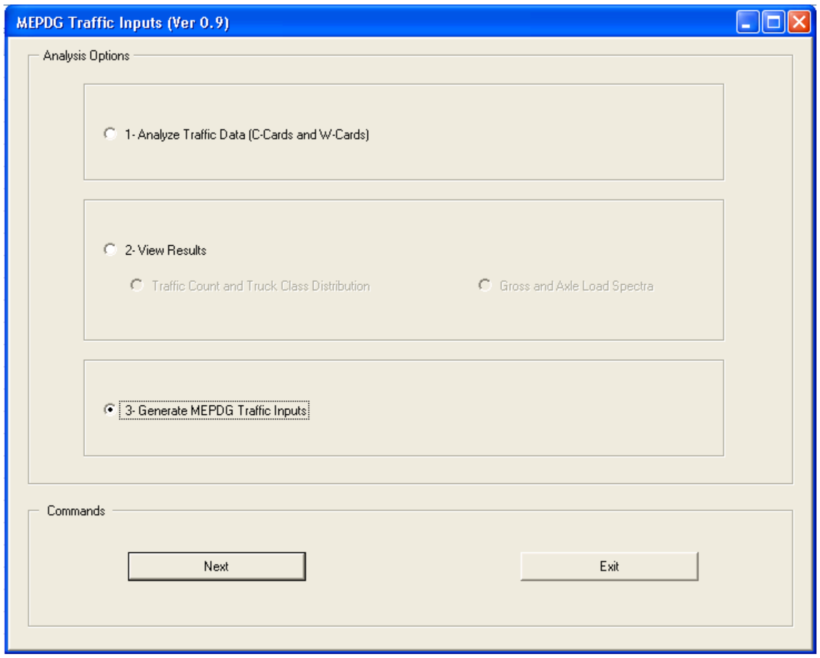
- Once the user has completed viewing the results, the use can return to the *Analysis Options* window by clicking the “Back” button or closing the program by clicking the “Exit” button



