Characterization of Truck Traffic in Michigan for the New Mechanistic Empirical Pavement Design Guide

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16. Abstract

The purpose of this study is to characterize traffic inputs in support of the new Mechanistic-Empirical Pavement Design Guide (M-E PDG) for the state of Michigan. These traffic characteristics include monthly distribution factors (MDF), hourly distribution factors (HDF) truck traffic classifications (TTC), axle groups per vehicle (AGPV), and axle load distributions for different axle configurations. Weight and classification data was obtained and used in this study from 44 Weigh-in-Motion (WIM) and classification stations located throughout the state of Michigan to develop Level 1 (site-specific) traffic inputs. Cluster analyses were conducted to group sites with similar characteristics for development of Level 2 (regional) inputs. Finally data from all sites were averaged to establish the statewide Level 3 inputs. The effects of the developed hierarchical traffic inputs on the predicted performance of rigid and flexible pavements were investigated using the M-E PDG. In addition, the impact of traffic data coverage (data collection period) was also explored by statistically comparing the performance differences between one week per month and continuous (year-round) input data. An algorithm based on discriminant analyses was developed to acquire the appropriate Level 2 traffic characteristic for pavement design.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols:

A: arbitrary site name A
AADTT: average annual daily truck traffic
AGPV: axle groups per vehicle
ALS: frequency of axle load
AR: total amount of axles per load bin or vehicle class
ART: total amount of axles across all load bins
B: arbitrary site name B
c: continuous data
d: difference value
EE: electrical equipment truck percentage
FC: functional class
FF: furniture and fixtures truck percentage
FMP: fabricated metal product truck percentage
FP: food product truck percentage
g: vehicle group
h: hour of day
HVOL: hourly volume count
HVOLTOT: average hourly volume count total
i:vehicle class
j: axle type
k: number of vehicle classes within each group
l: load bin
LLW: logs lumber and wood truck percentage
m: month of year
M: machinery truck percentage
MADTT: monthly average daily truck traffic
MADW: monthly average annual daily truck traffic by day of week
MALSW: monthly axle load frequency per load bin
MDF: monthly distribution factor
MM: machinery and manufactured products truck percentage
n: number of specific day of week within a given month
p: particular day of week within month
PP: paper and pulp products truck percentage
PM: printed matter truck percentage
R: region designation
RAT: roadway annual tonnage
RC: road class designation
RP: rubber and plastics truck percentage
t: total
TET: transportation equipment truck percentage
TOTREP: total axle repetitions per vehicle class
TOTVOL: total average volume count

TT: total tons
TTC: truck traffic classification distribution
VC5: vehicle class 5 percentage
VC9: vehicle class 9 percentage
VC10: vehicle class 10 percentage
VC13: vehicle class 13 percentage
w: day of week or one week per month data (OWPM)
x: number of days collected
y: number of vehicle records
z: counter variable

Abbreviations:

AADT: Average Annual Daily Traffic
AADTT: Average Annual Daily Truck Traffic
AASHTO: American Society of State and Highway Transportation Officials
AGPV: Axle Groups Per Vehicle
ANOVA: Analysis of Variance
ATR: Automatic Traffic Recorder
AVC: Automatic Vehicle Classification
CI: Confidence Interval
DOT: Department of Transportation
ESAL: Equivalent Single Axle Load
FHWA: Federal Highway Administration
GVW: Gross Vehicle Weight
HDF: Hourly Distribution Factor

EXECUTIVE SUMMARY

The purpose of this study is to characterize traffic inputs in support of the new Mechanistic-Empirical Pavement Design Guide (M-E PDG) for the state of Michigan. These traffic characteristics include monthly distribution factors (MDF), hourly distribution factors (HDF) truck traffic classifications (TTC), axle groups per vehicle (AGPV), and axle load distributions for different axle configurations. Weight and classification data was obtained and used in this study from 44 Weigh-in-Motion (WIM) and classification stations located throughout the state of Michigan to develop Level 1 (site-specific) traffic inputs. Cluster analyses were conducted to group sites with similar characteristics for development of Level 2 (regional) inputs. Finally data from all sites were averaged to establish the statewide Level 3 inputs. The effects of the developed hierarchical traffic inputs on the predicted performance of rigid and flexible pavements were investigated using the M-E PDG. In addition, the impact of traffic data coverage (data collection period) was also explored by statistically comparing the performance differences between one week per month and continuous (year-round) input data. An algorithm based on discriminant analyses was developed to acquire the appropriate Level 2 traffic characteristic for pavement design.

Based on the analyses and results of the study, following main conclusions and recommendation are presented in the report.

Use of OWPM data in conjunction with continuous AADTT resulted in similar predicted performance for each site. However, if the data retrieval takes minimal effort from WIM or classification stations, it is recommended that continuous traffic data be used wherever available.

The hierarchical traffic inputs in the M-E PDG are defined as follows:

- Level I – Converted WIM and classification data to the M-E PDG format using TrafLoad.
- Level II – Utilized cluster analysis to form groups with similar traffic characteristics. The group traffic characteristics were averaged to create a Level II traffic inputs.
- Level III – Average traffic characteristics from all sites were used as Level III data.

The development of Level II inputs established the following findings:

- Truck traffic classification (TTC) clustering identified three specific traffic patterns centered on VC 5 and VC 9.
- Monthly distribution factors were divided into three groups: VC 4-7, VC 8-10, and VC 11-13 (i.e., single-unit, tractor-trailer combination, and multi-trailer combination). Although three, four, and five MDF clusters were formed for VC 4-7, VC 8-10, and VC 11-13, respectively, all exhibited a similar trend of high peaks in the summer and low peaks in the winter months.
- Hourly distribution factors were grouped into three clusters.
- The single axle load spectra were grouped into three clusters, which peaked at 4-7 and 9-14 kips.

- The tandem axle load spectra exhibited five distinct clusters. Clusters 1-3 showed presence of lighter axles as compared to clusters 4 and 5. Two peaks observed in the spectra correspond to unloaded (9-14 kips) and loaded (30-35 kips) trucks.
- The tridem axle load spectra were grouped into three clusters. In general, the clusters had a large proportion of lighter axles around 12 kips followed by a small peak at 40-45 kips.
- The quad axle load spectra had shown four clusters. Peak values for the quad axle load spectra occur at 15-20, 50-60 and 104 kips.

Additionally, following observations were made based on the analyses of the traffic inputs:

- In general, insignificant seasonal (month to month) variations existed in axle load spectra for the most vehicle classes.
- The impact of directional difference in axle load spectra for most vehicle classes is negligible.
- The single axle load spectra for different vehicle classes at all sites were found to be similar based on cluster analysis. The single axle load distribution depends on the percentages of VC 5 and VC 9 in the traffic stream. The sites with higher proportions of VC 5 peak at 3-6 kips while sites with higher proportions VC 9 peak at 11-13 kips.
- The tandem axle load distributions depend on the axle load spectra of VC 9 only.
- The tridem and quad axle load spectra are a function of VC 10 and VC 13.

For pavement design, it is recognized that site specific data be used wherever available. For sites in which site-specific data is not available, it is necessary to know whether Level II or Level III data are acceptable at a minimum for design. To investigate the impact of traffic input levels on predicted pavement performance for flexible and rigid pavements, the M-E PDG was used. As a result of this investigation, selection of the appropriate traffic characterization for each traffic input was made. The following is the summary of findings:

- TTC significantly impacts predicted rigid pavement performance and moderately affects flexible pavement performance. Thus, TTC clusters (Level II) is suggested for use in case of the rigid pavement design. Although there was no apparent difference in impact between cluster averages and statewide values in case of flexible pavement design, it suggested using TTC cluster averages (Level II) for sake of consistency.
- MDFs have negligible impact on predicted rigid and flexible pavement performance. Therefore, it is recommended that a statewide average (Level III) be used.
- HDF significantly impacts rigid pavement performance but has a negligible impact on flexible pavement performance. Consequently, cluster average (Level II) HDFs should be utilized for rigid pavement design. In contrast, for flexible pavement, HDF characterizations produced absolutely no difference in predicted performance life. Therefore, statewide averages (Level III) for HDF can be used for flexible pavement design.
- AGPV had a negligible impact on predicted rigid and flexible pavement performance. Therefore, it is suggested that statewide averages (Level III) be used for this traffic input.
- Single axle load spectra have negligible to moderate effect on predicted rigid and flexible pavement performance. Therefore, it is recommended that statewide averages (Level III) be used for this traffic input.

- Tandem axle load significantly impacted rigid pavement performance and had a moderate influence on flexible pavement performance. Therefore, cluster averages (Level II) are suggested for both rigid and flexible pavement designs.
- Tridem axle load spectra negligible impact on rigid and flexible pavement performance. Statewide average tridem axle load spectra (Level III) can be used for this traffic input.
- Quad axle load spectra have a negligible impact on predicted rigid pavement performance but have a moderate effect on flexible pavement performance. Therefore, statewide average quad axle load spectra (Level III) can be used.
- The M-E PDG defaults traffic inputs don't accurately reflect the local traffic conditions in the state of Michigan. Therefore, the M-E PDG defaults are not recommended for use in the state of Michigan.

For the traffic inputs where site specific (Level I) data or only statewide values (Level III) need to be used, selection of the appropriate traffic input is obvious. The discriminant analysis algorithm can be adopted for the following traffic inputs which require Level II data:

- TTC
- HDF (Rigid only)
- Tandem Axle Load Spectra

The report also presents two categories of recommendations for MDOT: (1) general guidelines as documented in the Traffic Monitoring Guide (TMG) for the selection of appropriate WIM sites, and (2) specific recommendations about frequency of cluster analysis, additional WIM locations in different regions, and additional resources for traffic data processing for the purpose of pavement design.

CHAPTER 1 - INTRODUCTION

1.1 PROBLEM STATEMENT

The current AASHTO 1993 pavement design utilizes 18-kip Equivalent Single Axle Loads (ESALS) for establishing pavement thicknesses. These ESALS are based on load equivalency factors (LEFs) that are a function of (i) pavement type, (ii) slab thickness or structural number, (iii) axle type and load, and (iv) terminal serviceability index. To measure performance, the Present Serviceability Index (PSI) is considered as part of the current design practice. The development of the Mechanistic Empirical Pavement Design Guide (M-E PDG) under NCHRP Project 1-37 has changed the traffic characterization requirements for the pavement design; it utilizes axle load distributions rather than ESAL. Additionally, M-E PDG does not produce pavement performance in terms of PSI but instead has structural pavement distresses— percent slabs cracked, fatigue cracking and rutting, and functional distress such as International Roughness Index (IRI), as part of its rigid and flexible pavement outputs. Accordingly, the use of ESAL's is not compatible with M-E PDG and there is a need to characterize traffic directly.

1.2 BACKGROUND

The characterization of traffic is one of the significant elements in the analysis and design of pavements (flexible, rigid, and composite). The M-E PDG requires the full axle load spectra for each axle type for the design of new and rehabilitated pavements. The M-E PDG recognizes the fact that detailed traffic data over the years to accurately characterize future traffic for design may not be available. Thus, to facilitate the use of the M-E PDG regardless of the level of details of available traffic data, a hierarchical approach has been adopted for developing required traffic inputs:

- Level 1 – There is a *very good* knowledge of past and future traffic characteristics. At this level, it is assumed that the past traffic volume and weight data have been collected along or near the roadway segment to be designed. Level 1 is considered the most accurate because it uses the actual axle weights and truck traffic volume distributions measured over or near the project site.
- Level 2 – There is a *modest* knowledge of past and future traffic characteristics. At this level, only regional/statewide truck volume and weight data may be available for the roadway in question. Level 2 requires the designer to collect enough truck volume information at a site to measure truck volumes accurately.
- Level 3 – There is a *poor* knowledge of past and future traffic characteristics. At this level, the designer will have little truck volume information (for example, Average Annual Daily Traffic (AADT) and a truck percentage). In this case, a regional, statewide or some other default value must be used.

Traffic patterns in terms of truck volumes, vehicle class distributions, and axle loads vary considerably along various routes and locations even along a same route. Therefore, Level I traffic information can be collected only if weigh-in-motion (WIM) sites are present in proximity of the design project. The designer's ability to assess the current and future traffic patterns is then considered to be significant. In the event weight distributions are available only at a regional or a network level for the design project while truck volumes and classification data can be collected, the design guide assumes a Level 2 input, and the designer's ability to evaluate current and future traffic patterns is considered reasonable. Finally, if the designer has to rely on default inputs based on national traffic patterns, the designer assumes a poor knowledge (Level 3) of the current and future traffic characteristics.

1.3 RESEARCH OBJECTIVES AND SIGNIFICANCE

The overall goal of this research project was to characterize traffic-related inputs at various input levels for the M-E PDG for new and rehabilitated pavements (NCHRP 1-37A) in the state of Michigan. Based on the findings of this two year study, recommendations are made for traffic data collection for various input levels and need for additional resources required by MDOT.

1.4 BENEFITS TO MDOT

The results from this study will advance the understanding of the M-E PDG. An improved understanding of the significance of the traffic inputs and their impact on performance prediction will assist in making the transition from a purely empirical to a mechanistic-empirical design procedure. The results from this study include (i) documenting the method required to convert "raw" traffic data to the ME-PDG format for Level 1 inputs; (ii) developing axle load distributions, and several other traffic characterizations for the various axle types that can be used in different regions and different roads for Level 2 inputs, and (iii) providing input with regards to personnel needs and process change (if any) to deliver the required traffic inputs for the new pavement design methodology. The technology transfer package developed as part of this study will serve as a teaching tool for the present and the future pavement designers at MDOT.

1.5 RESEARCH PLAN

The objectives of this project were accomplished by executing the following six tasks over a period of 24 months.

1.5.1 **Task 1: Review and evaluation of the existing weigh stations and traffic counters locations**

Task 1 activities involved the following five subtasks:

- *Subtask 1a:* Identify various locations of weigh stations (including both WIM and static scales sites) along the pavement network in Michigan with assistance of the project technical advisory group (TAG).
- *Subtask 1b:* Identify and review of traffic count locations (including counters for classification and traffic counts)

- *Subtask 1c:* Determine the extent and quality of traffic loading data available at the WIM sites identified in subtask 1a. The quality check was to assess the data in terms of identifying outliers and/or anomalies.
- *Subtask 1d:* Determine the extent and quality of traffic count data available at the traffic count sites identified in subtask 1b. The quality check was to assess the data in terms of identifying outliers and/or anomalies.
- *Subtask 1e:* Based on the available data (subtasks 1b and 1d) the project team selected (in concert with the project TAG) appropriate locations for weight and count data for further analyses.

1.5.2 **Task 2: Identify data elements needed for traffic characterization**

The necessary traffic related inputs required in the M-E PDG are summarized within this task. In particular, the targeted traffic data needed for the various hierarchical input levels for traffic characterization are reviewed. For the locations selected in *subtask 1e,* the available data elements were matched with the required data elements.

1.5.3 **Task 3: Conversion of traffic to M-E PDG format**

Based on the results of tasks 1 and 2, the traffic database consisting of continuous truck classification and axle load data, was used to characterize truck traffic in Michigan according to various input levels. Due to its ease of use and compatibility with the M-E PDG, the software TrafLoad was selected for processing of the "raw" traffic data into the necessary traffic characteristics needed in M-E PDG. This traffic characterization facilitates the use of the new M-E PDG. During the course of the project, the MDOT requested to investigate the data coverage requirements i.e., if one week per month data was comparable to continuous data. As such, the effects of data coverage were investigated within this task.

1.5.4 **Task 4: Development of Traffic Characterizations for the State**

Based on the analysis results obtained from task 3, Level II and Level III traffic inputs were established for the targeted hierarchical inputs outlined in Task 2 to facilitate use of the M-E PDG in Michigan. These inputs were developed through clustering techniques based on statistical (hierarchical clustering algorithm) and operational significance (regions or road type (for example, Interstate versus US versus M routes)). The effect of utilizing the developed Level II and Level III traffic characterizations over site-specific data was also explored in this task. As a result of these analyses, specific recommendations for data to be collected at various input levels in specific regions with different traffic loadings and volumes could be made.

1.5.5 **Task 5: Technology Transfer**

A technology transfer workshop will be developed and presented to MDOT pavement designers and researchers who are the anticipated users of the new M-E PDG. The workshop will include:

- An introduction to the theory behind the traffic characterization in the new design guide;

- A description of the various required inputs and how reasonable values for these inputs can be obtained;
- A demonstration of how to prepare a complete input file; and
- Hands-on exercises that will allow each participant to develop the input and analyze the output of the problems those are of concern to them.

Each workshop participant will be provided a User's Guide and a Participant's Workbook for future reference and will address various aspects of transferring of the processes to MDOT.

1.5.6 **Task 6: Project Deliverables**

Over the course of 24 months the PIs participated in four ***quarterly meetings*** and submitted four ***quarterly reports*** summarizing the progress of project. If the MDOT deems necessary, the PIs can prepare a ***power point presentation*** project summarizing the project findings and recommendations of the study. In addition to the technology transfer package, the project team will also submit a ***final report*** summarizing the project findings to the project manager. Comments on the final report and presentation will be sought from the project advisory panel and the modified deliverables will be submitted.

1.6 ANTICIPATED RESEARCH RESULTS

The results of this research characterized traffic inputs at various hierarchical levels for the design of new flexible and rigid pavements of the M-E PDG in the state of Michigan. The final report and the technology transfer package document the protocol required to develop the necessary traffic input data. The technology transfer package will also serve as a teaching tool for the present and the future pavement designers at MDOT. This project will serve as the next step towards the adoption and implementation of the M-E PDG in the state of Michigan.

1.7 OUTLINE OF REPORT

The report consists of the following chapters:

1. *Introduction*
2. *Literature Review*
3. *Methodology*
4. *Data Analyses and Results*
5. *Conclusion and Recommendations*

Chapter 1 outlines the problem statement related to this project, the research objectives, benefits to MDOT and outline of the final report.

Chapter 2 presents past research related to (i) the traffic characterization in the M-E PDG (ii) the effect of data coverage on the development of traffic characteristics (iii) the required equipment used in Michigan for collecting traffic data (iv) the previous traffic characterization studies, including clustering techniques and effects of traffic-related inputs on predicted pavement performance.

Chapter 3 reviews tasks 1 and 2, and the methodologies applied for execution of task 3. This chapter addresses the procedures used for collecting and extracting “raw” traffic data as well as the M-E PDG traffic inputs selected for hierarchical data development. In addition, this chapter examines the effect of data coverage i.e., comparison between one week per month and continuous traffic data. The clustering techniques utilized in this project for development of Level II inputs are also reviewed in this chapter.

Chapter 4 covers the results of tasks 3 and 4 of the study. First, the effect of data coverage is evaluated followed by the developed traffic characteristics based on the “raw” traffic data. The sensitivity of these traffic characteristics in design is then assessed, which leads to the selection of final Level II and Level III traffic characterizations in the state of Michigan. Finally, criteria for the selection of the appropriate Michigan traffic input in future designs are presented.

Chapter 5 summarizes the conclusions reached that satisfy the project objectives. Recommendations for the implementation and further development of traffic characterization in M-E PDG for the state of Michigan are also provided.

CHAPTER 2 - LITERATURE REVIEW

The information presented in this chapter were obtained from (i) published journal articles such as Journal of the Transportation Research Record, the Journal of Transportation Engineering, etc., (ii) proceedings of various domestic and international conferences, and (iii) published research reports.

The literature review summarized in this chapter focuses on the following areas:

- Traffic characterization in the M-E PDG
- Effect of data coverage on the development of traffic characteristics
- Required equipment used in Michigan for collecting traffic data
- Previous traffic characterization studies

Traffic characterization is reviewed in order to identify the available traffic-related inputs in the M-E PDG. The effect of data coverage on the development of traffic characteristics was explored to gain particular understanding into the differences in developed traffic characteristics between using one week per month data and continuous data. A review of the required equipment used in Michigan allows for understanding of the sensors used to collect traffic data, the identification of error sources and the methods to identify those errors. Previous traffic characterization studies were explored to develop insight into the observed traffic characteristics in other states as well as the methods that led to their development.

2.1 TRAFFIC CHARACTERIZATION IN M-E PDG

The M-E PDG accepts an array of traffic inputs for use in design. Table 2.1 summarizes each of these traffic inputs with respect to the available hierarchical levels in the M-E PDG (1).

Table 2.1 Traffic data required for the three M-E PDG input levels

Data Elements/Variables		Input Level		
		I	II	III
Truck Traffic & Tire Factors	Directional distribution factor (DDF)	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Truck lane distribution factor (LDF)	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle/truck class	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle and tire spacing	Hierarchical levels not applicable for these inputs		
	Tire pressure			
	Traffic growth			
	Vehicle operational speed			
	Lateral distribution (wheel wonder)			
	Monthly distribution factor (MDF)	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Hourly distribution factor (HDF)	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
Truck Traffic Distribution and Volume	AADT or AADTT for base year	Hierarchical levels not applicable for these inputs		
	Truck dist/spectra by truck class	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle load dist/spectra by truck class and axle type	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Truck traffic classification group for design (TTC)	Hierarchical levels not applicable for these inputs		
	% of trucks			

As shown in Table 1, most of the data elements can be captured by hierarchical input data in the M-E PDG. Level I data is captured by site-specific WIM and classification sites. This data type has been provided by MDOT. Where site-specific information is unavailable for design purposes, the site-specific traffic characteristics will be grouped to form regional and statewide average values for the formation of Level II and Level III inputs.

2.2 EFFECT OF DATA COVERAGE ON DEVELOPMENT OF TRAFFIC CHARACTERISTICS

A study with the objective of characterizing truck traffic in California concluded in a preliminary analysis that WIM stations showed little differences between weeks in the same month (2). The TrafLoad software manual states that the program accepts as a minimum one week per month of data for all 12 months in order for a site to be Level 1A site specific (3). Studies performed by Cambridge Systematics reviewed in the TrafLoad manual, NCHRP Report 538, revealed that utilizing continuous 7-day data produced mean absolute percent errors of 10.1% and 9.9% for factored and un-factored ESAL counts respectively, when compared to “annual” (8 months of continuous data) estimates (3).

Chapter 4 of the M-EPDG manual specifies confidence intervals and associated error in prediction of axle load distribution, truck traffic distribution and AADTT for a given amount of traffic collection days based on LTPP data. Utilizing 12 weeks at 7 days per week yields a total of 84 collection days for a given year. The manual states that at a 95% confidence level, 84 days of collection will produce a 1-2% error in axle load distribution, 2-5% error in truck traffic distribution, and a 5-10% error in AADTT (1).

Additionally, another independent FHWA study assessed the actual variability in pavement life prediction. The study involved analyzing WIM stations, automatic vehicle classification (AVC) and automatic traffic recorder (ATR). The results most similar to the one week per month over 12 months WIM station collection scheme was regional data from AVCs consisting of 1 month for each of the 4 seasons and 1 week for each of the 4 seasons. For the given pavements utilized, at a 95% confidence level, the overall range in error from variation in traffic data prediction and difference in performance prediction from continuous data is approximately 38% and 50% respectively. It should be noted that continuous site specific WIM data was regarded as the “true” measure of truck traffic and performance prediction (4).

The Traffic Monitoring Guide (TMG) recommends that for any truck weight road group (TWRG) formed, at least one continuous WIM station should be incorporated to provide the most accurate truck traffic factors (5). Most encountered analyses on the subject of evaluating the effect of traffic sampling recognizes continuous site specific WIM data as the actual truck traffic pattern of the site.

2.3 WIM AND CLASSIFICATION SENSOR OVERVIEW

A review of the recommended data collection efforts was performed in order to make recommendations as to changes needed in the MDOT infrastructure or administration to accurately capture the traffic characterizations found in the state of Michigan. The data collection efforts consisted of:

- The WIM and classification equipment used in the state of Michigan
- Methodologies for quality control to ensure data accuracy.

- The count programs needed to establish volume, vehicle classification and axle loading

2.3.1 WIM and Classification Equipment Used in the State of Michigan

At the commencement of this project, the MDOT maintained several types of permanent WIM and classification sensor equipment for acquiring the Level I data provided for this research. The type of permanent sensors used along with a general operational description is outlined below:

- Bending plate
- Piezoceramic cables
- Piezopolymer cables (BL sensors)
- Piezoquartz sensors

Bending Plates: Bending plates have dimensions of roughly 6' long by 2' wide in which one plate is installed in each wheel path, either aligned in parallel or staggered fashion, flush with the pavement. The bending plate is placed in its own steel frame and is not as impacted on performance of the surrounding pavement. This ensures more accurate data. Two inductance loops usually accompany the bending plate to differentiate between vehicles and measure speed. Strain gauges are mounted to the underside of each plate. When a vehicle passes over the plate the strain measured by the sensor is converted to the amount of loading needed to produce that strain (6).

Piezo Cables: All piezo cables operate in a similar manner. A narrow cut, roughly 2" wide, is placed in the pavement and the piezo cable is placed so that the top of the sensor is flush with the pavement. When a truck passes over the sensor, a voltage is created which is converted into a load that would be required to produce the measured voltage. Typical piezo sites can consist of two piezo sensors, two piezo sensors and an inductance loop, or one piezo and two inductance loops. These configurations allow for the measurement of vehicle speed and axle spacing. The latter is necessary for vehicle classification as piezos are axle based classifiers based on the standard FHWA 13 vehicle classes, which the MDOT utilizes. Besides enhanced accuracy, piezoquartz sensors have an advantage over the other piezo sensors in that it is insensitive to temperature, a significant factor in a continental climate such as Michigan (6).

A limited review of the strengths and drawbacks of using the aforementioned sensors as suggested by Hallenbeck and Weinblatt is contained in Table 2.2 (6).

Table 2.2 Strengths and Drawbacks of Perm. WIM and Classification Sensors in Michigan

Type of Sensor	Strengths	Drawbacks
Classification		
Piezo Cable (ceramic, polymer[film], quartz)	Widely used and supported Best practices information available Ease of deployment Can work well in areas of high volume, if speeds are stable	Requires regular maintenance Difficult to maintain in areas of high traffic volume
WIM		
Piezo Cable (ceramic, polymer)	Easier, faster installation than most other WIM systems Generally lower cost than most other WIM systems Well supported by the industry	Sensitive to temperature changes Accuracy affected by structural response of the roadway Less accurate than piezoquartz Susceptible to lightning Meticulous installation required
Piezoquartz	Easier, faster installation than most other WIM systems May be more cost-effective (long term) if sensors are long-lasting Very accurate sensor Sensor is not temperature sensitive Growing support by industry	More expensive than other piezo technologies Requires multiple sensors per lane Above average maintenance requirement Sensor longevity data not available Accuracy affected by structural response of roadway
Bending Plate	Frame separates sensor from pavement structure Entire tire fits onto sensor Moderate sensor cost Sensor is not temperature sensitive More accurate than piezo cables Extensive industry experience with technology	Longer installation time required than piezo technologies Variability in sensor life

A more extensive review of each of the equipment summarized in Table 2 as well as other sensors available for permanent continuous data collection can be found in Chapter 2 and Chapter 3 of Halenbeck and Weinblatt (6).

While not reviewed in this project, it is recommended, as will be described in subsequent sections, that short-duration data collection be performed in addition to continuous collection. The following equipment is typically used for short-duration portable WIM and classification data using the FHWA 13-category system (6):

- Road tubes (Classification only)
- Piezoelectric sensors
- Capacitance mats (WIM)

Road tubes: Road tubes are the most frequently used short-duration classification sensor. Road tubes are pressure sensitive sensors, meaning that when a vehicle passes over the sensor, the air burst delivered inside the tube is converted to an electronic signal which marks the passing of a vehicle. The typical configuration is two road tubes placed parallel to one another on the road surface and perpendicular to traffic flow at a known distance apart. The distance setting allows for the calculation of vehicle speed and distance between axles (6).

Piezoelectric sensors: The piezoelectric sensors operate in the same manner as those reviewed for continuous data collection. The significant difference is that the portable short-duration sensor is mounted on top of the pavement surface rather than within the pavement surface. It causes additional dynamic forces which leads to the improper calculation of vehicle weight. Additionally, the dynamic impact could allow the sensor to inadvertently detect the presence of two axles instead of one, creating errors in vehicle classification as well. The need for significant calibration and accommodation for the inaccuracies of recorded weights can make DOTs decide against the use of portable WIM. Instead, placing more continuous, permanent WIM stations, flush with the pavement, is favored to collect additional weight and classification data using this sensor (6).

Capacitance mats: Capacitance mats, like piezoelectric sensors and road tubes are placed on the surface of the roadway. They consist of two metal plates with a dielectric material in between. They are placed in only one wheel path of the lane. When a vehicle passes over the mat, the plates are pushed closer together, increasing their capacitance. This capacitance increase is converted to the weight required to induce the capacitance. Since the mat is placed above the roadway, additional dynamic forces are created by the “bump” which, similar to piezoelectric sensors, causes inaccuracies in calculated vehicle axle weights (6).

Table 2.3 provides a limited review of the strengths and weaknesses of using the available portable sensor technology to collect short-duration WIM and Classification data.

Table 2.3 Strengths and Drawbacks of Portable Classification and WIM Technology

Type of Sensor	Strengths	Drawbacks
Classification/WIM		
Road Tubes	Inexpensive Very common Easy to use	Inaccurate under high volumes Difficult to install on multiple lanes
Piezo Cable (ceramic, polymer[film])	Ease of development Inexpensive sensor cost Classification data is considered reliable	Can be difficult to place in high-volume traffic conditions Sensitive to variations in temperature More accurate if used as a permanent installation Susceptible to lightning
WIM		
Capacitance Mats	Ease of deployment Modest sensor cost	Only measures one wheel path Creates the largest “bump” of the portable technologies

A more extensive review of each of the equipment summarized in Table 2 as well as other sensors available for permanent continuous data collection can be found in Chapter 2 and Chapter 3 of Hallenbeck and Weinblatt (6).

It is at the discretion of MDOT to select the proper equipment for its data collection efforts. When selecting the appropriate equipment for use Hallenbeck and Weinblatt suggest reviewing the following (6):

- Data collection needs of the users
- Data handling requirements and capabilities of the highway agency
- Characteristics of available makes or models of equipment

In addition to these considerations the actual physical characteristics of the site must be considered. For most equipment the site must meet the following criteria (6):

- Flat pavement (No horizontal or vertical curves)
- Smooth pavement(No bumps)
- Strong pavement
- Vehicles maintain a constant speed, usually above 10 mph
- Vehicles do not follow close to one another (as in urban areas)
- Vehicles maintain lanes

If the aforementioned properties are not met, weight and classification have the potential to be highly erroneous despite the best of calibration efforts. Poor pavement conditions will result in improper weight data while sporadic vehicle behavior will result in classification inaccuracies.

A more extensive list of questions that each agency should address for these issues can be found in Chapter 4 of Hallenbeck and Weinblatt (6). A sample selection sheet is also provided for use in choosing the proper equipment needed for the data collection effort.

2.3.2 Error Sources

Attention must be given to the potential errors that can be encountered when recording traffic data at WIM and classification stations as well as methodologies to detect those errors. The following summarizes the literature found on this subject.

The TrafLoad manual specifies eight sources of error associated with the collection of traffic loadings (3):

- The calibration of the data-collection equipment
- Differences in axle-weight distributions among different VCs
- Differences in vehicle loading rates between one road and another
- Differences in vehicle load by direction
- Variation in axle weights caused by changes in loading conditions by time of day
- Variation in axle weights caused by changes in loading conditions by day of the week
- Variation in axle weights caused by changes in loading conditions by time of year
- Future changes in loading conditions

WIM equipment is especially sensitive to calibration error, which is in turn affected by sensor installation, sensor condition, pavement roughness, environmental conditions and roadway geometrics (3). A study by Prozzi and Hong found that a 1% under calibration can cause a 3% overestimation of pavement life in flexible pavement design in the M-E PDG. The authors also found that a 1% over calibration lead to approximately 2% underestimation of pavement life (7). To reduce sensor error from environmental conditions, it is suggested that sensors be placed in a smooth, flat structurally sound pavement in good condition to ensure sensor accuracy. Producing 300’ concrete sections could provide a more structurally and long lasting base for sensor placement. Sensors also must be placed away from areas in which trucks will be either accelerating or decelerating and will maintain their lane when passing over the sensor (6). Calibration must be conducted periodically to ensure accurate weights are being taken.

The differences in axle load spectra amongst the different VCs are accommodated by the separation of each axle load spectra for each VC in the M-E PDG. The TrafLoad software is capable of generating axle load spectra for each VC and each axle configuration.

Differences in loading rates across various roads and between directions are due to differences in commodities carried and amount of loaded trucks (3). Variation by day, week or month is also heavily dependent on commodity and economic activity in the area. These economic activities must be tracked to ensure proper loadings are taken.

Seasonal changes are captured by creating axle load spectra for each month. The M-E PDG program assumes that loading rates do not change over the course of the design life. Research has supported that axle loadings do not vary from year to year (2). However, it is still possible that load distributions can change over time and could be a function of the following (3):

- Truck size and weight laws
- The commodity characteristics of specific routes
- The fraction of loaded and unloaded trucks on the roadway (trucking efficiency)

To accommodate for such changes, traffic loadings on roadways must be periodically checked to ensure temporal variation has not occurred.

The TMG provides the following sources of error for the collection of truck classification data from axle-based sensors (5):

- Inaccuracies in the distance measurement between the two axle sensors
- Inaccuracies of axle sensors
- Improper development of sensor classification algorithm (lack of calibration)
- Presence of more than one vehicle class with similar axle spacing
- Variable speed of vehicles as they pass over the sensor
- Lack of lane discipline when passing over the sensors
- Change in classification distribution and volume counts over time

The first four errors mentioned are controlled through the proper selection, installation and calibration of the classification sensor equipment. As with WIM sensors, classification sensors need to be put in structurally sound pavement that is free of bumps which may interfere with the determination if a truck axle has passed. Properly configuring the sensor and developing a robust algorithm for the conversion of axle spacing to vehicle classification will limit the number of erroneously classified vehicles.

The next two errors pertaining to vehicle movement over the sensor can be controlled through the proper selection of the site. Placement on a straight, limited access stretch of roadway with no stop-and-go traffic will allow trucks to pass over the sensor as designed. This will allow the sensor to perform as desired. However, even with these steps, the sensor should provide a log of the amount of unclassified or improperly classified vehicles so that the agency can determine if the site is working properly.

The final error pertains to the temporal variations of truck traffic distribution and volume over time. The M-E PDG assumes that vehicle classification does not change over the design life. Traffic volumes are accounted for by applying a growth factor algorithm within the program.

2.3.3 Quality Control

Since WIM and classification sensors have the potential to yield inaccurate traffic data, it is necessary to perform quality assurance checks to determine if the acquired data is erroneous. The general methodology for the quality control check is to review the data and flag any traffic patterns that are indicative of deviations from known trends. Particular emphasis is placed on analyzing VC 9 traffic (standard 5- axle tractor semi-trailer), which is well documented due to its prevalence in the traffic stream. The TMG recommended reviewing some of the following anomalies in VC 9 gross vehicle weight (GVW) that suggest possible site or calibration failure (5):

- A shift in peak loading value (calibration drift)
- High percentage of vehicles heavier than 80 kips
- A flat weight distribution (scale failure)

The TMG states that unloaded VC 9 trucks should have a GVW between 28 and 36 kip while loaded trucks should be between 72 and 80 kips. Simultaneous shifts from both of these peaks to either lower or higher weight value suggest that the WIM site has fallen out of calibration. A shift in only one peak can also be an indication of scale failure (5).

The maximum allowed GVW for VC 9 trucks is approximately 80 kips. If it is found that a large number of trucks are over this limit, the sensor should be checked for possible errors, unless this type of overloading is common (5). In Michigan, the maximum allowable load for VC 9 trucks is approximately 83 kips, as given in Table 11 of this report. As such, a large frequency of trucks exceeding this limit should not be expected. The TMG also states that when a WIM sensor fails, particularly a piezo-electric, an almost flat GVW distribution is produced.

It is also suggested that the recorded axle spacing of the tractor tandem axle on VC 9 trucks be checked as it is a fairly consistent parameter across the truck fleet. If this value is incorrect, it is possible that weights measurement and classification could be invalid.

In addition to reviewing weight data, Hallenbeck and Weinblatt (6) noted other checks that can be administered to collected traffic data to verify if the sensor may be failing:

- AADTT counts significantly off from previous records
- A change in VC9 percentage trucks from previous data collection
- Unusual HDF patterns
- Hours missing from the dataset
- Scale’s diagnostics reporting problems

Similar to VC 9 axle loading data checks, the majority of these suggestions involve comparing collected data with previously known trends of the site. Monitoring truck volumes and percentages for unexpected increases in volume as well as shifts in vehicle class distribution provide an indication of sensor failure.

LTPP also had a range of suggested data checks. While most checks echoed those already mentioned, there were a few reviewed that especially pertained to classification data. Table 2.4 reveals these LTPP checks along with the causes of error (8).

Table 2.4 Potential Classification Error Checks and Sources

Classification Data	
Check	Error
Abnormally large presence of motorcycles	Time-out or vehicle thresholds are too low
Large number of VC 8 vehicles	Closely following pairs of cars are recorded as trucks Passenger vehicles pulling trailers are being classified as tractors pulling trailers Axle sensors are routinely missing one of the tandem axles on conventional 5-axle tractor semi-trailer trucks.
Unusually large numbers of other VCs	Algorithm not properly configured to describe state's vehicle fleet.

It should be noted that this is only a limited review of quality control checks that can be implemented. It is at the discretion of the MDOT how to apply appropriate data control processes needed to verify the quality of collected traffic data. A more comprehensive review of data quality control checks can be found in the literature (3, 5, 6, 8)

2.3.4 Count Programs

A state highway program needs to collect the following truck data at a minimum (3, 5):

- Short-duration volume counts
- Continuous volume counts
- Short-duration classification counts
- Continuous classification counts
- WIM measurements

To facilitate this collection effort a modest number of continuously operating sites will be needed with a substantial amount of short-duration counts. The large amount of short-duration allows for the expansion of coverage within the state, while the continuous counts are performed for the creation of adjustment factors, such as time-of-day, day-of-week and seasonal adjustments (MDFs) for the short-duration counts (3,5). Wherever possible, TMG recommends the collaboration of data collection efforts between states and within states. Counts and weight measurements taken by neighboring states along with county and city operations such as intelligent transportation systems (ITS), long term pavement performance monitoring, weight enforcement and toll facilities can enhance the state's collection program (5). Such enhancements are better distribution of resources, more effective quality control, and reduction of wasted duplicative effort. The following highlights the data collection efforts needed to produce the aforementioned counts.

2.3.4.1 Uses and Output of Count Programs

The primary goal of volume counts is the collection of AADTT for the site. Volume counts are necessary for (5):

- Safety analyses endeavors
- Vehicle loading applications
- Vehicle use as part of revenue forecasts
- Statistics used by private sector for placement of business and services

Traffic classification is needed to determine the volume of each vehicle class present on the roadway. This data has implications on the following (5):

- Pavement design
- Pavement management
- Prediction and planning for commodity flows and freight movements
- Development of weight enforcement strategies
- Vehicle crash record analysis
- Environmental impact analysis
- Analysis of alternative highway regulatory and investment policies

Loading data from WIM stations collect axle load spectra by vehicle class and axle type. They are needed for but not limited to the following:

- Pavement design
- Pavement maintenance
- Bridge design
- Pavement and bridge loading restrictions
- Determination of need and success of weight law enforcement actions
- Determination of the need for geometric improvements
- Determination of need of safety improvements

As stated previously, in order to meet the needs of state agencies and others the volume count program should consists of the following:

- Short-duration volume counts
- Continuous volume counts

The following section outline the goals and reasoning behind each type of count, along with the recommended duration and location of the counts.

2.3.4.2 Short-Duration Count Program

A short-duration count program consists of coverage counts, which allow for the expansion of data coverage within the state and "special needs" counts, which are used for individual purposes such as project design or traffic study counts (5). The TMG recommends that the short duration volume coverage count program should provide comprehensive coverage across the roadway infrastructure on a cycle of 6 years. Short duration classification counts should account for at least 25-30% of all volume counts being conducted wherever possible. Additionally, at least one vehicle classification count should be made on each route annually (5). Taking counts over a cycle period ensures that at least some data is recorded for a particular roadway segment. However the state agency might need to collect more frequently than this based on available funding, the use of the data and the level of accuracy required. Particular areas where this would be needed are high-growth urban or recreational settings in which traffic can be highly variable (5). A roadway segment is typically considered to be in rural roads areas a 10-mile stretch of road with limited access and on interstates where individual traffic counts are within 10% that do not encompass interchanges. When performing short-duration coverage volume counts, a minimum of 48 hours should be collected (5). When performing classification counts, hourly volumes should be taken, for all lanes and all directions. For discontinuous WIM sites, the TMG recommends that one-week's worth of data should be recorded to account for day-of-week differences (5). Permanently mounted sensors should be used to collect discontinuous data as significant accuracy issues are associated with portable sensors. It is recommended that the count program should collect hourly volumes by direction and lane. This aids in signal timing, air quality analysis, noise analysis, planning studies and planning and timing of maintenance activities (5).

In addition to coverage counts, "special needs" counts are used for creating statistical samples for developing system wide summary measures and for the creation of point-specific estimates intended to meet project requirement and other studies. Statistical samples are created through random sampling of the roadway infrastructure to calculate unbiased estimate of traffic population means and totals. This however, can be an inefficient way of gaining understanding of a state's traffic data. Conversely, point-specific estimates gain site-specific knowledge of the traffic volumes that the roadway will experience and are implemented directly in design (5).

The coordination of effort between the collection of coverage counts and "special needs" counts allows for efficient use of agency resources. Ideally, the state agency should have an understanding of all counts that need to be performed, and determine if certain counts can be made for more than one purpose. This "list" should then be checked against known permanent counters to eliminate duplicative short-duration counting efforts. Additionally, the data collection needs of these locations should also be examined. For example, if more than a volume count is needed, a classification or WIM sensor that collects volume count data would be more appropriate resource than a counter. Again, it is necessary to convert these counts into unbiased estimates through adjustment factors. Guidance on factoring can be found in Chapter 3 of Section 3 and Chapter 4 of Section 2 in the TMG (5).

Short duration counts need to be designed so as to cover the state geographically as much as possible. The intent is to capture all traffic patterns that are found within the state. These travel patterns can be different due to physical attributes of the roadway and nature of trucking movements. Truck traffic in urban areas can exhibit different loadings than those in rural areas. Roads that serve agricultural sources can have different loadings and classification distributions than those for industry (5). Truck volumes can be dependent on functional class. Different geographical regions can also produce varying volume patterns, classification distribution and loading values due to freighting movements, and the nature of the road (through trucks vs. local). The coverage program needs to identify each of these elements and discern predictable traffic patterns from them. Commercial vehicle volume, classification and tonnage maps can be particularly useful in selecting homogeneous groups for each type of traffic characteristic (5).

2.3.4.3 Continuous Count Program

Vehicle classification, vehicle volumes, and axle loadings could vary by (5):

- Time of day
- Day of week
- Time of year
- Direction
- Geography

In addition to collecting accurate truck traffic data, continuous counts should be performed for the creation of adjustment factors to account for such variation, especially for the short-duration counts (3, 5). These counts are also usually established to observe unusual trends in traffic movement, confirm previous counts from historical data or to expand data coverage in areas which little information about traffic volume is known.

The TMG recommends the following guide for selecting continuous count locations (5):

- Determine “statewide” objectives for the continuous count program. Establish the number and distribution of count locations to develop adjustment factors.
- Determine what continuous data collection is needed for specific projects and what continuous data collection exists or is planned for operational purposes such as traffic management or weight enforcement
- Determine available funding
- Prioritize the “specific” project locations
- Place counters and WIM devices at the “specific” project locations for which funding exists
- Determine how the project data collection efforts help “statewide” needs such as factor group creation.
- Determine the number of additional continuous count and WIM locations to meet statewide needs
- Prioritize the remaining “statewide needs” locations

- Allocate counters and WIM devices to these “statewide needs” locations based on priority and available funding
- If funding remains after statewide needs are met, place additional continuous counters at the “specific” project sites for which counters are not currently allocated.

The number of continuous counters should be established in such a way that the diversity in traffic pattern can be represented while staying within budget and resource limitations.

An inventory of the current continuous volume recorders should be conducted, followed by a review of how the data are being used, who is using it, and future uses of the data if new procedures were implemented. Quality control should be addressed and put into place to ensure the data is representative of actual traffic. Systematic procedures need to be implemented in order to objectively identify invalid data, and control how the invalidated data is handled. This procedure also identifies if collected data is not being used correctly and leads to the determination of locations in need of data collection effort (5).

2.3.4.4 Continuous Volume Count Program

Determination of the vehicle volume patterns that need to be monitored has a direct impact on the number and placement of continuous volume counters. The identification of traffic patterns can be done through the use of cluster analysis as previously described. Factors such as MDFs from individual sites can be created and accordingly clustered to discover seasonal patterns in traffic volumes. These patterns can be compared against previous factor groups or patterns to determine if sites are being grouped together appropriately. This can also expose special cases in which the observed variation needs to be examined more closely, causing a need for additional continuous recording devices. In the case where cluster analysis does not compare to previously formed groups, reformation of the existing groups to form homogeneous factors is necessary. In such cases, geographical differences could separate the formed groups, or rural vs. urban designation. This more subjective approach can be beneficial when there is significant professional knowledge about the location’s travel tendencies. The TMG recommends that 3-6 volume seasonal groups be formed. Additional information on the formation of seasonal groups will be examined in subsequent sections.

The TMG recommends that for 95% confidence and 10% error in the precision of the traffic factors formed within a seasonal group, five to eight continuous counters should be established per group. Once the factor groups are formed, the locations of the continuous ATRs should be compared against the groupings. If less than five continuous ATRs exist for a group, then more will need to be added. If more than eight exist for a group, reduction or relocation of the continuous volume count sensor can be warranted (5).

2.3.4.5 Continuous Classification Count Program

Continuous counters should be placed to measure traffic volumes and distributions on different functional classes and geographic locations. They are utilized to create time-of-day, day-of week and MDFs and also assist in the application of axle correction factors to volume counts. These factors are separate than those created for volume counts as volume count adjustments do not accurately depict classification patterns (5). Roadways with primarily local traffic and primarily through traffic should be especially monitored. Highways should monitor all heavy truck movements over a variety of different roads consisting of interstate highways, major arterials, and routes with primarily intrastate freight movements (3). When forming factor groups, it is recommended that the following vehicle classes be combined to reduce computational efforts and eliminate the variability in factors from low volume classes (5):

- Single-unit trucks
- Single unit combination trucks (tractor-trailers)
- Multi-trailer combination trucks

The development of factors can be performed by having a continuous classification recorder on each roadway and have short-duration counts be adjusted based on the nearest continuous classification counter. Guidelines for adjusting short-duration classification counts can be found in Chapter 4 of Section 4 in the TMG (5). As with volume counts, vehicle class can be grouped by clustering analysis to identify traffic pattern trends in the data. The formation of truck groups are largely dictated by the amount of through trucks and the presence of agricultural or economic activity. Functional class is only applicable if it readily helps distinguish through truck movements versus local movements where interstates and principal arterials are known to have larger through movements. Areas with local truck traffic can have truck generation that is highly seasonal, such as agricultural harvesting. Thus truck commodity maps could indicate routes with similar trucking movements.

The TMG recommends that at least six continuous vehicle classification counters be established for each factor group. Continuous counts should be placed on different functional classes and different geographic regions within the state (5). Emphasis should be placed on roads that are primarily local or long hauls. When new sites are added, the data should be compared and placed into the appropriate existing factor groups.

2.3.4.6 Continuous Weight Count Program

Truck Weight Road Groups (TWRGs) are groups of roads formed by state agencies that have similar axle loading characteristics. The formation of such groups allows for the creation of axle load spectra tables which are needed when site specific load data is unavailable. There are a number of characteristics that can be used to define these groups, which include, but are not limited to (3, 5):

- Region of the state
- Areas of particular economic activity (agricultural vs. industrial)

- Nature of commodities carried
- Gross Vehicle Weight (GVW) per vehicle
- Principle trucking route (local or long-haul)
- Functional class (urban/rural)
- Percentage of empty, partial and full trucks
- Specialty cases (heavy truck patterns)

TWRGs should be established so that they can be easily applied by the state and provide a logical means to determine which roads are likely to have very high load factors and which have lower road load factors (5). Sites within a particular TWRG should have similar weight limitations, with consideration for frost restriction (3). A review of haul distances is important as combination trucks on long hauls are more likely to be fully loaded, whereas short hauls are more likely to be loaded one way and unloaded the other (3). Hence, urban areas and non-interstate rural routes are likely to have lower axle load spectra than main interstate routes. It is also recommended that the TWRGs formed be similar to the classification groups formed wherever possible. However, forming homogeneous groups across various traffic characteristics may not be entirely possible. Sites with directional differences in axle load spectra should be assigned their own TWRG. Such differences could include gravel haulers taking gravel to the site in one direction and returning empty for another load in the other. The TrafLoad manual offers guidance on the categorizing of a site into a TWRG. The following highlights this guideline (3):

1. Group each roadway together which contain similar size and weight limitations
2. Assign each road within a certain weight limitation the following:
    a. Functional Class/System (urban, rural, rural interstate, rural other)
    b. Region
    c. Direction
3. Divide up the above TWRGs into further groups if density of commodity or axle load spectra by direction varies.

The TrafLoad manual suggests there should be between three and eight sites in a TWRG (3). The TMG recommends that for all sites within a TWRG, a minimum of six should be monitored, with at least one of the WIM sites operating continuously and recording two or more lanes of traffic (5). The amount of permanent WIM stations and discontinuous portable systems is a function of the number of TWRGs created, the accuracy at which the measured weights are taken, and the budget of the state agency (5). Any additional site added to the group should be established in such a way that accurate data can be taken from the site. For roadways with unknown axle loadings, accuracy of the WIM data is paramount to physical placement of the site itself (6). More monitoring is implored but is at the discretion of the respective DOT based on manpower and budget limitations.