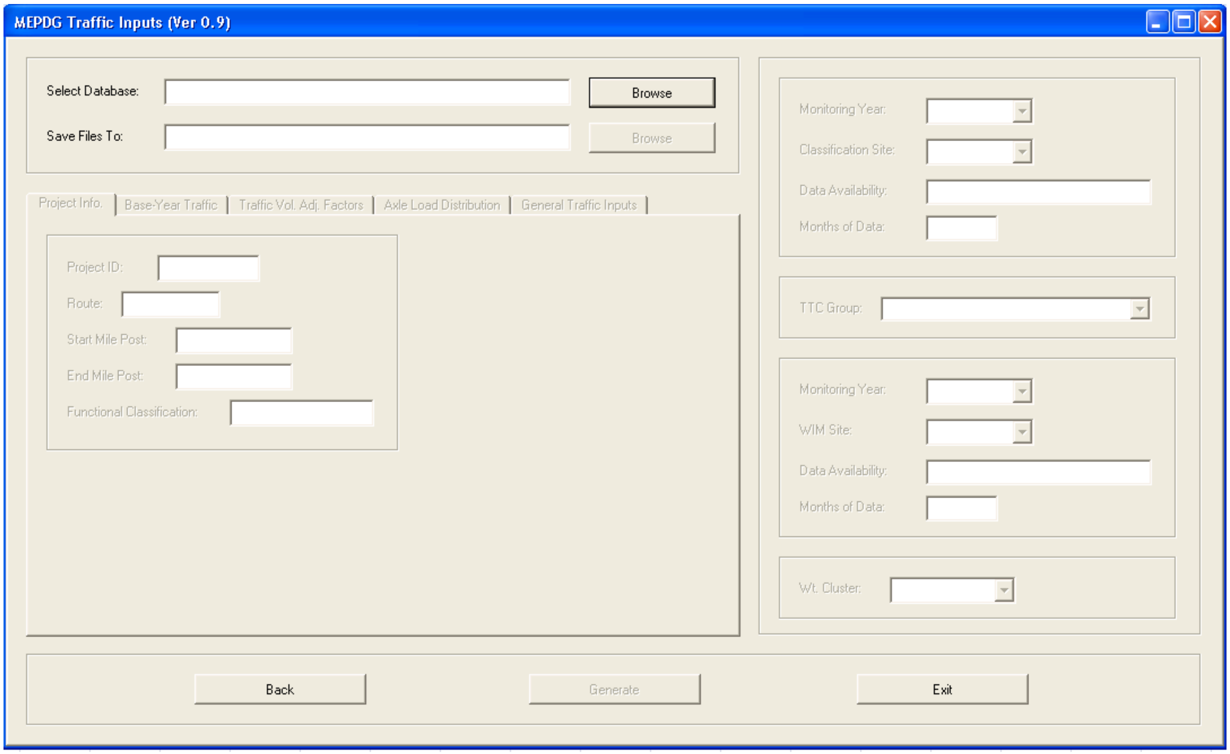
A.2.3 Generate MEPDG Traffic Inputs

This option generates the required traffic inputs that can be directly imported into the MEPDG.

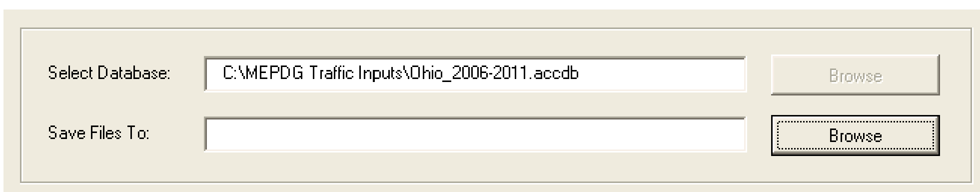
- To generate the MEPDG traffic inputs
    - Select the option button next to *Generate MEPDG Traffic Inputs* on the *Analysis Options* window
        - Click "Next" under the *Commands* section



- A new window opens displaying several tabs and sections

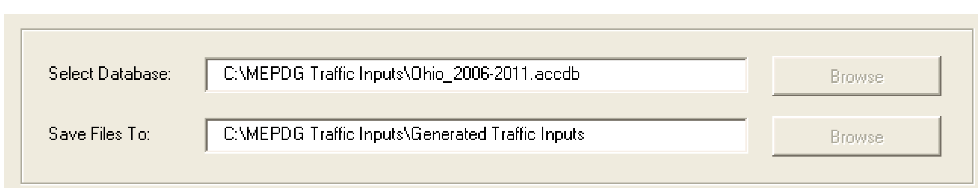


- Click “Browse” next to *Select Database*
  - Navigate and select the results database



Note: The user must select a valid results database to enable the “Browse” button next to *Save Files To*

- Click “Browse” next to *Save Files To*
  - Navigate and select an existing folder or a new folder