WIM collection sites should be distributed in such a way so as to measure truck patterns that differ by region or type of road. Each time a station is moved, the WIM site should be relocated to a location in which axle load spectra are unknown so that coverage of the state progressively increases. It is recommended, wherever feasible, that continuous permanent WIM stations be placed to accurately measure truck traffic data (3).

The selection of new WIM sites should be based on the following (5):

- The need to obtain more vehicle weight data on roads within a given truck weight group
- The need to collect data in geographic regions that are poorly represented in the existing WIM collection effort
- The need to collect data on specific facilities of high importance
- The need to collect data for specific research projects or other special needs of the state
- The need to collect weight information on specific commodity movements of importance to the state.

Caution should be given towards the placement of the WIM stations. WIM stations placed before load enforcement stations could produce biased results of the axle loadings. The TMG states that the number of WIM stations established within a state should fall between 12 and 90, where more stations should be added if there is a need to understand traffic data for a certain area.

2.3.4.7 Administrative Efforts

In order for traffic count programs to be successful, administrative efforts will need to be applied to ensure data is being properly collected, summarized and used. To facilitate this, the TrafLoad manual recommends the following administrative tasks (3):

Training for pavement designers on

- What traffic data are needed
- Why the data is important
- What effect the data will have on pavement design
- Where to acquire the data that has been collected
- How to request more data when available data is insufficient
- How to review traffic estimates being provided

Training for data-collection and analysis staff on

- What data are important for pavement design and what produces the most significant effect
- How that collected data will be used in the design process
- What the flow of traffic load data is in the pavement design process

Increased communication that

- Allows data-collection staff to correctly anticipate and schedule the data needs of designers
- Ensures the data and summary statistics produced by the data-collection personnel meet the needs of the pavement designers
- Ensures that the data required are transmitted to the pavement design staff in a timely manner and in a format that can be easily loaded into the mechanistic design software.
- Involves both the pavement design and data collection staff in the review and refinement of the data-collection and summarization process used to feed the design process.

A review of the

- Resources spent collecting traffic data.
- The relative value to the pavement design engineers of the various resources.
- The potential value of additional data collection expenditures to the program.

Heavy emphasis is placed on the need for effective communication between data collection personnel and pavement design engineers. It is paramount that each side understands one another's needs. In addition to a collaborative effort, summary of the data is crucial for creating a potent data collection and pavement design system. Readily accessible and relatable summarized traffic information makes efficient use of data collection efforts. Wherever possible, the collected data should be placed in a computer-based program, preferably with GIS linkage that allows for easily summarization and retrieval (5). Institutional changes must be made to ensure these guidelines are met.

2.4 OVERVIEW OF TRAFFIC CHARACTERIZATION PATTERNS

An overview of observed traffic characterization patterns in the literature prepared the staff with an idea of what could be expected from Michigan data. A review of the M-E PDG defaults was also performed for comparison. Emphasis was placed on the following traffic characterizations as they are readily grouped and compared for similarities by many state agencies.

- Truck Traffic Classification (TTC)
    - Percentage of truck traffic for each FHWA vehicle class 4-13, ten total
- Monthly Distribution Factor (MDF)
    - Set of 12 factors, one for each month
- Hourly Distribution Factor (HDF)
    - Set of 24 factors, one for each hour
- Axle load distribution/spectra
    - Loading proportions for each vehicle class and each axle group, 40 total

Each traffic characteristic is further discussed into the following:

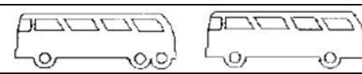
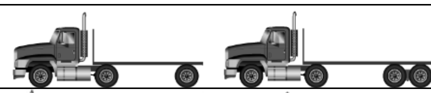
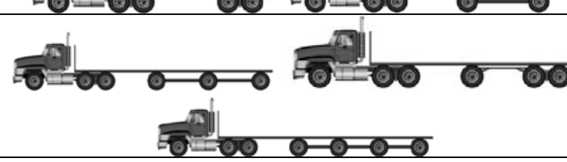
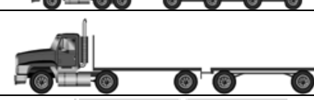
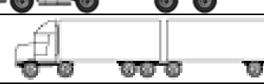
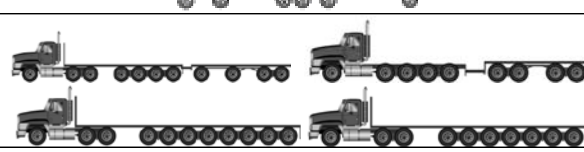
- Traffic characterization
- The effect each traffic characteristic has in the M-E PDG design

2.4.1 Traffic Characterization

2.4.1.1 Truck Traffic Classification

The FHWA separates all traffic into 13 vehicle classes, Class 1-Class 13 as shown in Table 2.5. The truck classes constitute Class 4-Class 13. There are two distinguishing characteristics regarding the classification of any truck: number of axles and trailer type, whether it is single unit, single trailer or multi-trailer. This separation is necessary as the gross vehicle weight (GVW) as well as the trip type, long haul or local can be characterized by the particular truck type. The GVW of each class will be discussed further in the discussion of axle load spectra.

Table 2.5 FHWA Vehicle Classes

FHWA Vehicle Class	Description	Example Vehicle Configuration
4	Two-Axle Buses	
5	Two-Axle, Six-Tire, Single-Unit Trucks	
6	Three-Axle Single-Unit Trucks	
7	Four or More Axle Single-Unit Trucks	
8	Four or Fewer Axle Single-Trailer Trucks	
9	Five-Axle Single-Trailer Trucks	
10	Six or More Axle Single-Trailer Trucks	
11	Five or fewer Axle Multi-Trailer Trucks	
12	Six-Axle Multi-Trailer Trucks	
13	Seven or More Axle Multi-Trailer Trucks	

NOTE: In reporting information on trucks the following criteria should be used:

- Truck tractor units traveling without a trailer will be considered single-unit trucks.
- A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered one single-unit truck and will be defined only by the axles on the pulling unit.
- Vehicles are defined by the number of axles in contact with the road. Therefore, "floating" axles are counted only when in the down position.
- The term "trailer" includes both semi- and full trailers.

The M-E PDG manual (1) reveals that VC 5 and VC 9 vehicles dominate the truck traffic distribution, with varying percentages of other truck classes. In research with national LTPP data related to the development of the M-E PDG program, it was found that three discernible patterns emerged:

- Equal frequencies of VC 5 and VC 9 trucks
- Higher frequency of VC 5 compared to VC 9
- Higher frequency of VC 9 compared to VC 5

Similar research (2, 9, 10, 11, 12) in Washington, Arkansas and California along with other national LTPP data, supported the same findings. When trying to form sites with similar Truck Traffic Classification (TTC), it was found that functional class or highway designations were not homogeneous within the TTC groups formed (2, 9, 11). Additionally, in the California study, number of lanes, direction, truck volume and percentage did not have any dominating patterns within the TTC groups. Instead it was found that geographical location and trucking route behavior, such as local or long hauls were more of a determining factor (2). TrafLoad states that single unit trucks, Classes 4-7 are typical of more local trips whereas single and multi-trailers have more long-haul behavior (3).

The M-E PDG offers 17 varying TTCs default values for use in design and are shown in Figure 2.1.

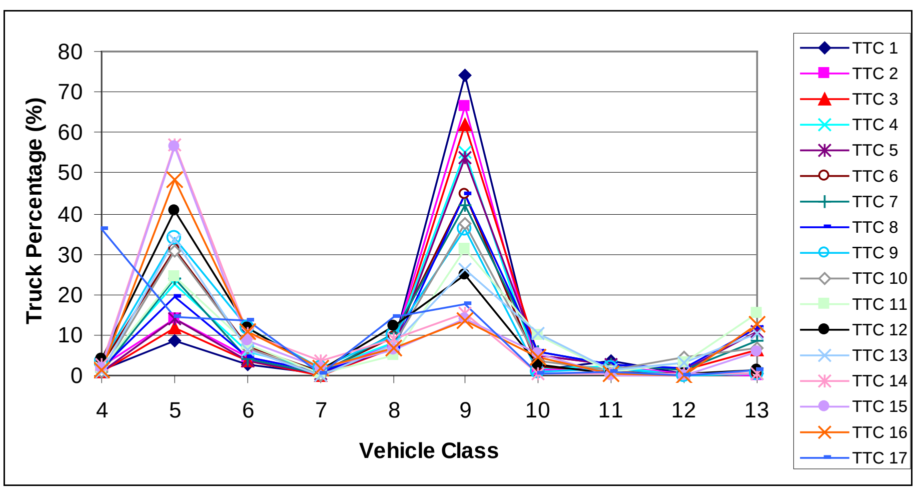


Figure 2.1 M-E PDG Default TTC Distributions

2.4.1.2 Monthly Distribution Factor

The monthly distribution factors (MDFs) convey the seasonal differences in AADTT by assigning a normalized weight factor to each month of the year. A seasonally independent value of 1 for each of the 12 MDFs in the M-E PDG is assumed as the default, Level III, data. Consequently, months with higher AADTT than others will receive a weight factor greater than 1 while months having lower AADTT will be assigned a weight factor less than 1. Other studies (1, 5, 9, 12) which evaluated MDFs, found varied distributions. Research presented in the Traffic Monitoring Guide TMG has suggested that two traffic patterns exist, consisting of a "flat urban" which is seasonally independent, and a "rural summer peak" in which the summer months experience higher AADTT than the winter (5). The TMG also states that most states track four or more seasonal patterns, based on a combination of functional class and geographic location. Additionally, MDFs can also be dependent on localized truck movements, particularly in agricultural areas (5). Subsequent analyses of MDFs in California found that most of the truck traffic exhibits a peak in summer months and a decline in the winter, with a peak value of 1.1 in the August and a low value of 0.9 in January (12). It was noted in this study that deviation from this base pattern could be attributed to local economic activity, such as logging or agricultural activities. Work by Tran and Hall showed that most of the sites in Arkansas showed peaks prior to the summer months and Christmas (9). Tam and Quintus, however, could not find a definitive monthly volume change within the traffic stream and recommended the default value be used unless a visible or known pattern can be determined (11). The M-E PDG Design Guide states that pavements may be sensitive to MDFs and are influenced by factors such as adjacent land use, location of industries in the area, and whether the site is rural or urban (1). The following can be stated in regards to seasonal factor groups from the TrafLoad manual (3):

- Seasonal variation is less in urban areas than rural
- The highest volumes are seen May-October, with the lowest being in January
- Local influences such as agricultural harvesting or mining can create significant seasonal variation on rural and non-interstate roadways
- Roads with more diverse truck classes limits the effect of local effects on seasonal patterns

2.4.1.3 Hourly Distribution Factor

HDFs establish the percentage AADTT that travel on the roadway for each of the 24 hours within a day. As most can relate to the increase of cars on the roadway during rush hour, or peak hour, time frames, trucks also exhibit time dependent behavior. The review of the literature found that most Hourly Distribution Factors (HDFs) exhibited a trend of having a peak period between the hours of 10:00 am and 5:00 pm (2, 11). The TMG cites a 1997 FHWA study by Hallenbeck (5) in which trucking patterns were found to exhibit two types of patterns. The first one being an almost constant percentage of trucks each hour throughout the day and the other having a single humped peak, typically during the morning. The constant percentage trucks throughout the day signified a greater presence of long-haul through trucks whereas the peaked distribution was found to be consistent with local trucks (5). Grouping of HDFs by Lu and Harvey (2) revealed three patterns.

The first pattern had the distinct peak between 10:00 am and 5:00 pm, which was typical of most sites. These sites were found to be urban in nature and were characteristically short hauls. The second grouping was much flatter, having closer to an even distribution across all 24 hours of the day. A check of these sites revealed they were more rural in nature and were on routes known for long hauls. The final grouping was a mixture of the first two, not as peaked as the first yet not as flat as the second. These sites were located in rural areas typical of having more medium distance hauls (2). In a study by Tam and Von Quintus that utilized national LTPP data found that most sites had similar peaked distribution between the hours of 10:00 am and 5:00 pm and little difference between rural and urban sites (11).

The M-E PDG establishes a HDF based on 5 distinct time-frames in which the hourly truck percentages within the specified time frame are constant. These time frames are (a) midnight to 6:00 am (b) 6:00 am - 10:00 am. (c) 10:00 am – 4:00 pm (d) 4:00 pm. – 8:00 pm and (e) 8:00 pm – midnight (1). The default HDFs in the M-E PDG are shown in Figure 2.2 while the actual values and time frames are shown in Table 2.6.

Table 2.6 Actual HDF Default Values in the M-E PDG

Hour	HDF	Hour	HDF
0	2.3	12	5.9
1	2.3	13	5.9
2	2.3	14	5.9
3	2.3	15	5.9
4	2.3	16	4.6
5	2.3	17	4.6
6	2.3	18	4.6
7	5	19	4.6
8	5	20	3.1
9	5	21	3.1
10	5	22	3.1
11	5.9	23	3.1

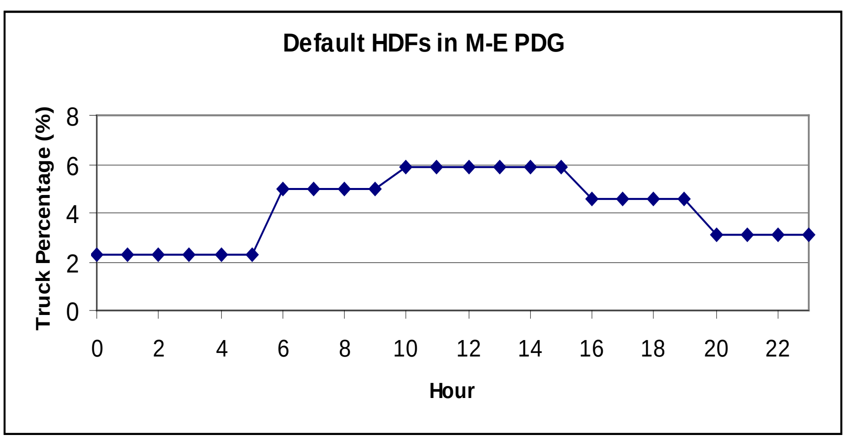


Figure 2.2 Default HDFs in the M-E PDG

2.4.1.4 Axle Load Spectra

The M-E PDG establishes an axle load spectra for each axle configuration within each vehicle class. The percentage of axles is distributed into the following load bins for each axle configuration and vehicle class.

Single: 3000-41000, in 1000 lb increments (39 bins)
Tandem: 6000-82000 in 2000 lb increments (39 bins)
Tridem: 12000-102000 in 3000 lb increments (31 bins)
Quad: 12000-102000 in 3000 lb increments (31 bins)

Research by Tran and Hall (13) found that the axle load spectra for the tandem axles could be divided into three distinct loading patterns based on cluster analysis:

- Equal proportion of loaded and unloaded trucks (light and heavy tandem axles)
- Higher proportion of unloaded trucks than loaded
- Higher proportion of loaded trucks compared to unloaded

Research by others show similar results (2, 10, 12). It was also concluded that the site specific single axle load spectra for all vehicle classes exhibited similar peaks and distribution within their respective vehicle class. As such, the researchers found it reasonable to create one set of single axle load spectra for each vehicle class to establish the statewide values (13). Working with WIM sites in California, Lu and Harvey made the following observations

- Of all steering axles in the traffic stream, most are from VC 5 and VC 9 vehicles
- Most single axles come from V C5, VC 8 and VC 11 trucks
- Most tandem axles consist of VC 9 trucks
- Most tridem axles come from VC 10 and VC 13 trucks

The study also revealed that axle loads were similar amongst region and travel corridors within the state (2).

Timm et al. cited a study performed in Texas, in which it was concluded that site specific load spectra are required for high volume design whereas lower volume sites required regional-specific data (9). The TrafLoad manual cited a California study by Cambridge Systematics in which the effect of using regional and 48 hour axle load spectra data over site specific data was studied. The research found that the regional data produced Mean Absolute Percentage Errors (MAPE) of 17-20%, while 48 hour axle load data had only 7% MAPE vs. site specific data (14).

The statistical significance of temporal and spatial differences in axle load distributions was explored by Turochy et al. at 13 WIM stations in Alabama (15). The study found statistically significant differences in axle load spectra between each day of the week and the statewide average, between each direction and the site average, as well as each of the site distributions and the statewide average. However, the authors note that the significance criterion for the test is heavily dependent on the number of sample observations, and as the number increases, small differences in axle load distribution become statistically significant.

Research by Wang et al. found that, when forming VC 9 single axle load distribution clusters from a set of 507 Midwest and southern LTPP WIM sites, the largest 10 groupings contained 80.5% of all sites. For VC tandem axles, the largest 10 and largest 20 contained nearly 55.8% and 73.5% of all sites. The findings suggested most axle load distributions could be deduced to a select few spectra. The same study also revealed that the axle load spectra exhibited significant spatial variation (16). Cluster memberships were observed to vary across and within states. Certain cluster could be seen in multiple states while others existed within one specific geographical area. Temporal variation was also noted. The same research performed cluster analysis of the axle load spectra for one month in 1998 and then ran a parallel cluster analysis for the axle load spectra in the same month five years prior in 1993. The results showed that the majority of sites switched cluster memberships after 5 years, revealing that axle load spectra could vary year to year (16). However, monthly variation within a current year, analyzed in other research, was found not to vary significantly (2, 10, 11, 17).

Analysis conducted on WIM stations in the LTPP North Central Region found that the differences in the axle load distributions for all analyzed WIM stations were found to be statistically different. However, reduction of the sites into three regions established axle load distributions that were not different statistically. The findings again support the reduction of axle load spectra into a select few distributions. The study also revealed the typical single and tandem axle load patterns of the regions. For single axles, the following was noted: (17)

- The maximum load observed is roughly 34 kips.
- The distribution had two distinct peaks at approximately 3.5 kips and 11 kips. The two peaks were representative of unloaded and loaded vehicles with tandem axles.
- For more than 95% of the sites, the proportion of the first peak was lower than that of the second.

For tandem axles the study noted the following (17):

- The maximum load observed was near 61 kips.
- Similar to single axles the tandem axle plots had two distinct peaks at 11 kips and 30 kips, which corresponded to mean axle loads of unloaded and loaded vehicles respectively.
- For more than 70% of the sites, the first peak contained a lower frequency than that of the second.

The research also found that 50% of all axles were single, 49% of all axles were tandem, while only 1% were tridem. In terms of ESALs, single, tandem, and tridem axles made up19%, 80%, and 1% of all ESALs respectively. (17) The findings suggest focusing the investigation on single and tandem axle load distributions, with particular emphasis on tandem axles.

2.5 EFFECT OF TRAFFIC CHARACTERISTICS IN DESIGN

Timm, Bower and Turochy (14) cited a study performed in Texas, in which it was concluded that site specific load spectra are required for high volume design whereas lower volume sites required regional-specific data. The authors also performed their own study in Alabama on the effect of flexible pavement design thickness when utilizing statewide load spectra compared to site specific load spectra. The research facilitated the averaging of single and tandem axle load spectra exclusively for obtaining statewide values and utilized an M-E design program called PerRoad to establish the design pavement thickness. The findings concluded that out of the 12 WIM stations involved, and 36 flexible designs utilized, 31 designs using the site specific axle load spectra within 0.5 in of the designs which utilized the statewide average axle load spectra. However, the researchers noted that sites with particularly heavy axle loads warranted more site specific axle load spectra as the disparity in pavement thickness for such sites exceeded 2 in for certain design scenarios. (14) The research also concluded that increasing soil stiffness reduced the difference in pavement design thickness between site specific and statewide axle load spectra.

Turochy et al. (17) assessed the practical significance of directional differences in axle distribution as well as differences between site-specific and statewide average load distribution. This was established by creating flexible and rigid designs altering only the respective axle load distribution. As access to the M-E PDG software was unavailable at the time of the study, the researchers utilized the 1993 AAHTO Design Guide to establish pavement thickness designs. The study found that directional axle load distribution was insignificant when compared to the overall site axle load spectra average, with differences in pavement thickness of 0.5 in and 0.3 in for flexible and rigid pavement respectively. Comparison of sites to the statewide average yielded rigid and flexible design of less than 0.7 in for 12 out of the 13 sites, which was considered negligible.

Tran and Hall performed an analysis of the effect of various traffic characterization inputs on flexible pavement design in the M-E PDG. Based on performance life due to rutting and fatigue cracking failure the following conclusions were reached:

- Statewide averages for M-E PDG TTC groups produced significantly different pavement performance lives (up to 20% difference) than those produced in by using the comparable M-E PDG defaults
- Statewide MDFs produced similar performance results as those generated from M-E PDG default values.
- Statewide HDF values did not create significantly different performance life than those created by M-E PDG default values

CHPATER 3 - METHODOLOGY

A review of all procedures used to facilitate the objective of characterizing traffic data for the state of Michigan is presented in this chapter. In particular, the methodologies applied for the following elements are discussed:

- Data collection and processing
- Identification of traffic inputs in need of characterization
- Methodology used for comparing effect of data coverage
- Methodology used for traffic characterization
- Methodology for selection of appropriate traffic characterization for design

3.1 DATA COLLECTION AND PROCESSING

The data collection and processing element reviews the existing data collection sites that MDOT currently maintains in which traffic data can be extracted. Attention is also given to the procedures for the conversion of the collected traffic data into traffic inputs using the software TrafLoad. Finally, quality control review of the data is presented which leads to the final selection of sites to be used in the analyses.

3.1.1 **Review of Existing Data Collection Sites**

Continuous MDOT maintained WIM and classification sites were utilized to acquire Level 1 traffic data throughout the state of Michigan. A complete list of the MDOT permanent classification and WIM sites can be found in Tables A1 and A2 in Appendix A of this report. A graphical depiction of the location of the WIM and classification sites within the state of Michigan can be seen in Figure A1 in Appendix A. Upon the commencement of the study, a review of the MDOT infrastructure identified the following

- Forty-four WIM stations
- Fifty-one classification stations including the 44 WIM stations and seven classification-only sites.

The available data at these sites were first evaluated to determine if usable traffic characteristics could be extracted. As stated previously, the program TrafLoad (3) selected for developing the traffic characteristics requires that for Level 1 data, a minimum of one week per month for all twelve months of the year be available. The MDOT was requested to extract two-year worth of data, from November 2005-October 2007 from every site where applicable in an attempt to ensure that at least one-week's worth of data was available for every month of the year. Initially, the first week's data of each month was extracted over the selected time period to provide Level 1 inputs. Subsequent discussions with the MDOT lead to a satellite analysis in which the effect of data coverage between one week per month and continuous time frames was assessed. This comparison was made in terms of differences in

developed traffic inputs and pavement performance life. To facilitate the continuous time frame, all available data over the same time period was also extracted.
The extent of the available weight data, the “W records” or “7 cards” is displayed in Table 3.1.

Table 3.1 Summary of WIM Data Extent

Number of Sites (44)	Timeframe of Data	Number of Months Covered
35	November 2005 – October 2007	24
1	November 2005 – March 2007	17
2	October 2006 – October 2007	13
1	November 2005 – September 2006	11
1	November 2005 – April 2006	6
1	July 2007 – October 2007	2
2	October 2007	1
1	None	0

At the time data extraction was performed, site 7179 was relocated and its data was no longer available. Out of the remaining 43 sites available, only 38 had data coverage longer than the required year. These sites were selected for further processing in TrafLoad and are shown uncrossed in Table A1. Sites 6349 and 8249 were also processed, but were later removed by a QC process to be described subsequently.

The extent of the available classification data, the “C records”, or “4 cards,” is shown in Table 3.2.

Table 3.2 Summary of Classification Data Extent for TrafLoad-Validated Sites

Number of Sites (51)	Timeframe of Data	Number of Months Covered
37	November 2005–October 2007	24
1	November 2005–October 2007 Missing June 2006–September 2006	20
1	May 2006–October 2007	18
1	November 2005–March 2007	17
1	June 2006–October 2007	17
1	July 2006–October 2007	16
2	October 2006–October 2007	13
1	November 2005–September 2006	11
1	November 2005–April 2006	6
1	June 2007–October 2007	5
1	July 2007–October 2007	4
2	October 2007	1
1	None	0

From Table 3.2, a total of 44 sites have at least one year's worth of classification data. This includes the 38 WIM stations from Table 8 and an additional six classification sites. The additional classification sites selected for further processing are shown uncrossed in Tables A1 and A2 of Appendix A. Sites 6349, 8249 and 7289 were also initially processed but removed by a QC algorithm as mentioned in Section 3.1.3.

3.1.2 **Processing of Raw Data in TrafLoad**

The mathematical algorithms present in TrafLoad that lead to the development of the traffic characterizations are lengthy and descriptive in nature; therefore to save space these are not included in the main report. However, a full discussion of the processes to develop the traffic characterization from the raw WIM and classification data can be found in Appendix A.