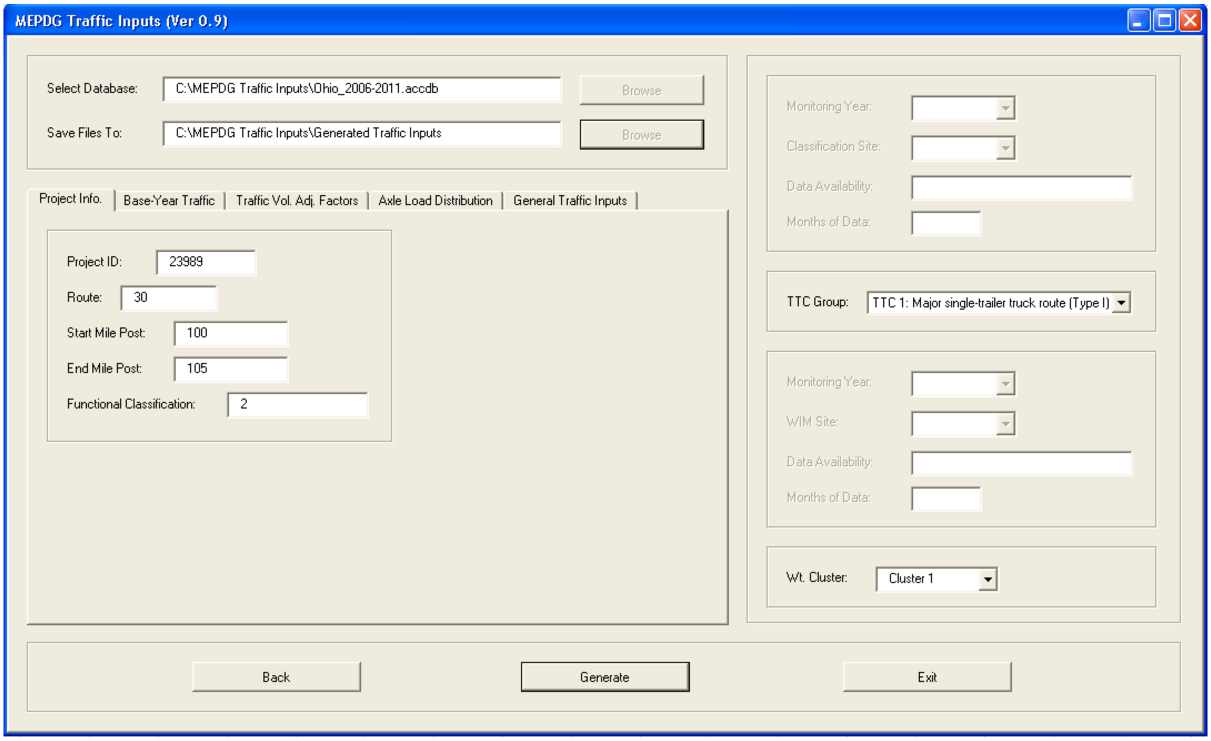


Note: Once a folder is selected, the other sections in this window will be enabled.

Note: The generated MEPDG traffic inputs will be created according to a standard text format and saved in the selected *Save Files To* folder.

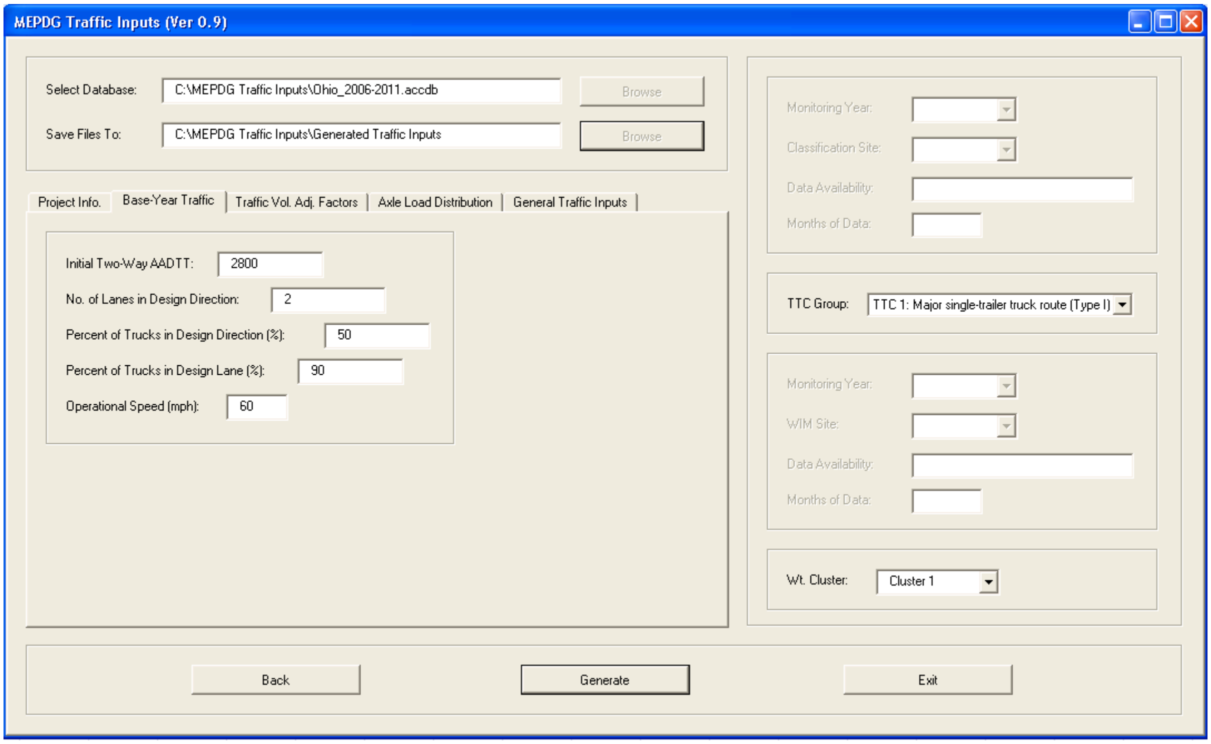
A.2.3.1 Project Information Tab

- The *Project Information* tab allows the user to enter basic information about the proposed pavement project



A.2.3.2 Base-Year Traffic Tab

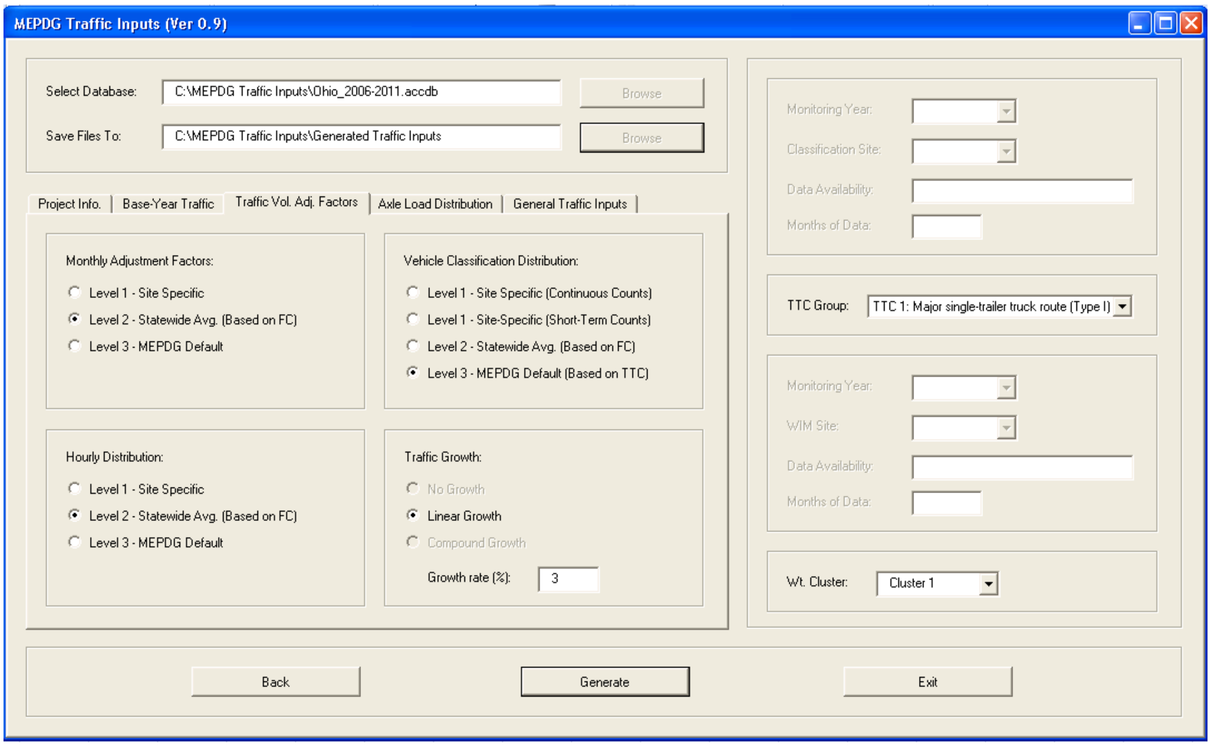
- The *Base-Year Traffic* tab enables the user to input information on initial two-way AADTT and roadway characteristics



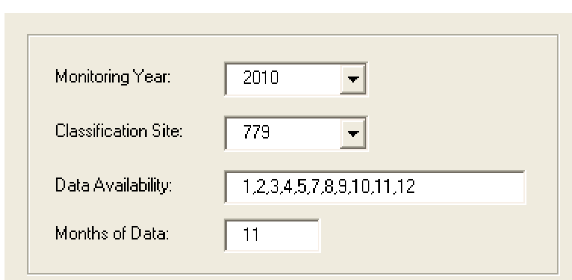
A.2.3.3 Traffic Volume Adjustment Factors Tab

- The *Traffic Volume Adjustment Factors* tab contains four subsections: *Monthly Adjustment Factors*, *Vehicle Classification Distribution*, *Hourly Distribution*, and *Growth Rate*