3.1.3 **Final Processed Sites**

The conversion of continuous traffic data to the M-E PDG format for the 38 WIM stations and six classification sites was performed using TrafLoad. Utilizing the continuous data, all sites were successfully processed excluding site 6349. TrafLoad did not process the north direction for load data despite doing so for classification data. The nature of the problem was unknown. Table 3.3 contains the quantity of successfully processed weight and classification files.

Table 3.3 Quantity of Processed Continuous Weight and Classification Data

Type of Data	WIM	Classification	Totals
Weight and Classification	37	N/A	37
Weight Only	0	N/A	0
Classification Only	1	6	7
Total	38	6	44

The processed sites will be used to characterize traffic into the hierarchical levels as inputs in the M-E PDG. For the same 44 candidate sites, TrafLoad was also used to produce traffic inputs from one week per month data. There was an error in the classification files that stated the program failed to process the classification data due to a lack of 24 hours of data for some months, days of week, direction, lane and or vehicle class, for sites 6469, 8249, 7289, 2029, 7069, and 7329. Similarly, the weight data for Site 6019 had missing weight information for certain classes within a given month for weekly data. It was assumed that the WIM or classification equipment for this site could have been offline or failed during some days or hours of the weeks selected for analyses. Consequently, these sites were excluded for the comparative analysis between one week per month and continuous data. Table 10 shows the number of sites that successfully processed weight and/or classification data.

Table 3.4 Quantity of Processed One Week Per Month Weight and Classification Data

Type of Data	WIM	Classification	Total
Weight and Classification	35	N/A	35
Weight Only	2	N/A	2
Classification Only	1	2	3
Total	38	2	40

3.1.4 **Data Quality Control Review**

While it is assumed that proper calibration procedures were conducted by MDOT to ensure accurate sensor readings, equipment can fail or fall out of calibration between scheduled maintenance. As such, implementation of quality control techniques such as those outlined in the literature review is crucial in highlighting potential erroneous data. The quality control utilized in this research consisted of a proper formatting check in TrafLoad followed by a subsequent review of the processed data.

TrafLoad has a built-in formatting validation algorithm that can be applied when uploading raw weight and classification files into a database. The validation process checks each line of traffic data within a file to determine if it is in proper card-4 or card-7 format as outlined by the TMG. If TrafLoad is unable to read the file, an error message will be created indicating the problem. However, data that is properly formatted and proven to be so through the validation process in TrafLoad does not necessarily indicate that the data contained within these sites will be reliable or accurate. The true quality of the data could only be verified when all sites have been processed and results such as axle load spectra, TTC and AADTT have been evaluated for anomalies.

The quality checks performed directly on the processed traffic inputs were similar to those observed in the literature review. Since this was the first extensive traffic characterization effort in the state of Michigan, there was little axle loading information to compare the accuracy of the developed traffic data. To overcome this discrepancy, the general guidelines outlined in the TMG for detecting sensor failure utilizing GVW were applied and are repeated below (5):

- A shift in peak loading value (calibration drift)
- High percentage of vehicles heavier than 80 kips
- A flat weight distribution (scale failure)

Since TrafLoad produces axle load spectra and not GVW, a review of individual axle load spectra was performed, in particular those for VC 9. The Michigan Truck Guide (18) designates the axle load limits for trucks on Michigan roadways as shown in Table 11. In reviewing axle load spectra, significantly large overloads were deemed to be an indication of possible sensor failure.

Table 3.5 Typical Axle Load Limit and Gross Vehicle Weight Limit

Vehicle Class	Max Single Axle Weight (kips)	Max Tandem Axle Weight (kips)	Max Tridem Axle Weight (kips)	Max Quad Axle Weight (kips)	Gross Normal Axle Weight (kips)	Gross Frost Axle Weight (kips)
VC5	18		-	-	33.4	21.7
VC6	15.4	32			47.4	30.8
VC7-1	15.4	-	39	-	54.4	35.4
VC7-2	15.4	-	-	52	67.4	43.8
VC8-1	18	-	-		51.4	33.4
VC8-2	18	32	-	-	65.4	42.5
VC9-1	18	32	-	-	82	N/A
VC9-2	18	32	-	-	83.4	54.2
VC10-1	18	32	N/A	N/A	101.4	65.9
VC10-2	18	32	N/A	N/A	91.4	59.4
VC10-3	18	32	N/A	N/A	119.4	77.6
VC11	-	-	-	-	87.4	56.8
VC12	N/A	N/A	N/A	N/A	N/A	N/A
VC13-1	18	32	-	-	117.4	76.3
VC13-2	15.4	32	39	-	151.4	98.4
VC13-3	18	32	-	52	161.4	104.9
VC13-4	18	32	52	-	117.4	76.3
VC13-5	15.4	32	52	-	125.4	81.5
VC13-6	15.4	26	39	52	132.4	86.1
VC13-7	15.4	32	39	-	143.4	93.2
VC13-8	15.4	32	39	52	138.4	90
VC13-9	15.4	32	-	52	151.4	98.4

*Note: "-" indicates axle type not in configuration. N/A means data was not given for the vehicle class.

From Table 3.5, it can be determined that the maximum axle load limits are as follows:

- Single - 18 kips
- Tandem-32 kips
- Tridem-39 kips
- Quad-52 kips

As previously stated in the literature review, it was found that truck traffic in the LTPP North Central Region, which Michigan is part of, had several characteristics for single and tandem axles. For single axles, the following was noted (17):

- The maximum load observed is roughly 34 kips.
- The distribution had two distinct peaks at approximately 3.5 kips and 11 kips. The two peaks were representative of unloaded and loaded vehicles with tandem axles.
- For more than 95% of the sites, the proportion of the first peak was lower than that of the second.

For tandem axles the study noted the following (17):

- The maximum load observed was near 61 kips.
- Similar to single axles the tandem axle plots had two distinct peaks at 11 kips and 30 kips, which corresponded to mean axle loads of unloaded and loaded vehicles respectively.
- For more than 70% of the sites, the first peak contained a lower frequency than that of the second.

Based on the TMG guidelines, axle load limits in Michigan and a review of the LTPP traffic data within the region, the following criteria were established for distinguishing potentially erroneous sites from axle load spectra:

- Single axle loads beyond 34 kips
- Single axle loads that had significant deviations of peak loadings from 3.5 kips or 11 kips
- Tandem axle loads beyond 61 kips
- Tandem axle loads that had significant deviations of peak loadings from 11 kips and 30 kips
- Flat axle load spectra

In addition to a review of axle load spectra, the vehicle classification for each site was also evaluated for abnormally high percentages (greater than 25%) in vehicle classes other than VC 5 or VC 9. This can be an indication that the sensor is misclassifying the trucks per LTPP stipulations. The results of the QC review as well as the selection of the final sites for analyses are presented in Section 4.1 of chapter 4.

Prior to clustering of the data to develop Level II inputs, the review of axle load spectra and TTC for potential errors also produced valuable observations with regard to the nature and behavior of the distributions. A review of the observations made is warranted as it will have an impact on the selection and creation of traffic inputs:

- **There is very little seasonal (month to month) variation in axle load spectra for most vehicle classes.** The exceptions to this are the vehicle classes that constitute a very low percentage of the traffic volume and are on low AADTT roads. These susceptible VCs: VC 4, VC 7, VC 8, VC 11, and VC 12 can produce highly variable load spectra due to low sample size.

- **There is little directional difference in axle load spectra for most vehicle classes.** Only VC 10 and VC 13 exhibited directional difference. This most likely is due to these truck types being local in nature, perhaps traveling to and from a logging site or gravel pit. It was anticipated that VC 10 and VC 13 would contain only a small percentage of the traffic stream. Consequently, there was only a need to analyze a single direction as was done in this analysis.

- **The single axle loads within a given vehicle class for nearly all sites are similar.** This can make it possible to obtain average values for the single axle load distribution for each vehicle class with seemingly minimal error.

- **The single axle load distribution seems to depend on the quantity of VC 5 and VC 9 vehicles.** Higher proportions of VC 5 yield a single axle load spectra (all vehicle classes) that is dominant around 3-6 kips while higher VC 9 proportions lead to distributions that have high frequencies that range from 11-13 kips.

- **The tandem axle load distributions greatly depend on the axle load spectra of VC 9.** Distributions using all axle load spectra from each vehicle class compared to that of VC 9 were very similar. This suggests VC 9 controls tandem axle loading.

- **The tridem and quad axle load spectra are almost entirely composed of VC 10 and VC 13 data.** This is due to the fact that other than VC 7, which makes up very little of the traffic stream, VC 10 and VC 13 are the only axles which have tridem and quad. Focus on these two vehicle classes for the state are all that is needed to capture these axle configurations.

3.2 IDENTIFICATION OF NECESSARY ELEMENTS FOR TRAFFIC CHARACTERIZATION

The traffic elements in the M-E PDG were identified in the literature review and are again stated in Table 3.6. Traffic data required for the three the M-E PDG input levels.

Traffic elements containing hierarchical levels were the focus of this research. A more detailed explanation of the specific elements assessed is contained in Section 4.2 of Chapter 4.

Table 3.6 Traffic data required for the three the M-E PDG input levels

Data Elements/Variables		Input Level		
		I	II	III
Truck Traffic & Tire Factors	Directional distribution factor	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Truck lane distribution factor	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle/truck class	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle and tire spacing	Hierarchical levels not applicable for these inputs		
	Tire pressure			
	Traffic growth			
	Vehicle operational speed			
	Lateral distribution factor			
	Monthly distribution factor	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Hourly distribution factor	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
Truck Traffic Distribution and Volume	AADT or AADTT for base year	Hierarchical levels not applicable for these inputs		
	Truck dist/spectra by truck class	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle load dist/spectra by truck class and axle type	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Truck traffic classification group for design	Hierarchical levels not applicable for these inputs		
	% of trucks			

3.3 WEEKLY VERSUS CONTINUOUS DATA

As requested by MDOT, an investigation was initiated to establish if using one week of data coverage for each month out of the year (OWPM) is reliable enough for use in the M-E PDG as compared to using continuous data for the entire year. The six traffic characteristics included in the investigation are: average annual daily truck traffic, (AADTT), axle groups per vehicle (AGPV), monthly distribution factors, (MDFs), hourly distribution factors (HDFs), truck traffic classification (TTC), and axle load spectra (ALS).

The TrafLoad software (3), which was used in the conversion of the raw WIM data to actual traffic characterizations suggested that OWPM data is acceptable for level 1 site specific data (highest available for a given site). The traffic data was extracted from the first week of each month from November 2005 to October 2007. Further investigation of five selected sites comparing continuous data (all available days) and OWPM data suggested that use of continuous data may be warranted. Subsequent provision of continuous data coverage for 2 years for all sites by the MDOT has allowed for a more extensive examination into the differences between OWPM and continuous data.

The differences between OWPM and continuous data coverage were assessed in two ways; (a) first, the comparison was made between the numerical differences in the traffic input values yielded by OWPM and continuous data, (b) second, the differences between one-week and continuous data inputs was assessed through an evaluation of predicted performance life of rigid pavements in the M-E PDG. There were several traffic characteristics that yielded a distribution of values rather than a single variable—ALS, MDFs and HDFs. It was desirable to ascertain a single value that would capture the difference in the distributions and provide a practical and relatable quantity to draw conclusions. This method was preferred over performing statistical analysis for comparing different distributions through tests like the Kolmogorov-Smirnov (K-S). The use of a single value allows for easy application of statistics on the difference between OWPM and continuous data. For the latter case, a base design was used and PCC slab thicknesses were determined through AASHTO design methods and ESAL calculations. The M-E PDG runs were executed for continuous and OWPM data from each site. The predicted performance life based on the limiting distress, percent slabs cracked, was recorded for both OWPM and continuous data. It should be noted that all other inputs (e.g., layer thicknesses, materials, and environmental variables) were held constant so as to attribute any difference in performance life solely to the differences in inputted traffic parameters based on the data coverage.

The following sections outline the procedures for assessing the difference between OWPM and continuous data both from a traffic characterization standpoint.

3.3.1 **Manipulation of Traffic Characterization Data for Comparison**

As previously mentioned, it was highly desirable to create a single value which captured the difference between the two data sets (OWPM vs. continuous) for statistical analyses of the data. Due to the nature of the traffic characterizations varying from a single unit value (AADTT) to a full distribution such as axle load spectra, the creation of a single unit value(s) was different for each traffic characterization. As a result, it is necessary to review the process for creation of a single value for each traffic characteristic.

3.3.1.1 Average Annual Daily Truck Traffic

As AADTT is a single variable itself, the difference in AADTT was measured as the difference between continuous AADTT and OWPM AADTT. It should be noted that these AADTT values are for a SINGLE design lane direction and not two-way totals. For statistical purposes, it is necessary to normalize these “raw” AADTT value differences into percentages as the physical magnitude of the difference for a given site would misconstrue the data. Equation 20 shows the relative difference in AADTT:

$$AADTT\%_d = \frac{AADTT_c - AADTT_w}{AADTT_c} * 100 \tag{20}$$

3.3.1.2 Truck Traffic Classification

In preliminary analyses of the data, it was found that the traffic stream was largely dominated by VC 5 and VC 9 and, to a lesser extent by VC 13 trucks. Rather than comparing all 10 vehicle classes, it was decided to compare the distribution between single unit trailers (VC 4-7), tractor trailer combinations (VC 8-10) and multi trailer combinations (VC 11-13). Grouping in this way allowed more dominant truck classes to be separated, and minimized the differences that would be seen in VC that are rarely present in the traffic stream. The creation of the single value for TTC for each grouping was done by summing the vehicle class percentages from each category and subtracting one week from continuous values as shown in Equation 21. Unlike AADTT, it was not necessary to calculate a relative percentage difference, as TTC percentages were already normalized values.

$$TTC_{di} = \sum TTC_{ci} - \sum TTC_{wi} \tag{21}$$

3.3.1.3 Monthly Distribution Factor

The default MDFs created by TrafLoad were separated into the same groupings as mentioned in the case of TTC. For each truck grouping of single unit trailers (VC 4-7), tractor trailer combinations (VC 8-10) and multi trailer combinations (VC 11-13), there were 12 factors corresponding to each month of the year. As an alternative, rather than having 36 values for each site, an average difference in MDFs between one week and continuous data across the 12 months was taken for each truck grouping as demonstrated by Equation 22. It is important to note that the absolute value of the difference had to be taken since the MDFs must always sum to 12, and thus it follows that the average difference (or sum of differences) will always be zero. The result of this computation yields a single average positive difference for each truck grouping. Since MDFs are normalized values, there was again no need to establish a percentage difference.

$$MDF_{di} = \frac{\sum_{j=1}^{12} \left| MDF_{cij} - MDF_{wij} \right|}{12} \tag{22}$$

3.3.1.4 Hourly Distribution Factor

The difference in HDF values was assessed in a similar manner to that of MDFs. Since the HDF must add to 100%, differences found between OWPM and continuous data for each hour of the day would sum to zero. As such, the absolute value of the difference was taken for each hour and averaged to create a single positive value for each site. The calculation can be seen in Equation 23

$$HDF_d = \frac{\sum_{j=0}^{23} \left| HDF_{cj} - HDF_{wj} \right|}{24} \tag{23}$$

3.3.1.5 Axle Groups per Vehicle

The single value for AGPVs was created through a straight difference between continuous and OWPM data for each axle type and vehicle class. The calculation is shown in Equation 24. For tridem and quad AGPV, only data from VC 7, VC 10, and VC 13 were used as they are the only VCs that have these axle configurations.

$$AGPV_{dij} = AGPV_{cij} - AGPV_{wij} \tag{24}$$

3.3.1.6 Axle Load Distributions

Single and tandem axles were chosen to be compared as they are the most prevalent axle types in all vehicle classes (2, 19). The VC 5, VC 9 and VC 13 were analyzed only as they were shown to be the most prevalent in the traffic stream in Michigan. To determine the variation in axle load spectra, a single average axle load value for OWPM and continuous data was created by multiplying the proportion in each axle load category by the loading value of that category as shown in Equation 25. Since TrafLoad produces monthly axle load spectra for each axle, a total of 24 values were available for comparison for each VC. As it has been stated in the literature (19), little month to month variation exists in axle load spectra, annual axle load spectra values were utilized by averaging monthly spectra. The numerical difference between OWPM and continuous data was calculated by subtracting the OWPM average axle load value from the continuous average axle load value for each site, as shown in Equation 26. These values were then normalized by calculating percentage difference for the same reasoning as AADTT.

$$AL_{ij} = \sum_{k=1}^{39} ALV_{kij} * ALP_{kij} \tag{25}$$

$$AL\%_{dij} = \frac{AL_{ijc} - AL_{ijw}}{AL_{ijc}} * 100 \tag{26}$$

3.3.2 **Traffic Input and M-E PDG Performance Comparison**

3.3.2.1 Traffic Input Comparison

One sample *t*-test and paired *t*-tests for the differences between continuous and OWPM data were performed to determine if the difference was significantly different than zero (*p*-value less than 0.05 for 95% two-tailed test). The *t*-test could not be performed for the MDF and HDF values as the differences were all positive values. Additionally, summary statistics such as mean, standard deviation, standard error and a 95% confidence interval were prepared to assess the data. The result of these analyses is reviewed in Chapter 4 of this report.

3.3.2.2 M-E PDG Performance Comparison

In order to establish the practical significance of the difference between OWPM and continuous data, rigid and flexible pavements designs were developed in the M-E PDG. The base rigid design used for this analysis is contained in Table 13. This designed was assumed to be representative of conditions at a potential site within the state of Michigan based on a previous M-E PDG sensitivity study in Michigan (20). All other parameters not specified in Table 3.7 were given default values in the M-E PDG.

Table 3.7 Rigid Base Design for the M-E PDG Analyses

Layer/Detail	Elastic Modulus (psi)	Thickness (in)
JPCP	550 (MOR) 4.2M (EM)	Variable
Crushed Gravel	25000	6
Sand Subbase-A3	15000	13
Clay Roadbed-A6	10000	Semi-Infinite
Joint Spacing	15 ft	
Dowel Bar Diameter	1.25 in (<10in) 1.5in (=>10in)	
Climate	Lansing, MI	

The proper design thickness to be used in the M-E PDG was calculated by using ESALs and AASHTO Design through the DNPS86 software. The pavement design life was assumed for 20 years handling traffic at a 2% growth rate. The ESALs were calculated through the site base year axle repetitions for each loading criteria and each axle type. The base year axle repetitions were established by running M-E PDF with the data from the site and extracting the base year axle repetitions for all axle configurations from the output. The LEFs were based on a 10” pavement. This resulted in thickness designs for the 36 WIM stations utilized in this study. The classification sites were not used as there were no supporting weight data for these locations.

The M-E PDG program calculates international roughness index (IRI), percent slabs cracked and faulting as part of its rigid analysis. FHWA specifies maximum design thresholds for the rigid performance predictors for various design lives. In a preliminary analysis, 20 year performance predictors proved to be too stringent using 95% confidence in the M-E PDG; Failure was occurring in half the design life. As a result a combination of the M-E PDG default and FHWA 30 year thresholds were used as failure criteria. The thresholds were mandated as follows:

- IRI-172 in/mi (M-E PDG default)
- Faulting- 0.236 in (FHWA 30 years)
- Percent Slabs Cracked- 15% (FHWA 30 years, M-E PDG default)

It was determined that the limiting distress was percent slabs cracked in the M-E PDG. The program was first run using AASHTO pavement design thicknesses established from the ESALs generated by the continuous data set. The design life at which the percent slabs cracked reached 15% was then recorded. The pavement thicknesses were then adjusted in the M-E PDG so as to ensure the percent slabs cracked threshold was as close as possible to 20 years as shown in Table A3 of Appendix A. The program was then rerun using OWPM data. Pavement life performance was recorded and compared to that of continuous data.

The flexible base design used in the analysis is contained in Table 3.8. This was also assumed to be representative of a potential site within the state of Michigan based on the same M-E PDG sensitivity study (20).

Table 3.8 Flexible Base Design for the M-E PDG Analyses

Layer/Detail	Elastic Modulus (psi)	Thickness (in)
Asphalt	Conventional Pen. Grade 60-70	Variable
Crushed Gravel	30000	8
Sand Subbase-A-1-b	26000	18
Silt Roadbed-A4	15000	Semi-Infinite
Climate	Lambertville, MI	

The climate selected was Lambertville, MI weather station. The elastic modulus was made higher for the asphalt case as it was necessary to combat the effects of rutting as the soil structure is designed to help support the traffic loadings. Similar to rigid pavement, the proper design thickness to be used in the M-E PDG was calculated by using ESALs and AASHTO Design through the DNPS86 software. The pavement design life of 20 was again assumed with 2% growth rate for traffic. The ESALs were calculated through the site base year axle repetitions previously calculated for each loading criteria and each axle type. This again resulted in thickness designs for the 36 WIM stations utilized in this study as shown in Table A4 of Appendix A.

The M-E PDG program calculates international roughness index (IRI), fatigue cracking and rutting as part of flexible analysis. The program also calculates longitudinal cracking but this type of distress was not used for failure criteria in the literature review and as such will not be evaluated here. For a given design life, the FHWA specifies maximum design thresholds for the flexible performance measures. In a preliminary analysis, 20 year performance predictors, like the rigid analysis, proved to be too stringent by using 95% confidence in the

M-E PDG. As a result, a combination of the M-E PDG default and FHWA 30 year thresholds were used as the failure criteria. The thresholds were mandated as follows:

- IRI-172 in/mi (M-E PDG default)
- Fatigue cracking- 10% surface area (FHWA 20 years)
- Total rutting- 0.70 in (Adjusted M-E PDG default)

It was determined that the limiting distresses were fatigue cracking and surface rutting in the M-E PDG. In similar fashion to the rigid design, the program was first run using AASHTO pavement design thicknesses established from the ESALs generated by the continuous data set. The design life at which fatigue cracking and surface rutting reached 10% and 0.70 in, respectively, was recorded. It was noted that in some instances surface rutting and fatigue cracking had inverse relationships. As such, the pavement thicknesses were then adjusted in the M-E PDG so as to ensure that at least both values maintained performance lives of 10 years or greater to facilitate comparison of these distresses where possible. The program was then rerun using OWPM data. Pavement life performance was recorded and compared to that of continuous data.

3.4 FORMATION OF TRAFFIC CHARACTERIZATION CLUSTERS

3.4.1 **Cluster Analysis Overview**

The TMG recommends for creation of factor groups the following (5):

- Cluster analysis
- Geographic/functional assignment of roads to groups
- Same road factor application

Cluster analysis uses a hierarchical mathematical algorithm that groups sites with similar traffic characteristics (i.e. least mathematical distance) together. Functional or geographic grouping is entirely based on professional knowledge of the state agency with the truck traffic on the roadway. In this case, emphasis on urban vs. rural and interstate vs. non-interstate could be assumed to have different travel patterns (5). If factors generated by the groups formed by this type of method have too high of variability, the groupings would need to be altered. The same road approach involves attaching a “zone of influence” about the continuous counter in which short counts taken within the roadway segments encompassed by the zone can use the continuous counter adjustment factor (5).

A literature review was undertaken to determine how some of the previously mentioned studies attempted to group WIM or classification recording devices together according to similarities within the previously described traffic characteristics. A majority of the literature highlighted grouping by using statistical clustering techniques, particularly a hierarchical clustering algorithm, to group the respective sites by a particular traffic characterization element. As such, a review of the accessible statistical clustering techniques was performed.

The statistical package, SPSS, planned for use in this study, employed the use of three different clustering techniques. The techniques available were:

- *k*-means
- Two-stage
- Hierarchical

In the *k*-means approach, a number of clusters must be specified prior to running the algorithm. These clusters are designated by a mean, or centroid value at which the sites (cases) would be clustered to. Utilizing a given distance measure, the algorithm places the site to the closest mean or centroid value, trying to minimize within cluster variation and maximize between group variation. The cluster means are updated continually with the addition of another case to a particular cluster. Since the cluster means are updated, it is common for a case to change clusters throughout the progression of the algorithm. This method is beneficial for large amounts of data where the number of clusters desired is known and some knowledge of the centroid value for each cluster is understood (21). Although useful for a single variable such as AADTT, this method would not be practical for TTC, where a single center mean is unintelligible. Due to these shortcomings this method is not desirable for clustering.

In the two-stage joining clustering approach, the procedure involves formation of pre-clusters to reduce the data size, followed by a hierarchical cluster analysis to create the final clusters. This method is typically utilized for extremely large data sizes or when there is a need to cluster both numerical (continuous) data and categorical data (21). As the project data are not large, and are entirely in numerical format, this technique was deemed impractical and was not investigated further.

In the hierarchical approach, specifically agglomerative clustering, the algorithm begins with all sites as individual clusters. A given distance measure is specified for distinguishing how far apart the two sites are as well as a methodology for grouping sites together based on the distances. The algorithm proceeds by grouping sites together based on the distance measure and methodology to form successive clusters until a final single cluster is formed. When a particular site is assigned to a cluster it remains in the cluster indefinitely. With this technique, the desired number of clusters does not need to be specified but rather can be selected after the analysis as the output produces clusters at each stage (21). This technique is suitable for smaller data sizes that are numerical in nature and contain multiple values for a given case. The majority of the clustering approaches researched in the literature utilized a hierarchical analysis for grouping traffic characterizations. Due to its suitability for the project data, and because of its prevalence of use in similar studies, the hierarchical clustering technique was selected for use in this study.