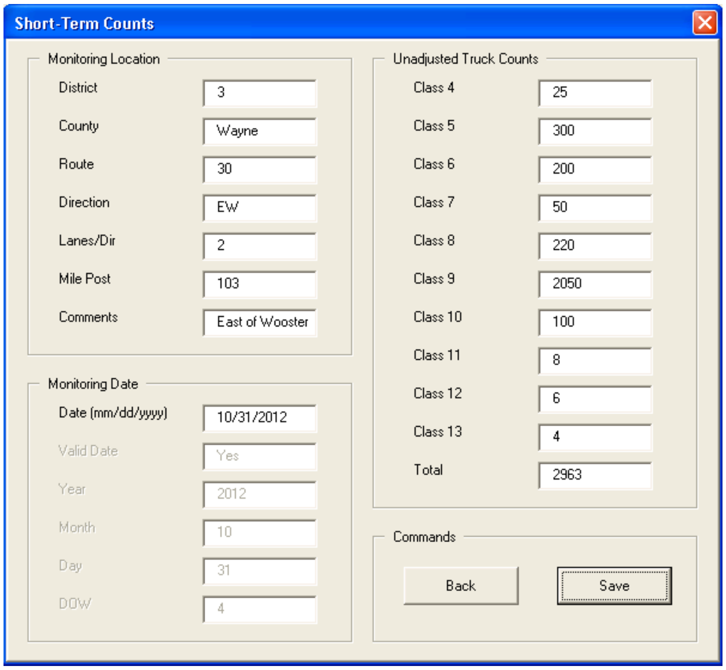
- The user can specify Level 1, 2, or 3 for the *Monthly Adjustment Factors*, *Vehicle Class Distribution*, and *Hourly Distribution Factors*



Note: By selecting Level 1 for the Monthly Adjustment Factors, Vehicle Class Distribution (Continuous Counts), or Hourly Distribution, the user must choose a continuous classification site from which the inputs will be generated. In order to facilitate the selection of a continuous classification site with sufficient traffic data, the VBA code provides the list and number of months with available data for the selected AVC site and year.

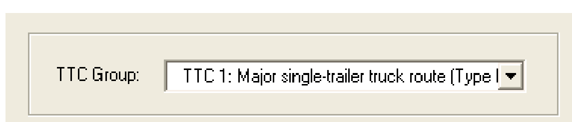


Note: If Level 1 (Short-Term Counts) is selected for Vehicle Class Distribution, the Short-Term Counts window shown below opens. This window allows the user to enter information about the traffic monitoring location including district, county, route, direction, number of lanes per direction, mile post, and location. The monitoring date must be entered in the form mm/dd/yyyy so that the program can identify the appropriate seasonal adjustment factors. Finally, the user must enter the unadjusted truck counts for truck class (4 through 13).

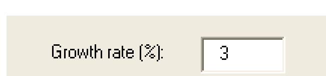


Note: By selecting Level 2 for the Monthly Adjustment Factors, or Hourly Distribution, the VBA Code will use Statewide Averages (Based on Functional Classification) in the generation of the MEPDG traffic inputs. It is not recommended to use Level 2 for the Vehicle Class Distribution.

Note: If Level 3 is selected, the VBA Code will use default MEPDG values to determine the inputs. For the Vehicle Classification Distribution, the user must choose a truck traffic classification (TTC) group.