3.4.2 **Hierarchical Cluster Analysis Procedure**

The hierarchical algorithm requires two inputs in order to commence clustering:

- A distance measure to determine how similar each site (case) is
- A procedure for determining how clusters should be formed

The distance measured is the actual calculation of the difference, or how far apart two sites (cases) are from one another. The most popular distance measures used are (22):

- Euclidean distance: $\sqrt{\sum_{i=1}^{n}(A_i - B_i)^2}$
- Squared Euclidean distance: $\sum_{i=1}^{n}(A_i - B_i)^2$
- Manhattan distance: $\sum_{i=1}^{n}|A_i - B_i|$
- Chebychev distance: $\sum_{i=1}^{n} Max|A_i - B_i|$

In the above formulas, A and B are the given site names, and *i* is the *i*th variable in a set of *n* variables. For instance, for the TTC dataset, the total number of variables (*n*) would be 10 (10 vehicle classes) and the first variable, *i*=1 would be the TTC percentage for VC 4.

The Euclidean distance is the most basic and widely used of the four distances. Manhattan distance produces very similar results to that of Euclidean. The squared Euclidean distance allows more sensitivity to outliers, which is more ideal for distinguishing variables within a site that are distinctly separate from each other. Chebychev difference only incorporates the highest difference between variables and will ignore differences in other variables within a case (22).

Of the four stated distances, the squared Euclidean distance was selected as it is necessary to ensure that distinct contrasts between particular variables for a pair of sites be captured in order to prevent the sites from being clustered together. This distance measurement corresponds to that used in the cluster analysis performed in the TMG and those done by other researchers in their studies of forming traffic classification clusters (5, 10).

The hierarchical clustering method establishes the clustering distance in which to group sites together with. The following are some typical linkage techniques

- Single linkage
- Complete linkage
- Un-weighted pair group average
- Ward's method.

In single linkage, the clustering distance between two clusters is computed by finding the two sites in each cluster that have the lowest Euclidean distance between them. Single linkage works well for sites that are string-connected. In contrast, in complete linkage the given clustering distance measure between two clusters is defined by the two sites from each cluster that are the furthest apart in terms of their Euclidean distance. This method is efficient when the clusters form distinct blocks. In un-weighted pair group average, the clustering distance is defined as the two clusters which have lowest average Euclidean distance between all sites within the two clusters. This method works well with string and clumped sites. Finally, in Ward's method, an alternate approach is utilized in which the next cluster to be formed minimizes the sum of squares for all cases within the whole cluster (22). This method is regarded as the most efficient and was used by the TMG cluster analysis as well as research in similar projects. As such, Ward's method was selected for use in this project.

3.4.3 **Clustering Example with TTC**

The clustering process using squared Euclidean distance with Ward's method is best explained through an example utilizing the TTC traffic characterization. The general approach is to create an SPSS database in which each site is a case having a traffic characterization, the TTC distribution, as its set of variables (10 total). When the hierarchical cluster analysis is run, the Euclidean distance between each site is calculated as given by the squared Euclidean distance formula previously. Table 3.9 shows this calculation for the two sites with the lowest Euclidean distance, 8229 and 5019.

Table 3.9 Euclidean Distance Calculation Between Site 8229 and Site 5019

TTC	Site 5019 TTC	Site 8229 TTC	Squared Euclidean Distance (SED)
VC4	1.74	2.46	0.511
VC5	23.6	23.46	0.018
VC6	3.59	4.32	0.527
VC7	0.36	1.4	1.077
VC8	4.78	4.07	0.501
VC9	49.27	50.08	0.660
VC10	8.73	5.78	8.683
VC11	1.39	1.65	0.068
VC12	0.18	0.56	0.147
VC13	6.36	6.22	0.021
		Summation	12.21

Once Euclidean distances are calculated, Ward's method is utilized in which the cluster being formed has the lowest change in the sum of squares within the cluster. The sum of squares is calculated by first taking an average of each variable (TTC percentage for all VCs) for all sites within the cluster. The squared Euclidean distance between the variable mean values for the cluster and the specific case variable values within the cluster is then computed. The summation of these computations across all cases is the sum of squares for the cluster. As an example, the sum of squares for the joining of Site 8229 and Site 5019 is shown in Table 3.10.

Table 3.10 Computation of Sum of Squares for First TTC Cluster

TTC	Site 5019 TTC	Site 8229 TTC	Mean TTC	Site 5019 (SED)	Site 8229 (SED)
VC4	1.74	2.46	2.10	0.128	0.128
VC5	23.6	23.46	23.53	0.005	0.005
VC6	3.59	4.32	3.95	0.132	0.132
VC7	0.36	1.4	0.88	0.269	0.269
VC8	4.78	4.07	4.43	0.125	0.125
VC9	49.27	50.08	49.67	0.165	0.165
VC10	8.73	5.78	7.26	2.17	2.17
VC11	1.39	1.65	1.52	0.017	0.017
VC12	0.18	0.56	0.37	0.037	0.037
VC13	6.36	6.22	6.29	0.005	0.005
			Summation	6.105	

Table 16 reveals that the sum of squares for the clustering of site 8229 and site 5019 is half the Euclidean distance between the two. This is indeed mathematically the case when forming a cluster having only two sites. As sites of more than two begin to form however, this will not occur. The algorithm of adding a new site to a cluster based on the lowest increase in within cluster sum of squares continues until all cases are in one group. An icicle plot depicting the formation of clusters can be shown in Figure 3.

Figure 3, starting from the bottom upwards, shows that the sites that form the first cluster in the analysis are site 8229 and site 5019. It follows that the second connection of site 7159 and site 7029 corresponds to the second cluster, continuing until all sites have been merged at the top of Figure 3.1.

At each cluster it is necessary to know what the overall clustering Euclidean distance is when a site is formed as it aids in determining when increasingly dissimilar sites are being formed. This corresponds to higher clustering Euclidean distances. The additional clustering Euclidean distance when a new cluster is formed is defined as half the largest squared Euclidean distance between the new site in the cluster and any existing site within the cluster. It follows then that the clustering Euclidean distance when forming Site 8229 and site 5019 is 6.105. This value should not be confused with the sum of squares, as when more than two sites are within a cluster, the highest Euclidean distance pair and the sum of squares within the cluster will be different. Subsequently, the clustering distance for the second cluster becomes the clustering distance from the previous cluster, 6.105, added to half the largest squared Euclidean distance between the new site and any existing site within the cluster. This computation continues for every new cluster formed. An illustrative form of these distances is depicted through a dendogram as shown in Figure 3.2. It should be noted that the dendogram are rescaled so that the total clustering Euclidean distance is 25.

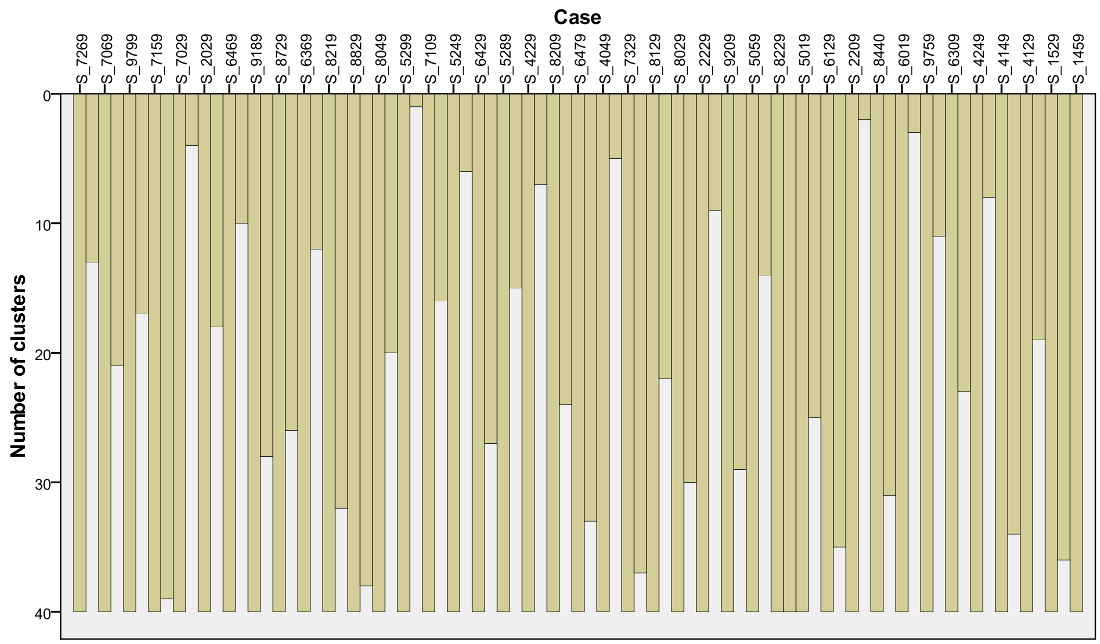


Figure 3.1 Icicle Tree Cluster Diagram for TTC Traffic Characterization

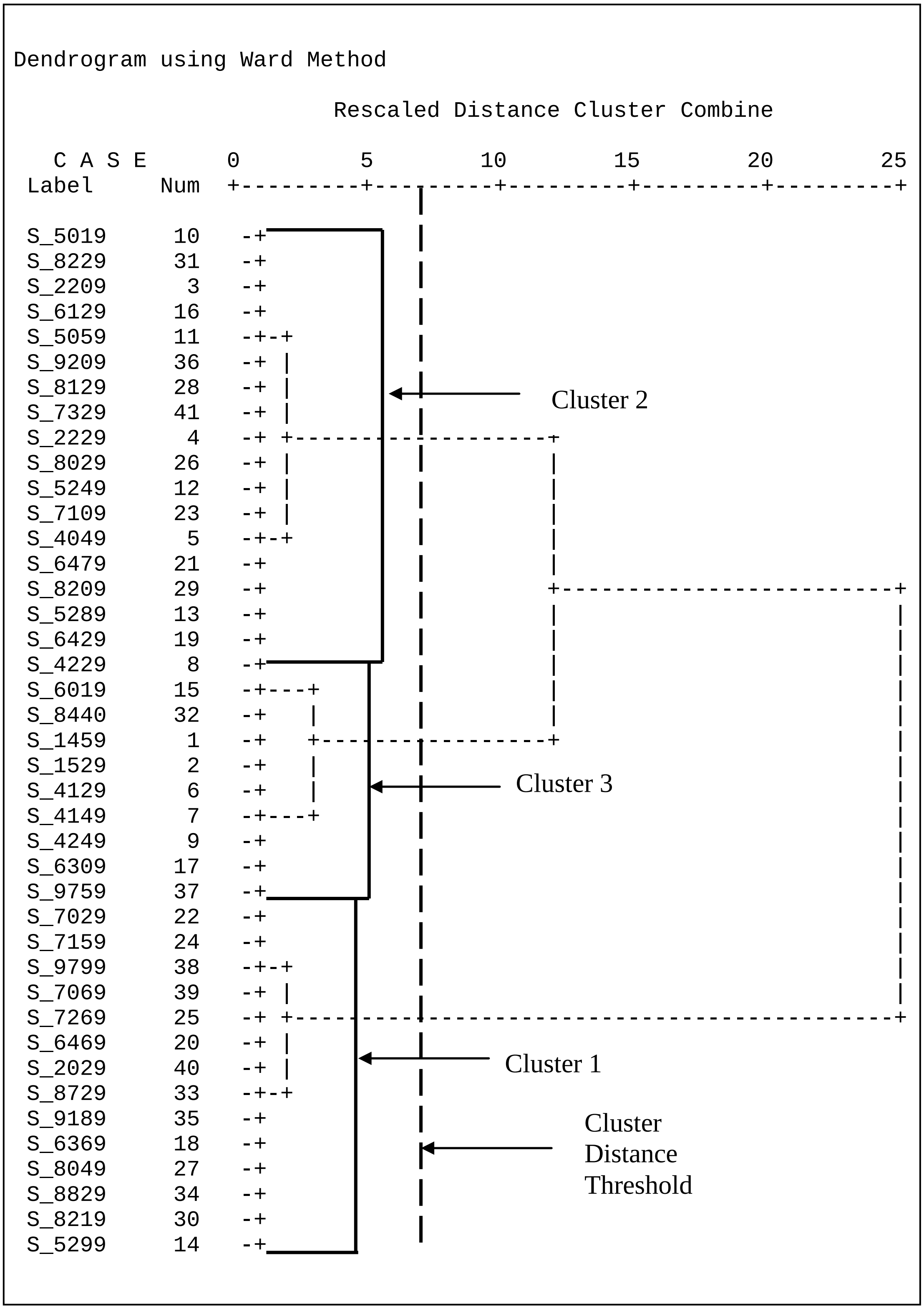


Figure 3.2 Clustering Dendogram for TTC Traffic Characterization

In Figure 3.2, the large jumps in scaled Euclidean distance during the formation of two main clusters and ultimately one large cluster are indicative of very dissimilar groups being formed when compared to prior clusters. In cluster analysis, the amount of clusters formed can be a combination of user input in conjunction with the dendogram. As there was relatively little knowledge of the data, to maintain objectivity in the formation of clusters, a scaled cluster distance value of 7 was selected to establish the number of clusters for each traffic characterization. Using this value, the clusters formed are as shown in Figure 3.2. The numbering scheme corresponds to that used in the cluster analysis results to follow.

This clustering process was repeated for all other traffic characterizations. The established traffic characterizations are as follows:

- TTC
- HDF
- MDF
- AGPV
- Annual Single Axle Load
- Annual Tandem Axle Load
- Annual Tridem Axle Load
- Annual Quad Axle Load

3.4.4 **Practical Significance of Developed Traffic Characterizations**

The practical assessment of utilizing Level II, clustered inputs (cluster averages), and Level III, statewide (average of all sites) or default values, over site specific data was done through a rigid and flexible pavement performance comparison. The base designs and thicknesses were those created for the data coverage comparison. The various site specific data were replaced by the baseline traffic characteristics on an individual basis and the resulting flexible and rigid pavement performance distresses reviewed previously were compared with site specific outputs to obtain differences in pavement life performance. The results of this analysis established the associated error in predicted performance when using Level 2 as compared to site-specific data. The various traffic characterization schemes assessed for the rigid and flexible analysis are shown in Table 3.11.

Table 3.11 Traffic Characteristics Created and Compared in the M-E PDG

	Cluster		Statewide		M-E PDG Default	
	Rigid	Flexible	Rigid	Flexible	Rigid	Flexible
HDF	X	X	X	X	X	
MDF	X		X	X	X	
TTC	X	X	X	X	X (Comp to TTC Avg)	
AGPV	X	X	X	X	X	
Single Axle Load Spectra	X	X	X	X	X	
Tandem Axle Load Spectra	X	X	X	X	X	
Tridem Axle Load Spectra	X	X	X	X	X	
Quad Axle Load Spectra	X	X	X	X	X	

The difference in traffic schemes between rigid and flexible analysis was due to the trends seen first in the rigid analysis. This will become apparent in a review of the results in Chapter 4.

3.5 DISCRIMINANT ANALYSIS PROCEDURE

Depending on the results of the effects of the hierarchical traffic characterizations on pavement performance life, it may be necessary to utilize cluster average (Level II) inputs over statewide or the M-E PDG defaults (Level III). However, the inherent difficulty that lies within this process is the selection of the *appropriate* Level II input for the given site to be designed. Thus it becomes necessary to develop an algorithm that will assist in selecting the proper Level II traffic characteristic for design by correlating it to known physical characteristics of the site. The technique that was administered in this project for such a purpose was discriminant analysis.

Discriminant analysis develops a set of linear regression equations (one less than the number of dependent variable categories) that take a group of known parameters, known as predictor variables, as inputs into the equation and uses the output of that equation to select the appropriate cluster group for the dependent variable. An example of such a linear equation is shown in Equation 27, where

$$y = b_1 x_1 + b_2 x_2 + ...b_{(n-1)} + b_n + c \qquad (27)$$

The b coefficients are the regression coefficients that are outputs determined through the discriminant analysis. There are as many coefficients as there are independent variables, n, in the analysis. The x variables in Equation 27 are the actual values of the independent variables at a given site and c is a constant.

In the case of this study, the dependent variable would be a given traffic characterization (i.e TTC, MDF, Tandem Axle Load Spectra) and the predictor variables would be known properties of the site to be designed. Examples of such properties that would be available and known by the MDOT prior to design would be:

- Vehicle freight commodity truck percentage for the following commodities:
    - Secondary Traffic
    - Clay, Cement, Glass and Stone Products
    - Food Products
    - Fabricated Metal Products
    - Transportation Equipment
    - Primary Metal Products
    - Chemical Products
    - Logs, Lumber and Wood Products
    - Farm Products
    - Petroleum or Coal Products
    - Machinery
    - Rubber and Plastics
    - Waste or Scrap Metal
    - Paper and Pulp Products
    - Nonmetallic Ores and Minerals
    - Furniture and Fixtures
    - Miscellaneous Manufacturing Products
    - Printed Matter
    - Electrical Equipment
    - Empty
- Functional class (urban/rural setting)
- Average trip distance (long haul or local trip distinction)
- Road class (Interstate, US highway, Michigan road)
- AADTT
- Vehicle class percentage (assuming the MDOT takes classification counts)
- Geographic location (region within Michigan)
- Yearly truck tonnage

Vehicle freight commodity percentage, functional class, average trip distance, and tonnage are all information that can be acquired from the planning department within the MDOT prior to the design of the road. AADTT and vehicle class percentage could also be determined through counting efforts. The geographic location was stratified into the seven regions designated by the MDOT as shown in Figure 3.3.

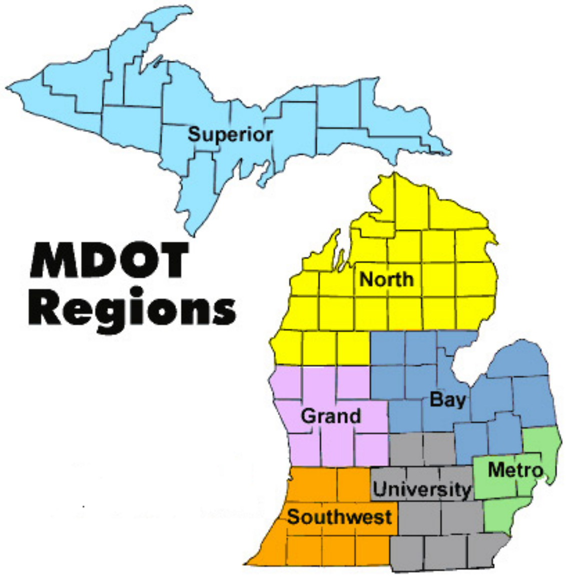


Figure 3.3 MDOT Regions Within Michigan Utilized for Discriminant Analyses.

It should be noted that SPSS requires the independent variables be in numerical form for discriminant analysis. Accordingly, the MDOT regions were each given a numerical designation. Also, the functional class was changed numerically to reflect either rural (1) or urban (2) site conditions. Finally road class was changed numerically to be interstate (1), US highway (2), and Michigan road (3).

From the established list of available physical data regarding the site, it was necessary to determine which specific variables could be used to establish differences between clustered (Level II) traffic characterizations. Since the equation is linear in nature, a Pearson correlation matrix was established between all predictor variables and the traffic characterization cluster groups to evaluate the linear relationships amongst variables. As will be shown in the M-E PDG analyses, it was determined that that HDF, TTC, and tandem axle load spectra would need at a minimum Level II data. As such correlation between the cluster group designation of these particular traffic characterizations and the predictor variables was paramount. Only predictor variables (site properties) that had a significant correlation above 0.4 were considered for use in the discriminant analysis. The predictor variables selected for use in the discriminant analysis are outlined below. The correlation values can be found in Table A5 of Appendix A.

- Vehicle freight commodity truck percentage for the following commodities:
    - Food Products
    - Fabricated Metal Products
    - Transportation Equipment
    - Logs, Lumber and Wood Products
    - Machinery
    - Rubber and Plastics

- Paper and Pulp Products
    - Furniture and Fixtures
    - Miscellaneous Manufacturing Products
    - Printed Matter
    - Electrical Equipment
- Road class
- Geographic region
- AADTT
- VC5%
- VC9%
- Functional class (rural/urban)
- Roadway annual tonnage

A complete listing of the values for each of these site characteristics can be found in Table A6 of Appendix A. It should be noted that, as will be stated in recommendations, that site specific truck traffic classification data will be provided. Consequently VC 5% and VC 9% were included as part of the independent variables.

An example using HDF as the dependent variable is presented to demonstrate the process of the discriminant analysis, explaining critical components. Since HDF has three categories, the analysis will produces two functions to facilitate the analysis. The first equation developed attempts to maximize the differences in the dependent variable by altering the coefficients of the predictor variables. The second equation and subsequent equations (for those traffic inputs with more than three clusters) tries to maximize the difference between dependent variables to account for the remaining variability not captured in the first equation. Generally speaking, the first function is the most powerful and contributes the most toward discriminating among the dependent variable (23).

Once the set of predictor variables are established for each site, they were placed in SPSS along with the dependent variable (classification grouping for each site) and the discriminant analysis was run. There are a number of outputs that SPSS produces in addition to the discriminating equations that explain the significance of the variables involved, validate assumptions, and assess the value of the model as a whole. Each will be explained subsequently.

The first output that SPSS produces is the Wilks' Lambda test for significance of variables. The test is a univariate analysis of variance (ANOVA) which determines if the means of the particular predictor variable are different amongst the traffic input clusters (three in the case of the HDF groups as will be shown in Chapter 4) (23). A value of one reveals that all means are equal whereas a value close to 0 suggests that group means significantly differ. It is desirable to have a value as close as possible to zero, which suggests that group means for the predictor variables are significantly different from one another, and thus could be more effective in discriminating the dependent variable. Table 18 displays the results of this test for the aforementioned predictor variables for the case of the single axle load spectra clusters.

Table 3.12 reveals that with the exception of functional class, paper and pulp products and logs lumber and wood products, the means of the discriminating variable are significantly different between the HDF (groups)($p<0.05$). It should be noted that this significance does not necessarily suggest that the variable will effectively discriminate. This means that, even though the average value could be different across clusters, the weight assigned to it (coefficient) in the discriminant equation could still be insignificant. A significant result here is only indicative that the variable can potentially be effective at discriminating the dependent variable.

Table 3.12 Wilks' Lambda Results for Predictor Variables used in Single Axle Load Spectra Cluster

Tests of Equality of Group Means					
	Wilks' Lambda	F	df1	df2	Sig.
Region	.854	2.817	2	33	.074
Functional Class	.897	1.904	2	33	.165
Food Product Truck %	.739	5.818	2	33	.007
Fabricated Metal Products Truck %	.786	4.489	2	33	.019
Machinery Truck %	.638	9.361	2	33	.001
Rubber and Plastics Truck %	.741	5.754	2	33	.007
Furniture and Fixtures Truck %	.793	4.301	2	33	.022
Electrical Equipment Truck %	.768	4.983	2	33	.013
Total Tons	.493	16.998	2	33	.000
VC 5 %	.594	11.272	2	33	.000
VC 9 %	.375	27.547	2	33	.000
AADTT	.439	21.080	2	33	.000
Miscellaneous Manufacturing Products Truck %	.681	7.725	2	33	.002
Road Class	.750	5.498	2	33	.009
Printed Matter Truck %	.813	3.796	2	33	.033
Paper and Pulp Products Truck %	.996	.065	2	33	.937
Logs, Lumber and Wood Products Truck %	.883	2.180	2	33	.129
Transportation Equipment Truck %	.772	4.878	2	33	.014

The next output produced by SPSS is the Box M test. This procedure tests for homogeneity of variances amongst the predictor variables within each cluster group, which is an assumption in discriminant analysis. A result of significance ($p < 0.05$) forces a rejection of the null hypothesis, stating that the group variances are equal (23). In this analysis, the sample size is small (41 values) and in some cases the cluster sizes are uneven. This will result in the Box M test being significant in all cases, violating the assumption of equal variances. However it has been stated in literature that the procedure can still be used despite this violation (23). Accordingly the results of the Box M will not be discussed.

Following the Box M, SPSS outputs several elements that determine how well the regression functions obtained classify the dependent variable and account for the variance among groups. These elements are the eigen value, canonical correlation, and the Wilk's lambda. The eigen value reflects how well a discriminating function explains the variability in the dependent value. High eigen values indicate that variation is captured well with the given function and thus discriminate among the groupings effectively. Similarly canonical correlation is a measure of how well the function matches the cluster groups formed in the dependent variable. A correlation of 1 is indicative that the dependent variable can be entirely explained by the discriminating function. The eigen values and canonical correlation can be seen in Table 3.13 (23).

Table 3.13 Eigenvalue and Canonical Correlation for HDF Discriminant Functions

Eigen values				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.739	82.8	82.8	.933
2	1.397	17.2	100.0	.763

For the HDF model, the first function explains the variation very well, as indicated by a high eigenvalue, 6.7, and canonical correlation of 0.93, which is close to 1. Both values indicate that the function sufficiently discriminates the dependent variable.

The Wilk's Lambda for the model test whether or not the discriminant functions are effectively discriminating between the clusters. The Wilk's Lambda for the HDF model can be found in Table 3.14. A finding of significance for the first row, which tests the entire model (all discriminant functions), rejects the null hypothesis that the cluster mean discriminant scores between cluster groupings are equal. (The discriminant scores are the output values when the independent variables from a given site are put into the discriminant functions) (23).

Table 3.14 Wilk's Lambda Test for Significance of Model

Test of Functions	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	.054	71.553	36	.000
2	.417	21.420	17	.208

Once the overall model has been evaluated for how successful it discriminates, the individual components of the model are reviewed. SPSS outputs a set of standardized discriminant coefficients that reveal the relative importance (discriminating power) of each independent variable in the established functions. The larger the standardized discriminant coefficient variable is, the more discriminating power it has (23). Table 3.15 displays these standardized coefficients for the two functions created for the HDF dependent variable.

Table 3.15 reveals that Miscellaneous Manufacturing Products Truck %, VC 9%, Total tons and Machinery Truck % hold the most discriminating power in function 1, and thus the overall model. It is these values that will be more influential in classifying the HDF groups. However, it should not be assumed that the rest of the variables can be ignored. They contribute, although on a smaller scale, to the overall effectiveness of the model. Additionally, deletion of variables will cause the standardized coefficient, and accordingly the overall model, to change. This could reduce the discriminatory power of the model.

Table 3.15 Standardized Canonical Discriminant Function Coefficients

Independent Variables	Function	
	1	2
Region	.102	-.526
Functional Class	-.694	-.019
Food Product Truck %	.248	-.901
Fabricated Metal Products Truck %	-.695	-.266
Machinery Truck %	1.302	-.353
Rubber and Plastics Truck %	-.987	1.315
Furniture and Fixtures Truck %	-.329	-.159
Electrical Equipment Truck %	1.124	-.487
Total Tons	1.426	-.955
VC 5 %	.982	.577
VC 9 %	1.821	.013
AADTT	-.086	1.159
Miscellaneous Manufacturing Products Truck %	-2.154	.989
Road Class	.904	.175
Printed Matter Truck %	.454	-.338
Paper and Pulp Products Truck %	-.534	1.102
Logs, Lumber and Wood Products Truck %	.434	-1.313
Transportation Equipment Truck %	1.004	.494

Once the individual variables and the model have been assessed for its discriminatory capability, the regression coefficients used for the discriminant function seen in Equation 27 are determined. The regression components for the two functions established for the HDF dependent variable are shown in Table 3.16.

Table 3.16 Regression Coefficients Created by SPSS

Independent variables	Function	
	1	2
Region	.062	-.319
Functional Class	-.150	-.004
Food Product Truck %	.091	-.329
Fabricated Metal Products Truck %	-.320	-.122
Machinery Truck %	1.379	-.374
Rubber and Plastics Truck %	-.879	1.171
Furniture and Fixtures Truck %	-.620	-.300
Electrical Equipment Truck %	1.170	-.507
Total Tons	1.395E-7	-9.347E-8
VC 5 %	.083	.049
VC 9 %	.166	.001
AADTT	.0001	.001
Miscellaneous Manufacturing Products Truck %	-7.435	3.413
Road Class	1.572	.303
Printed Matter Truck %	1.400	-1.042
Paper and Pulp Products Truck %	-.148	.305
Logs, Lumber and Wood Products Truck %	.098	-.298
Transportation Equipment Truck %	.313	.154
(Constant)	-13.812	-.356

Once the equations are established, SPSS then tries to cluster each site in the analysis into an appropriate cluster based on the discriminant score from the inputted coefficients and independent variable values into the regression equations. To aid the user in classifying a given site, SPSS outputs a territorial map as shown in Figure 3.4.

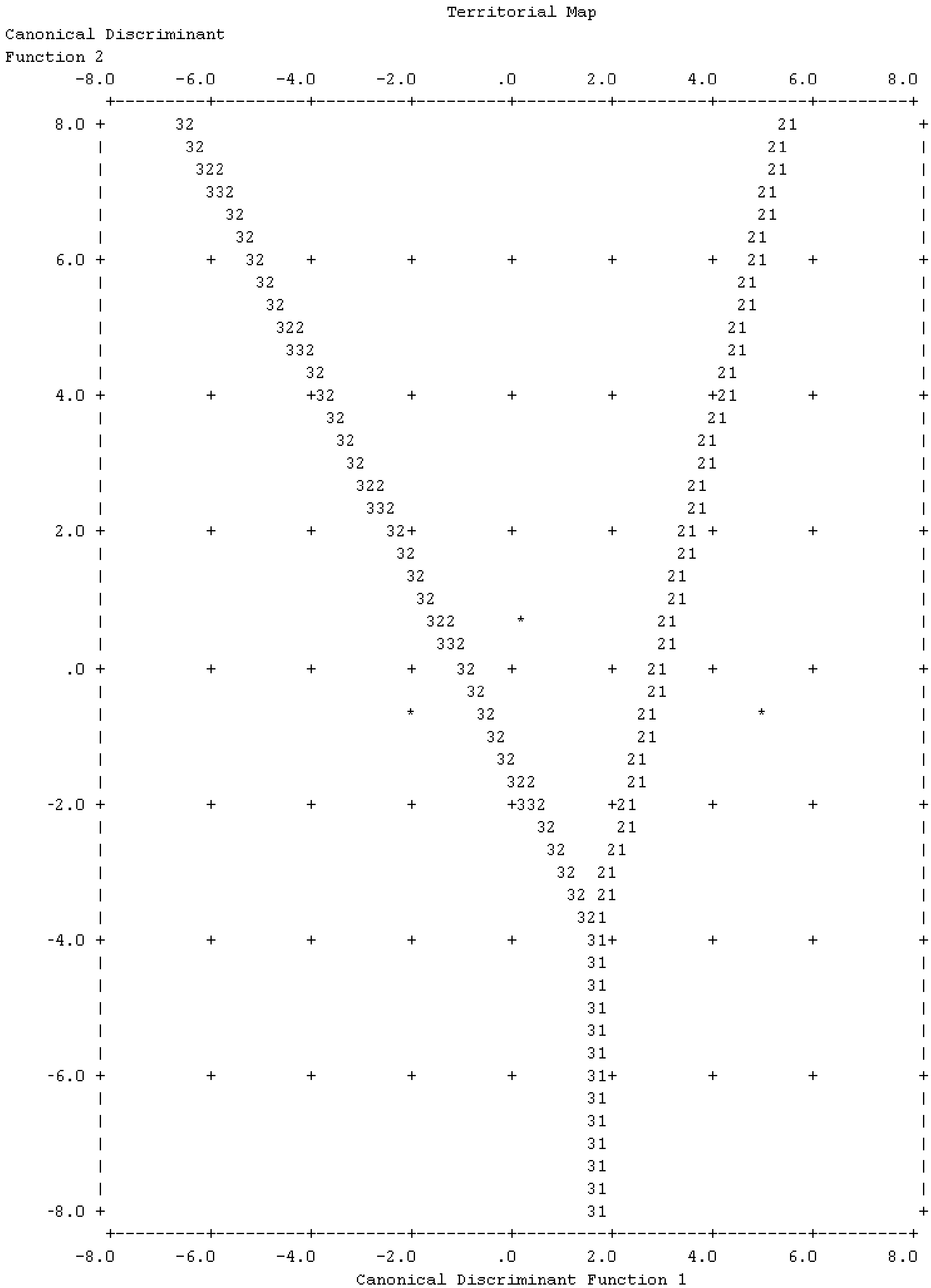


Figure 3.4 Territorial Map for Classification of Dependent Variable

The discriminant score is calculated for each function and then plotted on the territorial chart. The numbers, 1-3, marked on Figure 6 are the outer boundaries of the cluster groupings. The "+" symbols are reference points for plotting and the "*" is the discriminant score cluster means. The region that the plotted point resides in is the cluster grouping the site will be placed in. To illustrate this procedure, data from Site 1459 can be used as an example. The discriminant equations, function 1 and function 2, developed for HDF are shown in Equation 28 and 29 respectively.

$$\begin{aligned}
&y = 0.062*(R) - 0.150*(FC) + 0.091*(FP) - 0.320*(FMP) \\
&+1.379*(M) - 0.879*(RP) - 0.620*(FF) + 1.170*(EE) \\
&+1.135E-7*(TT) + 0.083*(VC5) + 0.166*(VC9) + 0.0001*(AADTT) - \\
&7.435*(MMP) + 1.572*(RC) + 1.400*(PM) - 0.148*(PP) + \\
&0.098*(LLW) + 0.313*(TET) - 13.812 = -2.05
\end{aligned} \tag{28}$$

$$\begin{aligned}
&y = -0.319*(R) - 0.004*(FC) - 0.329*(FP) - 0.122*(FMP) \\
&-0.374*(M) + 1.171*(RP) - 0.300*(FF) - 0.507*(EE) - \\
&9.347\text{E - }8*(TT) + 0.083*(VC5) + 0.166*(VC9) + 0.001*(AADTT) + \\
&3.413*(MMP) + 0.303*(RC) - 1.042*(PM) - 0.305*(PP) - \\
&0.298*(LLW) + 0.154*(TET) - 0.356 = 1.00
\end{aligned} \tag{29}$$

Thus the point plots (-2.05, 1.00) as shown in Figure 6, classifying Site 1459 in cluster 3 This is, in fact, where Site 1459 was clustered for the HDF traffic characterization.

An alternative to utilizing the two function regression equation and territorial plot is to use Fisher's linear discriminant functions. These functions are in the same form as the regression functions of Equation 27 and derived from the developed two-function discriminant model. The difference in Fisher's function is that the variable coefficients are not the same and that there are as many functions as there are cluster groupings for the independent variable. Rather than plot the point on a territorial map, the discriminant scores, (now called classification scores) are calculated for each Fisher function. The site is then assigned to the cluster whose corresponding function produces the highest discriminant score (23). The developed Fisher linear discriminant coefficients for the HDF dependent variable are shown in Table 3.17.

Table 3.17 Fisher's Linear Discriminant Coefficients for HDF Variable

Independent Variables	HDF		
	1	2	3
Region	.854	1.353	.507
Functional Class	-1.451	-.675	-.291
Food Product Truck %	-4.838	-4.457	-5.400
Fabricated Metal Products Truck %	-2.927	-.984	-.409
Machinery Truck %	21.080	14.999	10.592
Rubber and Plastics Truck %	-15.924	-14.435	-9.627
Furniture and Fixtures Truck %	-7.998	-4.070	-3.091
Electrical Equipment Truck %	14.782	10.109	5.963
Total Tons	2.880E-6	2.408E-6	1.843E-6
VC 5 %	4.098	3.552	3.440
VC 9 %	5.574	4.723	4.291
AADTT	-.0044	-.0074	-.0042
Miscellaneous Manufacturing Products Truck %	-116.520	-87.319	-60.573
Road Class	32.470	23.673	20.212
Printed Matter Truck %	57.649	53.170	47.277
Paper and Pulp Products Truck %	-1.504	-1.529	-.488
Logs, Lumber and Wood Products Truck %	1.886	2.145	1.250
Transportation Equipment Truck %	4.685	2.697	2.209
(Constant)	-276.774	-189.364	-156.574

Once the regression coefficients were derived, the classification scores could be calculated. The linear equations and classification scores for each HDF cluster 1-3 is contained in Equations 30-33, respectively.

$$\begin{aligned}
y &= 0.0854*(R) - 1.451*(FC) - 4.838*(FP) - 2.927*(FMP) \\
&+ 21.080*(M) - 15.924*(RP) - 7.998*(FF) + 14.782*(EE) \\
&+ 2.880E\text{-}6*(TT) + 4.098*(VC5) + 5.574*(VC9) - 0.0044*(AADTT) - \\
&116.52*(MMP) + 32.470*(RC) + 57.649*(PM) - 1.504*(PP) + \\
&1.886*(LLW) + 4.685*(TET) - 277.74 = 125.414
\end{aligned} \tag{28}$$

$$
\begin{aligned}
y &= 1.353*(R) - 0.675*(FC) - 4.457*(FP) - 0.984*(FMP) \\
&+ 14.999*(M) - 14.435*(RP) - 4.070*(FF) + 10.109*(EE) \\
&+ 2.408E\text{ - }6*(TT) + 3.552*(VC5) + 4.723*(VC9) - 0.007*(AADTT) - \\
&87.319*(MMP) + 23.673*(RC) + 53.170*(PM) - 1.529*(PP) + \\
&2.145*(LLW) + 2.697*(TET) - 189.364 = 149.339
\end{aligned} \tag{29}
$$

$$
\begin{aligned}
y &= 0.507*(R) - 0.291*(FC) - 5.400*(FP) - 0.409*(FMP) \\
&+ 10.592*(M) - 9.627*(RP) - 3.091*(FF) + 5.963*(EE) \\
&1.843\text{E - }6*(TT) + 3.440*(VC5) + 4.291*(VC9) - 0.0042*(AADTT) - \\
&60.573*(MMP) + 20.212*(RC) + 47.277*(PM) - 0.488*(PP) + \\
&1.250*(LLW) + 2.209*(TET) - 156.574 = 154.294
\end{aligned} \tag{30}
$$

From Equations 28-30, HDF cluster 3 is again selected for Site 1450 as it has the highest classification score. As this technique is numerically definitive in classifying values as opposed to judging spatially on the territorial map, Fisher's linear discriminant coefficients is recommended for clustering sites for dependent variables which require cluster averages (Level II) as inputs into the M-E PDG.

SPSS automatically classifies each site used in the analysis and compares the predicted cluster membership using the discriminant functions with the original cluster memberships assigned to the site. This output is displayed in Table 3.18.

Table 3.18 Classified Sites into HDF Clusters through Discriminant Analysis

		HDF Cluster	Predicted Group Membership			Total
			1	2	3	
Original	Count	1	**5**	0	0	5
		2	0	**16**	1	17
		3	0	0	**14**	14
	%	1	100	.0	.0	100
		2	.0	94	6	100
		3	.0	.0	100	100

The discriminant analysis correctly classified 97.2% of the sites with the developed regression equations. As such, if cluster averages are needed for this traffic input, selection of the appropriate HDF can be done with a significant amount of reliability then randomly guessing. The discriminant analysis was applied to all traffic inputs which required cluster averages as a design input. These specific inputs will be identified and discussed in Chapter 4.

CHAPTER 4 - RESULTS AND DISCUSSIONS

This chapter contains a summary of the results based on the methodology presented in Chapter 3. The presentation of this data serves as a basis to qualify the conclusions and recommendations presented in chapter 5. The analyses results are categorized in five parts and they include:

- Selection of final sites
- Effect of data coverage between OWPM and continuous data
- Identification of the M-E PDG traffic element selected for further analyses
- Traffic characterization (development and clustering)
- Impact of traffic characterization on the M-E PDG outputs

4.1 SELECTION OF FINAL SITES FOR ANALYSES

The axle load distributions and TTC for all sites with available data were evaluated for potential errors according to the QC procedures outlined in Section 3.1.4. The following observations were made with regard to potentially erroneous data:

- Site 1459-Bark River had high single axle loadings (41 kips) for VC 4 and VC 8 for June, August and December.
- Site 5019-St. Johns had a high single axle loading (39 kips) for VC 4 in August.
- Site 5249-Morley had high small single axle loading spikes (41 kips) across all VCs.
- Site 7289-Bangor had an abnormally high presence of VC 13 vehicles (38%).
- Site 8049-Fowlerville had a very high single axle load spike (34 kips) for VC 4 in July which constituted nearly 50% of all axles. This was an indication that the scale failed at one point during the month.
- Site 6349-Flint (OWPM data) had a flat axle load spectra across all axle load spectra.
- Site 8249-Luna Pier had a shift in peak loading values, almost 10 kips in some instances, from 11 kips to 30 kips.

It should be noted that most sites contained axle load spectra with some very small percentage, under 1%, of the truck volume in an abnormally high range. The aforementioned sites had percentages greater than this.

The results from the quality control check highlighted some possible erroneous data within certain months of a year for a specific site. The extensive failures found at Sites 6349, 7289, and 8249 were reason for their removal from the analyses. However, since annual averages were to be used for analysis as will be explained later, the effect of the high one-month variation spikes was minimized due to averaging. As such, data for these sites were accepted as part of the analyses. The final data summary for the continuous and OWPM is shown in Table 4.1. An overview of some basic properties regarding the collection sites can be seen in Table 4.2. The final sites utilized for the week and continuous analyses are presented in

Table A1 and Table A2 of Appendix A. Shaded sites indicate OWPM data that was not used, while an “X” represents continuous data that were excluded from the analyses.

Table 4.1 Quantity of Weight and Classification Data for One Week Per Month and Continuous Data

Type of Data	OWPM	Continuous
Weight and Classification	34	36
Weight Only	1	0
Classification Only	3	5
Total	38	41

Table 4.2 Summary Statistics of the MDOT WIM and Classification Sites

Parameter	Number of Sites
Setting	Rural: 29 Urban: 12
Functional Class	Urban Interstate: 8 Urban Arterial/Fwy: 5 Rural Interstate: 10 Rural Arterial/Fwy: 13 Rural Minor Arterial: 5
Sensor Type	Piezo: 18 Bending Plate: 3 Quartz: 20

4.2 IDENTIFICATION OF NECESSARY ELEMENTS FOR TRAFFIC CHARACTERIZATION

While there are 13 traffic related inputs provided in M-E PDG, emphasis was placed on the following traffic characteristics for determining hierarchical traffic inputs:

- Truck Traffic Classification (TTC)
  - Percentage of truck traffic for each FHWA vehicle class 4-13, ten total
- Monthly Distribution Factor (MDF)
  - Set of 12 factors, one for each month
- Hourly Distribution Factor (HDF)
  - Set of 24 factors, one for each hour
- Axle Groups per Vehicle (AGPV)
  - Single, Tandem, Tridem, Quad

- Axle load dist/spectra
    - Loading proportions for each vehicle class and each axle group, 40 total

The aforementioned traffic characterizations were selected based on the ability to develop a hierarchical structure for design purposes. AADTT, an essential traffic component, was excluded from the analyses as it was expected that AADTT would be known by MDOT prior to design. Consequently AADTT hierarchical inputs are not applicable to this research. AADTT was only characterized for the possible purpose of using in discriminant analysis as a possible discriminatory variable for the selection of Level II data. The remaining data elements will be used to assist characterizing Level I input and stratifying the traffic patterns into Level II data for use in ME-PDG.

4.3 EFFECT OF DATA COVERAGE BETWEEN OWPM AND CONTINUOUS DATA

The impact of using OWPM data in lieu of continuous data was assessed in terms of differences in traffic input values and differences in pavement performance as predicted by the M-E PDG. Establishing significant differences in input values allow for possible explanation of differences in pavement performance life for both rigid and flexible pavements.

4.3.1 **Traffic Input Differences**

The numerical traffic input differences were calculated and normalized for all traffic inputs as outlined in Chapter 3. The results from this analysis are presented in Tables B1-B6 of Appendix B. Statistical analysis was conducted to summarize data and draw conclusions. It is important to note here that Site 6469-Port Huron and Site 6019-Carsonville are missing OWPM classification and weight data, respectively. Sites 2209-Deerton and 9799-Cicotte do not contain weight data. To ensure that all data could be compared numerically both from a traffic input standpoint and M-E PDG performance, inputs from these sites were not considered from all analyses as comparisons could not be made in the M-E PDG. Thus a total of 34 sites with both OWPM and continuous data were used in the analyses. The mean, standard deviation, and 95% confidence intervals (CIs) for the normalized differences from each traffic input were calculated. It was assumed that the WIM stations were independent sites and the traffic characterizations created were random independent samples from a normal population. It is also important to note that those sites that did not have both continuous and OWPM data available for processing in the M-E PDG were not included in the statistical analyses. These sites are shaded in Tables A1 and A2 in Appendix A. One sample *t*-test and paired *t*-tests were performed to quantify the differences between continuous and OWPM data. The *t*-test could not be performed for the MDF and HDF values as the differences were all positive values. The results of the statistical analyses are presented in Table 4.3.

The results in Table 4.3 show that with the exception of AADTT and tandem axle average load for VC 9, the differences (at a p-value of 5%) between OWPM and continuous traffic characterizations were not statistically significant. The average AADTT difference is approximately 3.2% with a CI between 2.3% and 4.1%. The AADTT average difference appears to be lower than the M-E PDG research findings of 5-10%. The CI for VC 9 was between -0. 48% and -0.05%. A review of the data revealed that Site 1459-Bark River had a percentage difference of -10.165%. The next largest difference out of the 35 sites analyzed was less than half that value, -4.59% from Site 8049. This indicated that Site 1459 is an outlier and is causing the bias towards OWPM over predicting the average tandem VC 9 axle load. Despite this bias, a 95% CI bound of less than 0.5% seems acceptable from a practical perspective. The Actual differences in AGPV approached zero. Confidence intervals at 95% for the difference in average axle load values and TTC percentages for all values fell within 1 % of zero. Both traffic characterization differences were within the 1-2% difference specified by the M-E PDG manual. Besides AADTT, the MDFs exhibited the most variation. Knowing that the default value for MDFs is 1 in the M-E PDG, average magnitude differences between 0.08 (VC 8-10) up to 0.16 (VC 11-13) suggesting possible differences in values of 10% to 20%. The VC 5 single and tandem axle load had standard deviations close to 2% with a 95% CI of almost 1%. This variation appears to be on the same scale as VC 9 and could have some implications in pavement performance life as it can have obtain the same volume of trucks on the roadway. The implications of these observations were explored in pavement performance life tests in the M-E PDG.

Table 4.3 Statistical Analysis Results for Difference in Traffic Characterizations Using OWPM and Continuous Data

Variable	Mean difference	Std. Dev.	Std. Error	CI Min	CI Max	*t* value	df	Sig. 2 Tailed
AADTT	3.22%	2.46%	0.42%	2.36%	4.08%	7.63	33	0.000
TTC VC4-7	0.30%	1.21%	0.21%	-0.12%	-0.73%	1.46	33	0.153*
TTC VC8-10	-0.36%	1.11%	0.19%	-0.75%	0.03%	-1.88	33	0.068*
TTC VC11-13	0.06%	0.62%	0.11%	-0.16%	0.27%	0.52	33	0.606*
MDF VC 4-7	0.12	0.07	0.01	0.09	0.15	N/A	N/A	N/A
MDF VC8-10	0.08	0.02	0.00	0.07	0.08	N/A	N/A	N/A
MDF VC11-13	0.16	0.12	0.02	0.11	0.20	N/A	N/A	N/A
HDF	0.07%	0.04%	0.01%	0.05%	0.08%	N/A	N/A	N/A
Single AGPV	0.0112	0.2733	0.0148	-0.0180	0.0404	0.76	339	0.450*
Tandem AGPV	-0.0001	0.0237	0.0013	-0.0033	0.0018	-0.57	339	0.567*
Tridem AGPV	-0.0019	0.0265	0.0026	-0.0070	0.0032	-0.736	104	0.464*
Quad AGPV	0.0047	0.0296	0.0029	-0.0011	0.0104	1.615	104	0.109*
SA VC5	-0.21%	1.82%	0.31%	-0.84%	0.43%	-0.67	33	0.510
TA VC5	0.03%	1.43%	0.25%	-0.47%	0.53%	0.12	33	0.905
SA VC9	-0.07%	0.41%	0.07%	-0.21%	0.07%	-1.02	33	0.314
TA VC9	-0.26%	0.62%	0.11%	-0.48%	-0.05%	-2.50	33	0.018
SA VC13	-0.13%	1.74%	0.30%	-0.74%	0.47%	-0.45	33	0.656
TA VC13	0.44%	1.32%	0.23%	-0.02%	0.90%	1.95	33	0.059

* Indicates Paired t-test

4.3.2 **Statistical Significance of M-E PDG Rigid Pavement Output**

The comparison between OWPM and continuous data predicted pavement performance life was established by subtracting OWPM performance life from continuous performance life (in years). This resulted in 34 values for comparison, referred to as the performance life difference. In all cases, it is assumed that the continuous data, and resulting performance life represents the true values for the site. Using the difference in this manner allows positive values to represent under prediction in pavement life. This implies that OWPM performance life has a shorter performance life than what actually occurs, which is conservative. In contrast, a negative value is indicative of an over prediction of performance life. This implies that the OWPM performance life has a longer performance life than what actually occurs, which is un-conservative. As noted previously, it was found that AADTT, MDFs, VC 5, and VC 9 had significant traffic input differences, either statistically or practically. VC 5 has an equal amount of variation as VC 9. Since AADTT, VC 9 and VC 5 have direct influence on the volume and truck type in the traffic stream it was deemed important to see if any observed differences in pavement performance life between OWPM and continuous data could be attributed to differences in these traffic inputs. To facilitate this, in addition to the continuous and OWPM runs, OWPM data using continuous AADTT, OWPM data using continuous VC 9 single and tandem loads and OWPM data using VC 5 single and tandem loads were also analyzed in the M-E PDG. The performance lives for all OWPM vs. continuous rigid pavement runs are contained in Table B7 of Appendix B. A. Descriptive statistics and 95% confidence intervals (CIs) for the difference in performance life were calculated and are shown in Table 4.4.