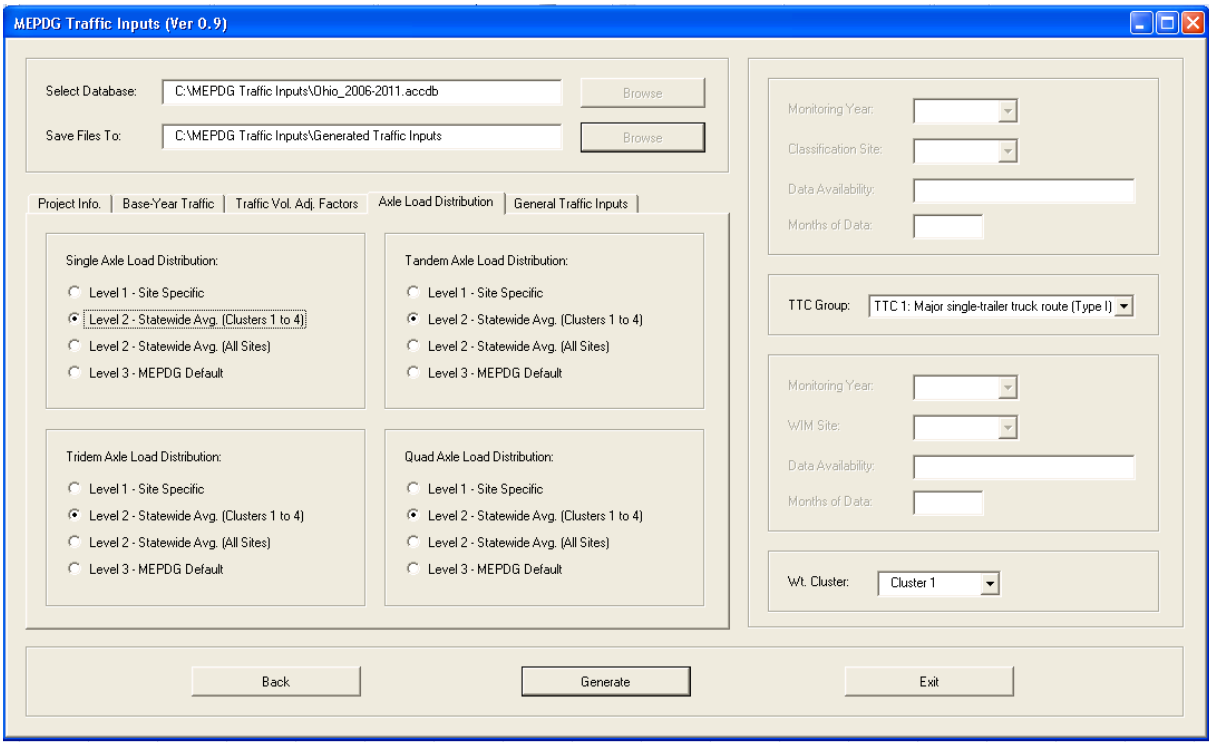


- The user must specify the traffic growth rate model (No Growth, Linear Growth, or Compound Growth) and input the growth rate (%) in the box provided

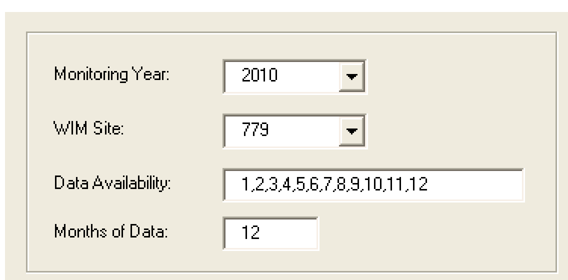


A.2.3.4 Axle Load Distribution Tab

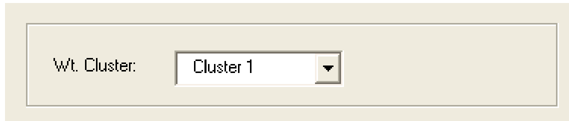
- The *Axle Load Distribution* tab contains four subsections for the single, tandem, tridem, and quad axle load distributions
    - The user can choose Level 1, 2 (Clusters 1 to 4), 2 (All Sites), or 3 for each subsection



Note: If Level 1 is selected for any of the sections under this tab, the user must choose a continuous WIM site from which the inputs will be generated. The VBA code provides the list and number of months with available data for the selected WIM site and year.



Note: If Level 2 Statewide Average (Clusters 1 to 4) is selected for any of the four sections, the user must choose a weight cluster.