Table 4.4 Statistical Summary of Difference in the M-E PDG Rigid Performance Life (in yrs) when Using OWPM vs. Continuous Data

Continuous vs.	Performance Life Differences							
	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
OWPM	34	-1.45	1.06	0.18	-3.25	1.17	-1.81	-1.08
OWPM Using Continuous AADTT	34	-0.71	0.90	0.15	-2.33	1.25	-1.03	-0.40
OWPM Using Continuous VC5 Single and Tandem Axle Load	34	-1.42	1.04	0.18	-3.33	0.92	-1.79	-1.06
OWPM Using Continuous VC9 Single and Tandem Axle Load	34	-1.57	0.89	0.15	-3.08	1.08	-1.88	-1.26

The first step in the analysis was to assess if OWPM data were comparable to continuous data. This was performed through a paired *t*-test using the recorded performance life for each of the respective data coverage lengths. The results of the paired *t*-test are shown in Table 4.5.

Table 4.5 Paired *t*-test Between Continuous and OWPM Data for Rigid Pavement Performance Difference

	Paired Differences (in years)					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Continuos – OWPM Rigid	-1.44529	1.05783	.18142	-1.81439	-1.07620	-7.967	33	.000

Referring to Table 4.5, it is observed that OWPM is different than continuous data; OWPM data over-predicts pavement life at a 95% reliability of one to two-years.

To test whether the significant difference in pavement performance life between OWPM and continuous data is due to the observed differences in traffic inputs, three additional performance runs were generated:

- OWPM and continuous AADTT data
- OWPM and continuous VC 5 single and tandem axle loads
- OWPM and continuous VC 9 single and tandem axle loads

A one-way ANOVA was conducted on the difference in performance life for each run that had a variation from the continuous data. This was done to assess if any one of the three variables altered contributed significantly to the observed difference in performance life between OWPM and continuous data. Each site was again considered to be a random independent sample from a normal distribution. The results from the ANOVA analysis are shown in Table 4.6.

Table 4.6 One-Way ANOVA Results for Difference in Means for Rigid Pavement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.463	3	5.154	5.411	.002
Within Groups	125.734	132	.953		
Total	141.196	135			

Table 4.6 shows that the ANOVA test results were significant ($p << 0.05$); at least one of the OWPM runs is different from another. In order to determine the interaction between runs, Tukey's contrast was applied to discover which particular group mean(s) is different from another. Table 4.7 summarizes the result of the Tukey's test. A $p < 0.05$ for a row indicates

that the two groups are statistically different from each other. A summary of the ANOVA and Tukey's contrast can be found in the literature (24). In Table 30, the numbers correspond to the following:

1. OWPM data
2. OWPM data with continuous AADTT
3. OWPM data with continuous VC 5 axle load values
4. OWPM data with continuous VC 9 axle load values

The results in Table 4.7 reveal that OWPM data with continuous AADTT has a statistically significant different mean value than those from other data sets. Since one week data with continuous AADTT produced the closest mean value to zero as well as the lowest confidence interval, the data suggests that use of continuous AADTT in conjunction with other OWPM is needed for improved accuracy in rigid pavement.

Table 4.7 Tukey's Contrast Test for Testing Differences of Means within Groups

(I) FACTOR	(J) FACTOR	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-0.734*	0.237	0.012	-1.3503	-0.119
	3	-0.022	0.237	1.000	-0.640	0.594
	4	0.123	0.237	0.954	-0.493	0.739
2	1	0.734*	0.237	0.012	0.119	1.353
	3	0.712*	0.237	0.016	0.096	1.328
	4	0.858*	0.237	0.002	0.242	1.474
3	1	0.022	0.237	1.000	-0.594	0.6380
	2	-0.712*	0.237	0.016	-1.328	-0.096
	4	0.145	0.237	0.928	-0.470	0.761
4	1	-0.123	0.237	0.954	-0.074	0.493
	2	-0.858*	0.237	0.002	-1.474	-0.242
	3	-0.145	0.237	0.928	-.0761	0.471

* Indicates the mean difference is significant at the 0.05 level.

4.3.3 **Statistical Significance of M-E PDG Flexible Pavement Output**

The same process used for rigid pavement was repeated for flexible pavements. The following summarizes the pavement performance differences based both on rutting and fatigue cracking.

4.3.3.1 Performance life based on rutting

Descriptive statistics for the pavement life differences based on rutting for each data coverage scenario is presented in Table 4.8. Table 4.8 shows that, all traffic characterizations over-predict the performance life as much as one year with a 95% confidence ($p < 0.05$).

OWPM using continuous AADTT produces a tighter confidence interval around zero. The results of the paired *t*-test comparison between OWPM and continuous performance life can be seen in Table 4.9.

Similar to the other distress performances, the OWPM data overestimated pavement performance by as much as 3.25 years, with a confidence interval from roughly 0.5 to 1.5 years. To determine if any of the continuous data was a factor in changing the OWPM performance life significantly, an ANOVA was conducted on the various scenarios. The results are presented in Table 4.10.

Table 4.8 Statistical Summary of Difference in the M-E PDG Flexible Performance Life (Rutting) (in yrs) when using OWPM vs. Continuous Data

Data type		Performance Life Differences						
		Descriptive Statistics					95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
OWPM	29	-1.031	0.9736	0.18079	-3.25	1.17	-1.4014	-0.6607
OWPM Using Continuous AADTT	29	-0.7817	0.93095	0.17287	-3.08	1.25	-1.1358	-0.4276
OWPM Using Continuous VC5 Single and Tandem Axle Load	29	-1.1034	0.88493	0.16433	-3.25	1.17	-1.4401	-0.7668
OWPM Using Continuous VC9 Single and Tandem Axle Load	29	-1.0345	0.97429	0.18092	-3.25	1.17	-1.4051	-0.6639

Table 4.9 Paired *t*-test Result for Difference in Performance Life between OWPM and continuous Based on Rutting for Flexible Pavement

Data type	Paired Differences (in yrs)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Continuous Performance Rutting Life –OWPM Rutting Performance Life	-1.04538	.97673	.19155	-1.43989	-.65087	-5.457	25	.000

Table 4.10 One-Way ANOVA Results for Difference in Means Based on Rutting for Flexible Pavement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.737	3	.579	.653	.583
Within Groups	99.313	112	.887		
Total	101.050	115			

the ANOVA test indicates that the identified significant differences in the three traffic inputs are not contributing to the observed difference between continuous and OWPM performance life.

4.3.3.2 Performance life based on fatigue cracking

The basic descriptive statistics for the performance life difference between continuous and the aforementioned OWPM data sets can be seen in Table 4.11.

Table 4.11 Statistical Summary of Difference in the M-E PDG Flexible Performance Life (in yrs) Based on Fatigue Cracking when Using OWPM vs. Continuous Data

Data type		Performance Life Differences						
		Descriptive Statistics					95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
OWPM	29	-0.6300	1.23332	0.22902	-2.67	2.50	-1.0991	-.1609
OWPM Using Continuous AADTT	29	-0.2734	1.06073	0.19697	-2.25	3.25	-.6769	.1300
OWPM Using Continuous VC5 Single and Tandem Axle Load	29	-0.6897	1.01515	0.18851	-2.58	2.08	-1.0758	-.3035
OWPM Using Continuous VC9 Single and Tandem Axle Load	29	-0.6269	1.15513	0.21450	-2.67	2.42	-1.0663	-.1875

The descriptive statistics revealed that OWPM data had closer pavement life performance to that of continuous data than those found in the rutting analysis. The maximum pavement performance life difference was less than 2.7 years, with a maximum confidence interval bound close to 1 year. The paired *t*-test to determine if OWPM data is statistically significant from continuous data can be found in Table 4.12. The test determined that the OWPM and continuous performance lives were significantly different from one another.

Table 4.12 Statistical Summary of Difference in the M-E PDG Flexible Performance Life Based on Fatigue Cracking when Using OWPM vs. Continuous Data Type

Data type	Descriptive statistics			95% Confidence Interval of the Difference		*t*	df	Sig. (2-tailed)
	Mean	Std. Dev.	Std. Error Mean	Lower	Upper			
Continuous Performance Rutting Life –OWPM Rutting Performance Life	-0.630	1.233	0.229	-1.099	-0.161	-2.751	28	0.010

The one-way ANOVA test was conducted and shown in Table 4.13 to determine if any of the three traffic input variables (AADTT, single and tandem VC 5 and VC 9 loads) could account for the observed differences seen between OWPM and continuous data.

Table 4.13 One-Way ANOVA Results for Difference in Means Based on Fatigue Cracking for Flexible Pavement

Comparison	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.138	3	1.046	.835	.477
Within Groups	140.311	112	1.253		
Total	143.448	115			

As with the rutting distress, variation with the other selected continuous traffic collection schemes did not seem to have an impact on pavement life performance between OWPM and continuous data.

4.3.3.3 Summary

The OWPM pavement performance life both under and overestimated the performance life predicted by continuous data with a 95% CI bound of 1.5 years. Maximum performance life differences were around 3.33 years. A check to see if the three traffic inputs that exhibited the most variation from continuous data (AADTT, single and tandem VC 5 and VC 9) determined that they were not extensively contributing to the difference in pavement performance life. The only exception to this was the continuous AADTT value for rigid pavement. A 95% CI of less than 1.5 years warrants the use of OWPM data. However, if the data retrieval takes minimal effort, continuous traffic inputs should be used as they are regarded as the most accurate.

4.4 TRAFFIC CHARACTERIZATION DEVELOPMENT

The following represents the results of the traffic clustering technique explained in Chapter 3, used to characterize Level II inputs for design. Plots of the formed clusters using the hierarchical clustering technique can be found in Appendices B through F. Additionally plots of statewide axle load vs. M-E PDG default values can be found in Appendix G for reference. It is important to note that clusters containing two or less sites were removed from the analysis. Having such a small sample size in a cluster is more indicative of a special case condition than a regional Level II traffic pattern.

4.4.1 **Average Annual Daily Truck Traffic**

While a formal hierarchical cluster analysis was not performed on AADTT, the formation of AADTT grouping is reviewed here for the sake of completeness. As mentioned in the week versus continuous investigation, one-way design lane AADTT groups were divided into 3 groups; low, medium and high. The details of each group are summarized Table 4.14.

Table 4.14 Established One-Way Design Lane AADTT Levels

AADTT Level	AADTT Value Range	AADTT Designation
Low	0-999	1
Medium	1000-2999	2
High	Above 3000	3

The AADTT clusters and scatter plot illustrating the spread of AADTT values within each range can be seen in Tables B10-B12 and Figure B1, respectively, of Appendix B. The low AADTT sites dominate the data, while high AADTT sites are the scarcest. It is again emphasized that these AADTT ranges can be changed at MDOT’s discretion. These ranges may also need to be adjusted when searching for similarities across various traffic characterizations. Using too large of a range for a given AADTT level could mask these relationships.

4.4.2 **Truck Traffic Classification**

Figure 4.1 illustrates three distinct TTC patterns, each distinguished by the percentage of VC 5 and VC 9 trucks. The hierarchical clustering for TTC resulted in the creation of three distinguishable dominant traffic patterns:

Cluster 1—dominance of VC 9 trucks, with a smaller proportion of VC 5
Cluster 2—roughly equal dominance of VC 5 and VC 9
Cluster 3—dominance of VC 5 vehicles, with a lesser proportion of VC 9 trucks

These results are similar to what was observed in the literature (2, 10). Sites in cluster 1 were found to be mostly on principal interstates, such as I-96, I-94, and I-69, with one-way

AADTT ranging from over 1500 to almost 5500. The cluster 2 contained a majority of sites that were located on north-south routes, such as I-75, US-131, US-127, US-23 and had AADTT less than 2000. The final cluster, cluster 3, had sites mostly on rural arterials, such as US-2, M-46, M-57, and M-6, generally with AADTT of less than 1000. It was suggested by MDOT that comparable M-E PDG default TTC groups be found for these cluster averages. The most comparable TTC value was found by determining the least sum of squares between the cluster mean and the default TTC value. The comparable TTC values for clusters 1, 2 and 3 were TTC3, TTC 7 and TTC 15, respectively. The graphical comparison is shown in Figure 4.1.

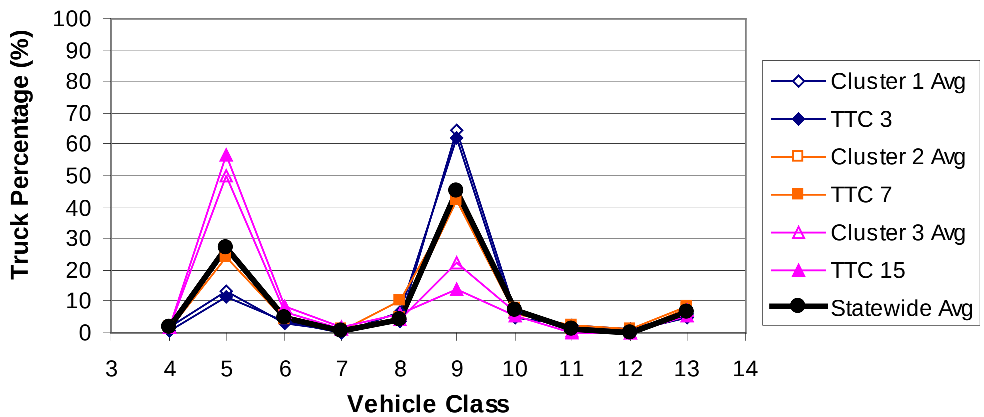


Figure 4.1 Compiled TTC Values

4.4.3 **Monthly Distribution Factors**

MDFs were established for single unit trailers (VC 4-7), tractor trailer combinations (VC 8-10) and multi-trailer combinations (VC 11-13) as these were the default settings in TrafLoad and were recommended for use over individual classes in the literature (7, 13). Figure 4.2 represents the MDF clustering for single unit trailers (VC 4-7). It should be noted that four clusters (6 sites) were excluded after the analyses as they contained two or less sites in each cluster and therefore signify more site-specific patterns rather than any regional similarity. The three cluster averages shown in Figure 4.2 have distinct patterns. The cluster 1 exhibits minor seasonal variability, having MDFs close to 1. Most of these sites were located in the southern Lower Peninsula on a variety of roads with varying functional class and direction. The cluster 2 depicts a general rise in MDFs during the summer with lower values in winter. Major north-south routes, such as I-75, US-131, and US-23 are present in this cluster and most sites are located along the middle region of the Lower Peninsula. The cluster 3 in Figure 4.2 displays higher MDFs in summer and fall, with much lower MDFs in winter and spring. Sites in this cluster are located in the northern Lower Peninsula and Upper Peninsula with low AADTT.

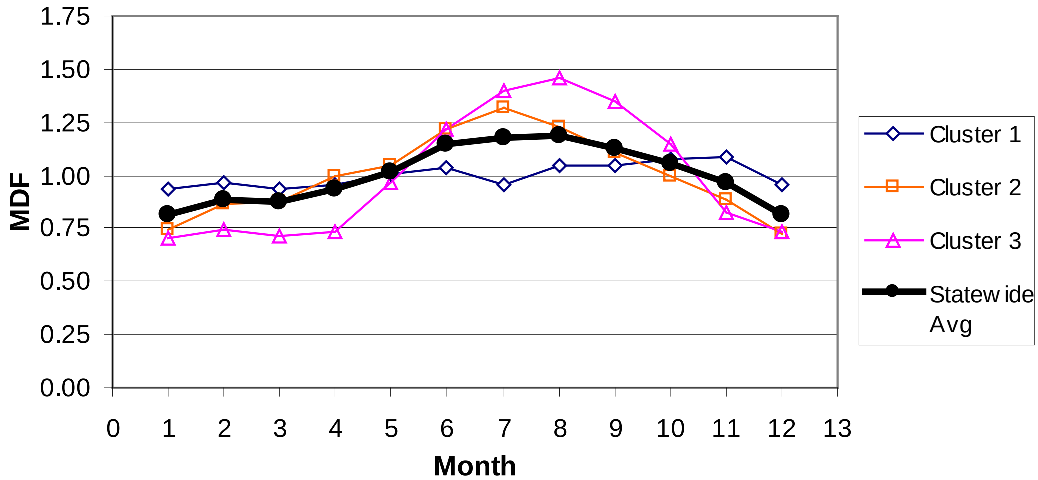


Figure 4.2 Compiled VC 4-7 MDF values

The VC 8-10 MDFs revealed much less variability than VC 4-7 as shown in Figure 4.3. The first cluster produced higher MDFs during the summer months with lower values in the winter. The three sites in this cluster had AADTT less than 300, which probably contributed to its distinct pattern over the other two clusters. The next two clusters appear to have little MDF variation throughout the year, having values close to one. This suggests that the majority of VC 9 traffic is seasonally independent.

Clustering of VC 11-13 MDFs resulted in twelve clusters. A total of seven clusters, which included eight sites, were removed from the analysis again due to having two or less sites in the cluster. The remaining five clusters are shown in Figure 4.4. The clusters 1 and 2, exhibit high summer and low winter VC 11-13 MDFs. These clusters contained sites that were located in the south central Lower Peninsula and Metro Detroit area and had varying functional class and AADTT values. The cluster 4 also showed VC 11-13 MDFs having high summer and low winter values. There were no dominant patterns found within this cluster. Cluster 3 exhibited little seasonal difference and had sites located mainly in the southwestern portion of the Lower Peninsula on major freeways, such as I-94, I-96 and US-131. The cluster 5 had lower spring VC 11-13 MDFs with higher summer and fall values. The three sites in this cluster were all on US-2 in the Northern Peninsula which is a known logging and mineral transport route.

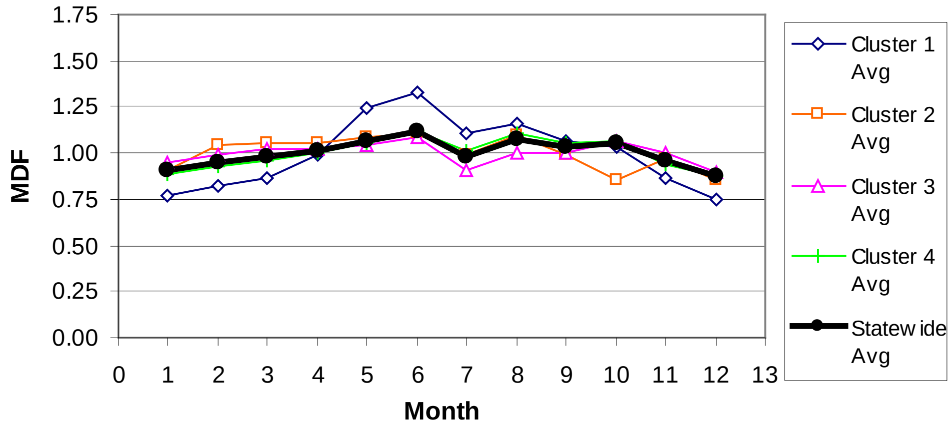


Figure 4.3 Compiled VC 8-10 MDF values

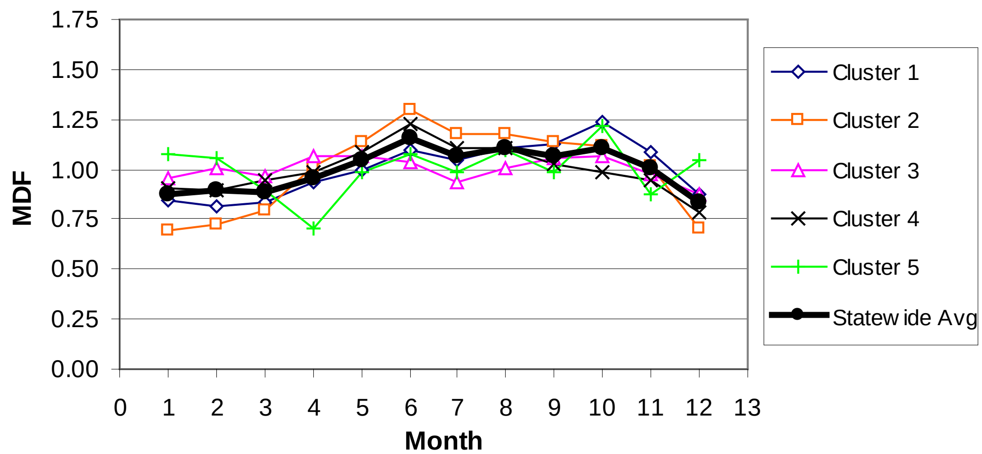


Figure 4.4 Compiled VC 11-13 MDF values

4.4.4 **Hourly Distribution Factors**

The cluster analysis resulted in three clusters from the spectrum of HDFs. Average values for these clusters are shown in Figure 4.5. Cluster 1 contains relatively even to heavier evening proportions of trucks at the site. The majority of sites in this cluster are in the lower southern peninsula located on major east-west interstates, such as I-94 and I-69, with one-way AADTTs greater than 1600. Cluster 2 has a higher percentage of trucks than cluster 1, on average of 1-2% each hour between 6:00 am and 5:00 pm. A review of sites in this cluster show that many are on major north-south routes, such as I-75, US-131, and US-127, with another dominant east-west route, I-96, that connects all three. Cluster 3 average has a roughly a 1-3% higher truck percentage between the hours of 6:00 am and 5:00 pm than either clusters 1 and 2. Sites in this cluster are located on principal arterials with lower AADTT. Suggesting that hauls on this road might be more local in nature. The M-E PDG default value, as shown in Figure 4.5, mirrors cluster 1 the most, having a more equal truck volume percentage over the hours of the day.

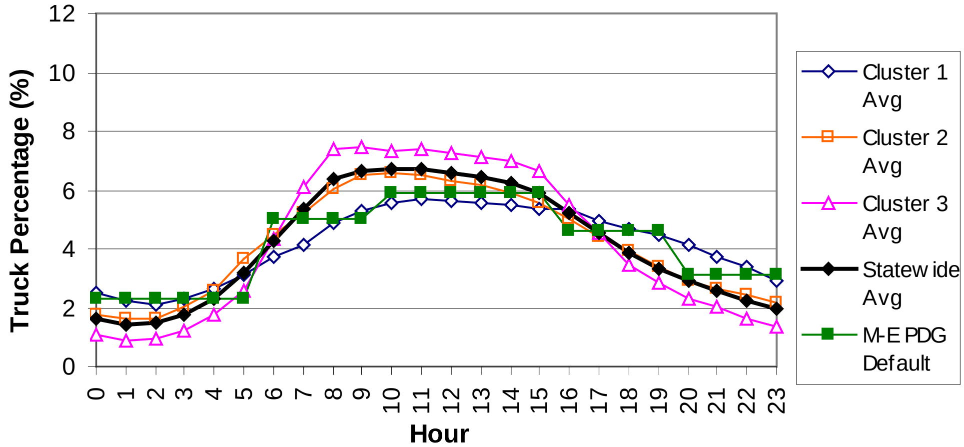


Figure 4.5 Compiled HDF Values

4.4.5 **Axle Groups per Vehicle (AGPV)**

Cluster analysis of single AGPV yielded five clusters, two of which were single sites. These clusters were removed from the analyses. Figure 4.6 shows the cluster average single AGPV for all VCs for the remaining three clusters as well as the statewide average. Since sites 6019 and 6309 did not have single AGPV values for VC 11, they were excluded from the analyses. Including them would have created a large relative distance and would have resulted in the formation of only two clusters based on the clustering algorithm.

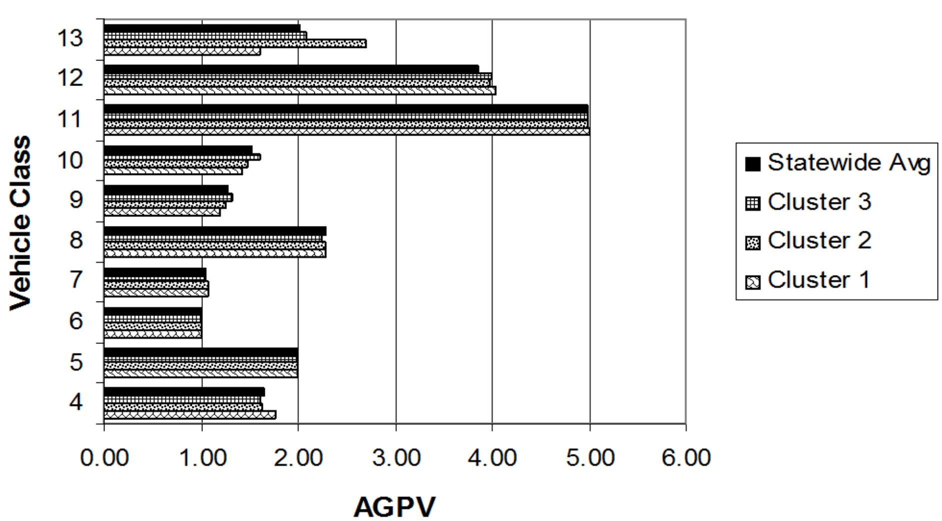


Figure 4.6 Single Axle AGPV Cluster Values

Figure 4.6 reveals that there is a small variation in single AGPV averages between clusters. Little discernible traffic or physical attribute patterns existed for the cluster groups. This suggests that single AGPV is standardized for each VC.