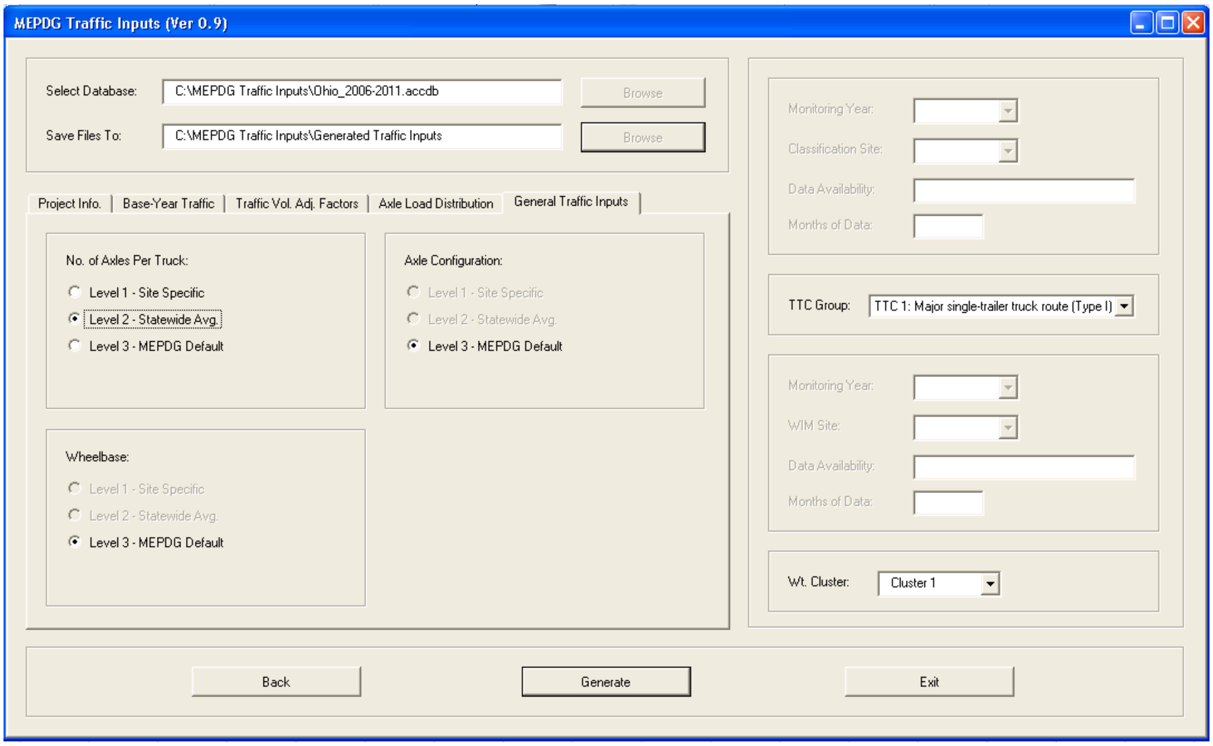


Note: If Level 2 Statewide Average (All Sites) is selected for any of the four sections, the statewide average axle load spectra will be used in the analysis

Note: If Level 3 is selected for any of the four sections, the VBA Code will use default MEPDG values

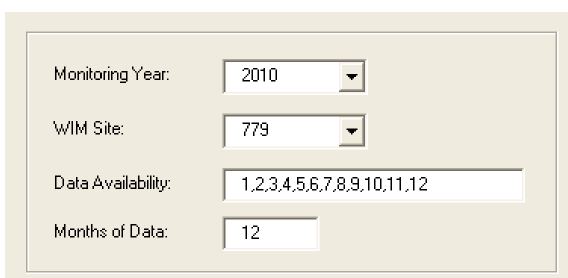
A.2.3.5 General Traffic Inputs Tab

- The *General Traffic Inputs* tab contains three subsections: Number of Axles Per Truck, Axle Configuration, and Wheelbase



Note: Levels 1 and 2 are disabled for the *Axle Configuration* and *Wheelbase* subsections. The VBA Code will use default MEPDG values (Level 3) for these inputs.

Note: If Level 1 is selected for the *Number of Axles Per Truck* subsection, the user must choose a continuous WIM site from which the inputs will be generated. The VBA code provides the list and number of months with available data for the selected WIM site and year.

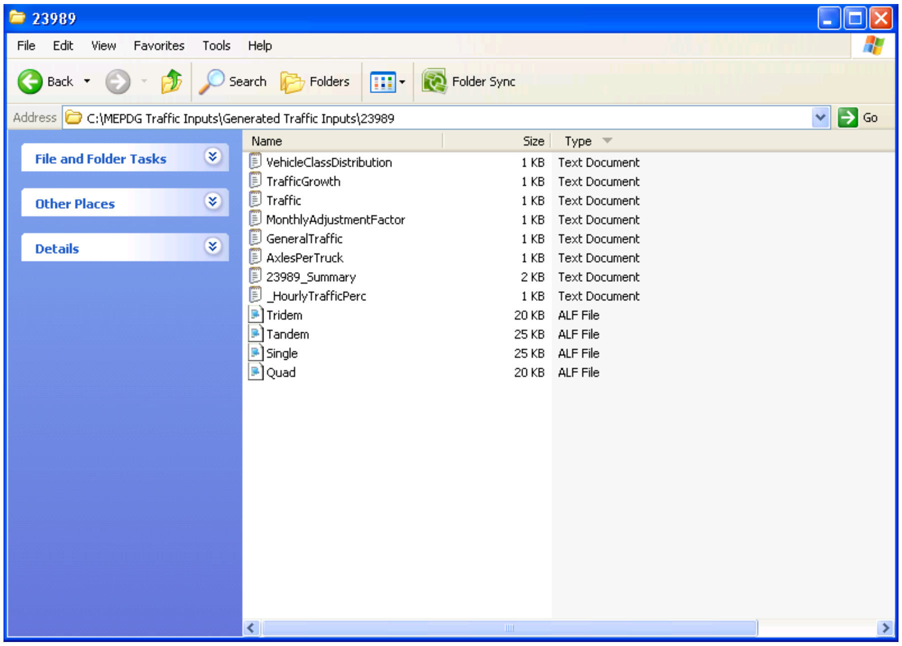


Note: If Level 2 is selected for the *Number of Axles Per Truck* subsection, the VBA Code will use statewide averages based on all WIM sites within the state.

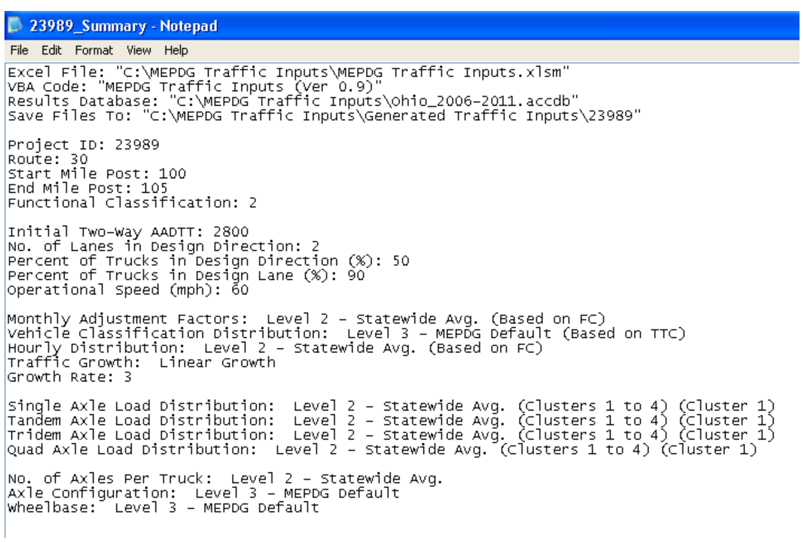
Note: If Level 3 is selected for the *Number of Axles Per Truck* subsection, the VBA Code will use default MEPDG values.

- To generate the MEPDG traffic inputs at the selected hierarchal levels
    - Click the “Generate” button

Note: The generated MEPDG traffic inputs are created according to a standard text format and saved in a subfolder with the same name as the *Project ID* in the selected *Save Files To* folder.



- In addition to the MEPDG traffic inputs, the VBA Code creates a summary file with the selected hierarchal level for each traffic input.


23989_Summary - Notepad
File Edit Format View Help

Excel File: "C:\MEPDG Traffic Inputs\MEPDG Traffic Inputs.xlsm"
VBA Code: "MEPDG Traffic Inputs (Ver 0.9)"
Results Database: "C:\MEPDG Traffic Inputs\Ohio_2006-2011.accdb"
Save Files To: "C:\MEPDG Traffic Inputs\Generated Traffic Inputs\23989"

Project ID: 23989
Route: 30
Start Mile Post: 100
End Mile Post: 105
Functional Classification: 2

Initial Two-Way AADTT: 2800
No. of Lanes in Design Direction: 2
Percent of Trucks in Design Direction (%): 50
Percent of Trucks in Design Lane (%): 90
Operational Speed (mph): 60

Monthly Adjustment Factors: Level 2 - Statewide Avg. (Based on FC)
Vehicle Classification Distribution: Level 3 - MEPDG Default (Based on TTC)
Hourly Distribution: Level 2 - Statewide Avg. (Based on FC)
Traffic Growth: Linear Growth
Growth Rate: 3

Single Axle Load Distribution: Level 2 - Statewide Avg. (Clusters 1 to 4) (Cluster 1)
Tandem Axle Load Distribution: Level 2 - Statewide Avg. (Clusters 1 to 4) (Cluster 1)
Tridem Axle Load Distribution: Level 2 - Statewide Avg. (Clusters 1 to 4) (Cluster 1)
Quad Axle Load Distribution: Level 2 - Statewide Avg. (Clusters 1 to 4) (Cluster 1)

No. of Axles Per Truck: Level 2 - Statewide Avg.
Axle Configuration: Level 3 - MEPDG Default
Wheelbase: Level 3 - MEPDG Default