The tandem AGPV cluster averages are presented in Figure 4.7. As with single AGPV, five clusters were formed utilizing the clustering algorithm. However, two clusters were removed, as they contained two or less sites within them, leaving three final clusters.

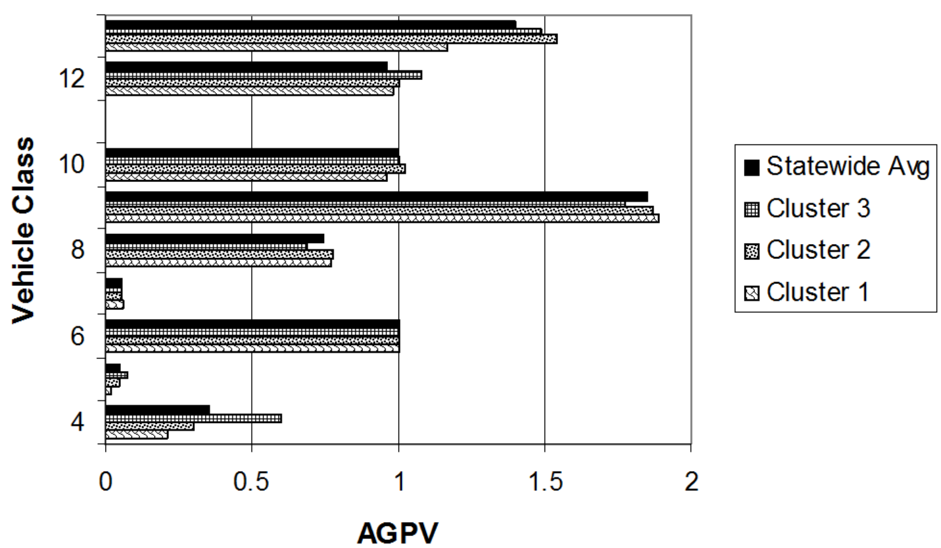


Figure 4.7 Tandem AGPV Cluster Values

Figure 4.7 displays little variation in tandem AGPVs across sites for all VCs, with the exception of VC 4. Cluster 1 sites are located predominantly in the Metro region while most sites in cluster 2 were in the west and southwest portions of the state. Cluster 3 sites were in the northern portions of the state and in the UP. Since VC 4 tandem AGPV seemingly is the only discriminating variable, the regional correlation could be to the particular type of buses used within that region. School districts or charter companies could feasibly purchase similar model buses.

The four tridem AGPV clusters can be observed in Figure 4.8. Unlike single and tandem AGPV, the tridem AGPV seems to exhibit more variation between clusters. Tridem axles are only found on VC 7, VC 10, and VC 13 trucks. The VC 9 values shown in Figure 4.9 could be a result of a semi-tractor trailer combination hauling another smaller trailer behind it, in which the third set of axles after the trailer tandem causes the sensor to register a tridem configuration. A review of site attributes within each cluster did not reveal any patterns that could serve to account for the differences in variation between clusters. However, since cluster 3 has only three sites, the high tridem AGPV observed could be the result of highly site-specific characteristics.

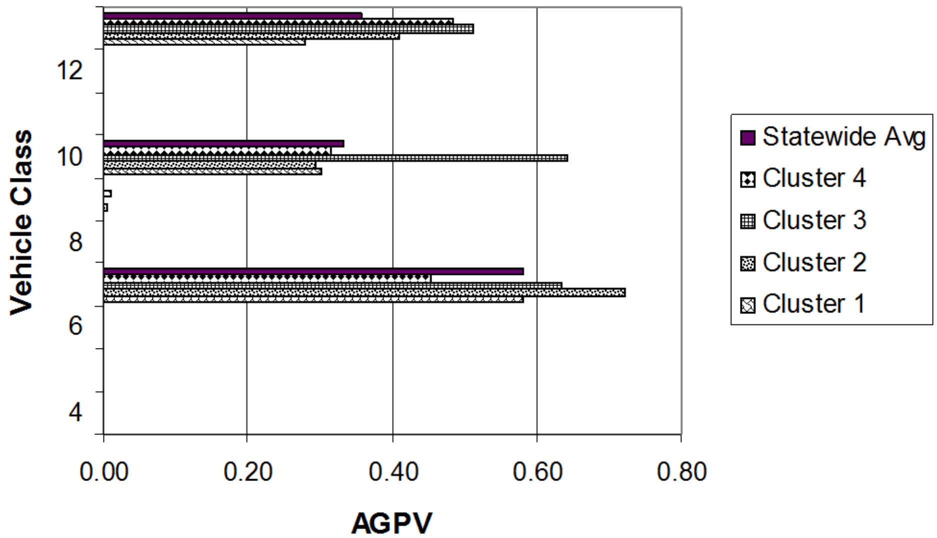


Figure 4.8 Tridem AGPV Cluster Values

Clustering of quad AGPV resulted in six clusters. This was reduced to five as one cluster had just two sites. The five cluster averages for quad AGPV for all vehicle classes is displayed in Figure 4.9.

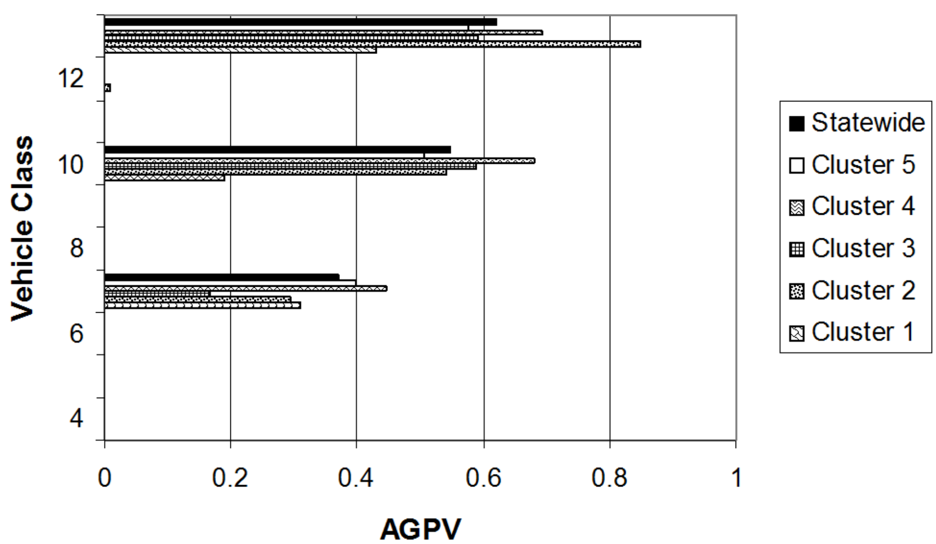


Figure 4.9 Quad AGPV Cluster Values

From Figure 4.9, there seems to be distinct differences in quad AGPV values across clusters. Cluster 1 has lower quad AGPV than the other sites while cluster 2 and cluster 4 seem to have the highest. Again, preliminary analysis showed little distinguishable attributes within the clusters formed.

4.4.6 **Single Axle Load Spectra**

The overall single axle load spectra and related clusters are presented Figure 4.10. Three clusters were formed and are directly related to the two peaks observed in the data. The first peak occurs at approximately 4 to 7 kips while the second peak occurs at 9-14 kips. A review of the individual single axles for all VCs at all sites revealed the following:

- High proportions of VC 5 single axles are concentrated in the 4-7 kip range, whereas singles axles from other VCs typically have low proportions at this range.
- All remaining VC single axle load spectra peak at the 9-14 kip range with the exception of VC 7, which contributes little to the traffic stream.
- Single axle load spectra across all sites displayed similar shaped distributions within the same VC.

These observations suggest that the axle load spectra is not influenced so much by the shape of the axle load spectra itself but instead the actual distribution of the truck traffic, particularly the presence of VC 5. Cluster 1 has a higher proportion of axles in the 9-14 kip range than the 4-7 kip range. The sites in cluster 1 show a dominance of VC 9 truck traffic, having roughly 30% or more traffic than that of VC 5. Cluster 2, has a more even proportion of 9-14 kip axles and 4-7 kip axles. Sites in this cluster had a more even proportion of VC 5 and VC 9 trucks having a distribution difference of less than 30% between the two. Cluster 3 shown in Figure 3 reveals a much higher proportion of 4-7 kip axles than that of 9-14 kips. This cluster had sites with a higher VC 5 percentage than VC 9 for nearly all cases. Because single axles seem to be dependent on the VC distribution rather than the shape of the axle load spectra, using a statewide axle load spectra within all vehicle classes for single axles could be practically acceptable.

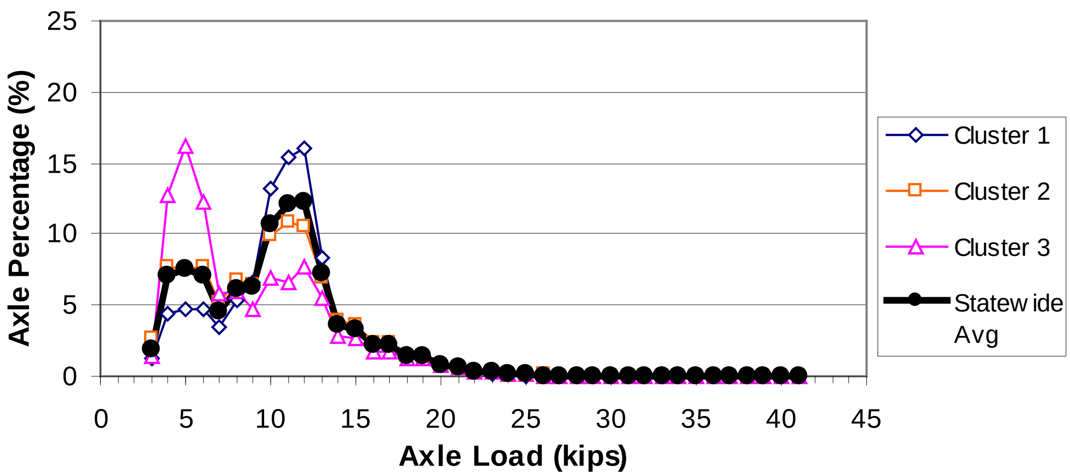


Figure 4.10 Cluster Averages for All Single Axle Load Spectra

4.4.7 Tandem Axle Load Spectra

The overall tandem axle load spectra clusters can be seen in Figure 4.11. Five clusters resulted from the data. Clusters 1-3 were shown to have more light axles than heavy, whereas Clusters 4 and Cluster 5 are heavier in nature. The two peaks seem to correspond to unloaded (9-14 kips) and loaded (30-35 kips). Clusters 1-3 consist of mostly secondary arterials and rural freeways scattered throughout the state. All sites have AADTT less than 2000. Nearly all sites in cluster 4 are located on major east-west routes, I-94, I-96, and I-69 in the southern Lower Peninsula and have AADTT ranging from above 1600 to almost 5500. Cluster 5 had no dominant traffic patterns.

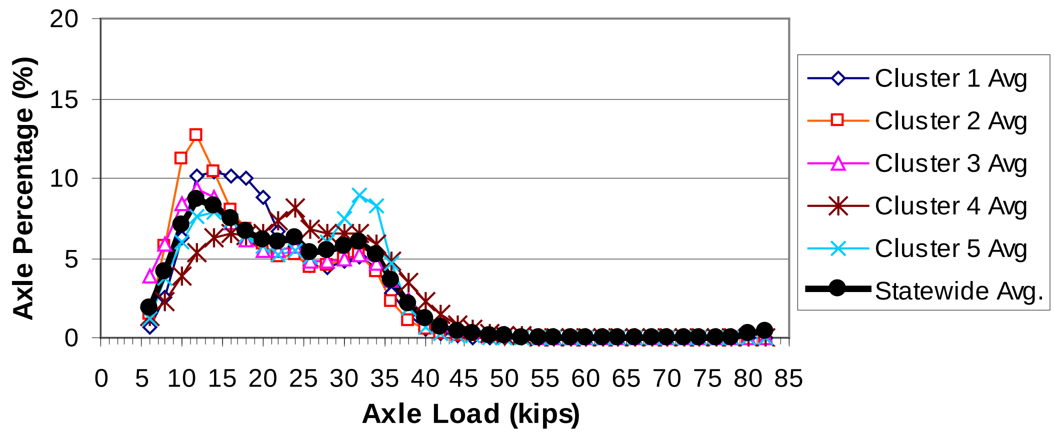


Figure 4.11 Cluster Averages for All Tandem Axle Load Spectra

4.4.8 Tridem Axle Load Spectra

A total of five tridem axle load spectra clusters were created using the clustering algorithm. Two clusters were excluded from the analysis as they contained only one site. The three remaining clusters can be seen in Figure 4.12. The general trend of the tridem axle clusters appears to be a large proportion of light axles around 12 kips followed by a smaller peak value around 40-45 kips. Sites found in the first cluster had higher AADTT on average and were primarily located in the southern Lower Peninsula on principal arterials or interstates. Sites contained in cluster 2 were also mainly on principal arterials scattered across the state that had AADTT ranging from 300 to 2200. Finally, cluster 3 sites were on secondary arterials and freeways with relatively low AADTT, mostly under 1000.

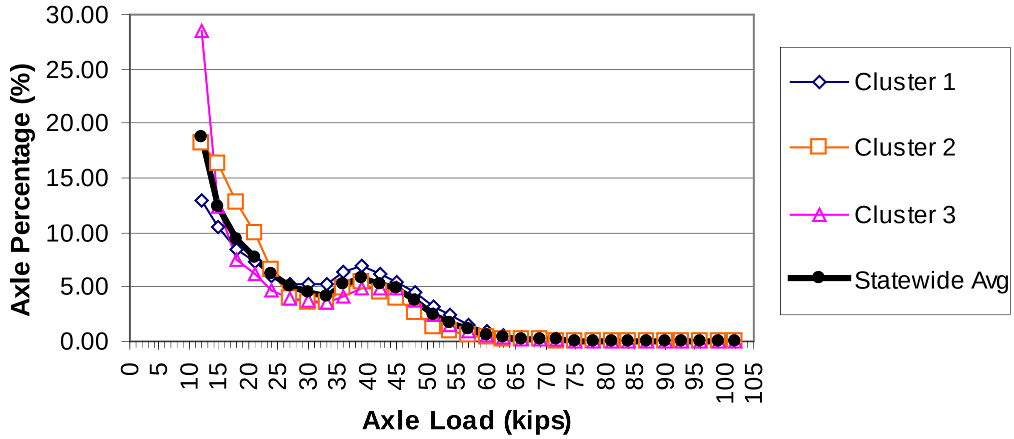


Figure 4.12 Cluster Averages for All Tridem Axle Load Spectra

4.4.9 Quad Axle Load Spectra

The overall quad axle load spectra can be seen in Figure 4.13. A total of six clusters were formed. However, two clusters were removed for having two or less sites and two clusters were combined to form cluster three due to a similar loading distribution. Peak values for the quad axle load spectra occur at the 15-20 kip, 50-60 kip, and the 104 kip range. Perhaps the most significant finding in the analysis of overall quad axles is the presence of the 104 kip load. Having such a high loading on one quad axle, double the allowed weight of 52 kips as shown in Table 12, at all sites suggests is most likely due to the TrafLoad processing itself is erroneous. A truck having two successive quads in a raw data file is seemingly being combined into one axle in TrafLoad. Consequently, the quad axle loads developed in this report will be inherently erroneous. However, relative sensitivity analyses performed with quad axle loads can still yield productive results.

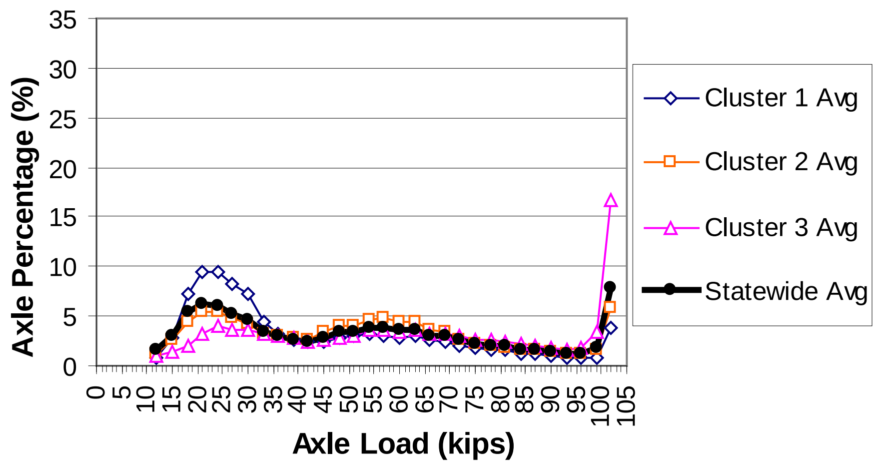


Figure 4.13 Cluster Averages for All Quad Axle Load Spectra

Most of the sites contained in cluster 1 are in the Bay or University regions on roads having an AADTT of less than 2000. Dominant characteristics could not be established for cluster 2. Cluster 3 contained sites in the Metro, Southwest and Superior regions.

4.5 IMPACT OF TRAFFIC CHARACTERIZATIONS IN THE M-E PDG

Comparison of the various traffic characterizations in the M-E PDG allows for the determination of which traffic characterization (Level II or Level III) for a particular traffic input is appropriate, at a minimum, for design when Level I is unavailable. Level I, when available, should be used wherever possible as it is regarded as the actual traffic for the site. If it is found that the predicted pavement performance is insensitive to a particular traffic input, statewide or M-E PDG default values could be used (Level III). Should this be the case, however, it will be recommended that statewide values be used as they are more representative of the state than national data. If a predicted performance was found to be sensitive to a particular traffic input, there may be a need to develop Level II inputs at a minimum. This section assesses the performance of the various traffic characterizations for both rigid and flexible pavements. The basic procedure for the rigid analysis was to establish the continuous (site-specific) predicted performance life for each site, which was already performed in the OWPM-continuous comparison. Subsequently, for each traffic parameter, the site specific value was being replaced with the following:

- Statewide average (Level III)
- Cluster average (Level II)
- M-E PDG default (Level III)

The M-E PDG program was run for each adjusted traffic characterization and the predicted performance life based on the threshold values was recorded. This process was adopted for all traffic inputs. The resulting pavement life difference was calculated by subtracting the traffic characterization value from the site-specific continuous value. As with the OWPM-continuous comparison, positive pavement life differences indicated that the pavement life was being under predicted while negative values indicated an over prediction in pavement life.

Once the pavement life performances were compiled, statistical analyses of the data was conducted. For each traffic input, descriptive statistics were calculated for summary of the data. An ANOVA (*p*-value of 0.05 for 95% confidence, 2-tailed test) was then used to determine if there was any effect of using a specific traffic characterization over another. If the ANOVA was significant, Tukey’s contrast was used to determine the specific interactions between traffic characterizations. For ease of understanding, an error bar chart is used in place of Tukey’s contrast table to visually assess the differences in the various traffic characterizations. The results of these analyses, lead to the recommendation of the appropriate minimum traffic characterization, Level II or Level III that is needed when Level I data is not available. While there were multiple statistics performed to gain understanding of the data, the most critical were the 95% CI and the minimum and maximum values, as they gave a true indication of the practical variability in the data. Table 4.15 reviews the criteria used to determine the impact (sensitivity) of the difference between traffic characterizations and correspondingly select the proper level needed for design.

Table 4.15 Impact Designation for the M-E PDG Results

Designation of Impact	95% CI Bound (Years)	Minimum or Maximum Bound (Years)
Significant	CI Bound > 1	MM Bound > 5
Moderate	½ < CI Bound < 1	2 < MM Bound < 5
Negligible	CI Bound < ½	MM Bound < 2

The designations were not only used to measure each traffic characterizations performance against site specific values, but also to determine the impact between traffic characterizations. The traffic characterization which led to an improvement in the designation as compared to another, that particular traffic characterization was recommended. If the impacts of all traffic characterizations analyzed were similar, then Level III data (lowest and easiest to input) was recommended.

4.5.1 **Rigid Pavement Analysis**

4.5.1.1 Truck Traffic Classification

Table 4.16 summarizes the descriptive statistics for the predicted performance life values based on 10% slabs cracked for each TTC traffic characterization. Table 4.17 shows the results of the ANOVA test.

Table 4.16 Descriptive Statistics for TTC Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide TTC	36	-0.17	3.09	0.51	-5.67	6.67	-1.22	0.87
Cluster Average TTC	36	0.04	1.99	0.33	-4.67	4.75	-0.63	0.72
M-E PDG Comparable Cluster TTC Values	36	-0.16	2.64	0.44	-6.83	5.33	-1.06	0.73

Table 4.17 One-Way ANOVA Pavement Life Difference Results for TTC Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.07	2	0.53	0.08	0.92
Within Groups	716.36	105	6.82		
Total	717.43	107			

The results of the ANOVA analysis suggest that while TTC does impact performance, the three traffic characterizations are not significantly different from one another. Figure 4.14 displays the error-bar chart for the TTC traffic characterizations. Since the 95% confidence intervals overlap, the TTC characterizations do not produce a noticeable statistical difference in rigid pavement design life between one another. These observations suggest statewide values could be used. However, the cluster averages produce a maximum under and over prediction of at least one year than the other hierarchical traffic characterizations. Additionally, the CI for the cluster TTC is at least half a year closer to Level I data than the other hierarchical levels. Accordingly cluster TTC values should be used for better pavement performance results.

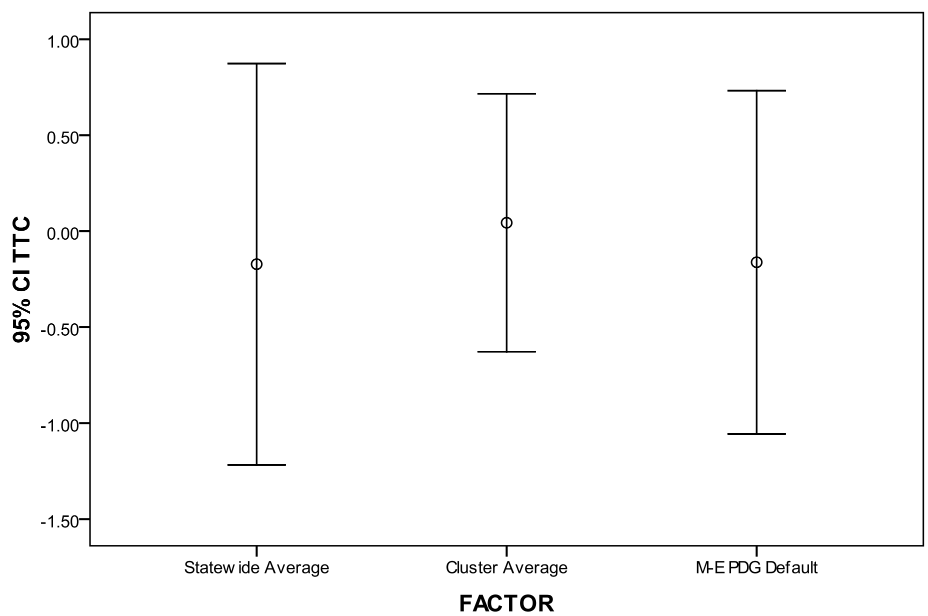


Figure 4.14 Error Bar Chart for Differences in Rigid Performance Life Based on TTC Traffic Inputs

4.5.1.2 Monthly Distribution Factor

The descriptive statistics for each MDF traffic characterization can be found in Table 4.18.

From Table 4.18, the 95% confidence intervals for each traffic characterization are less than one-year. The maximum observed difference in performance life from site-specific data was an over-prediction in performance of 1.75 years. This observation suggests that MDFs have a weak effect on M-E PDG performance. The one-way ANOVA results to prove significant difference amongst the traffic characterizations are shown in Table 4.19.

Table 4.18 Descriptive Statistics for MDF Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide MDF	36	0.16	0.44	0.07	-0.83	1.08	0.01	0.31
Cluster Average MDF	36	0.03	0.27	0.05	-1.75	0.17	-0.06	0.12
M-E PDG Default MDF	36	-0.53	0.45	0.07	-0.75	0.67	-0.68	-0.38

Table 4.19 One-Way ANOVA Pavement Life Difference Results for MDF Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.55	2	4.78	30.54	0.00
Within Groups	16.42	105	0.16		
Total	25.97	107			

Table 4.19 reveals that there is a significant difference between the means of the three traffic inputs. To further explore this finding, an error bar chart was produced for the MDF inputs as shown in Figure 4.15.

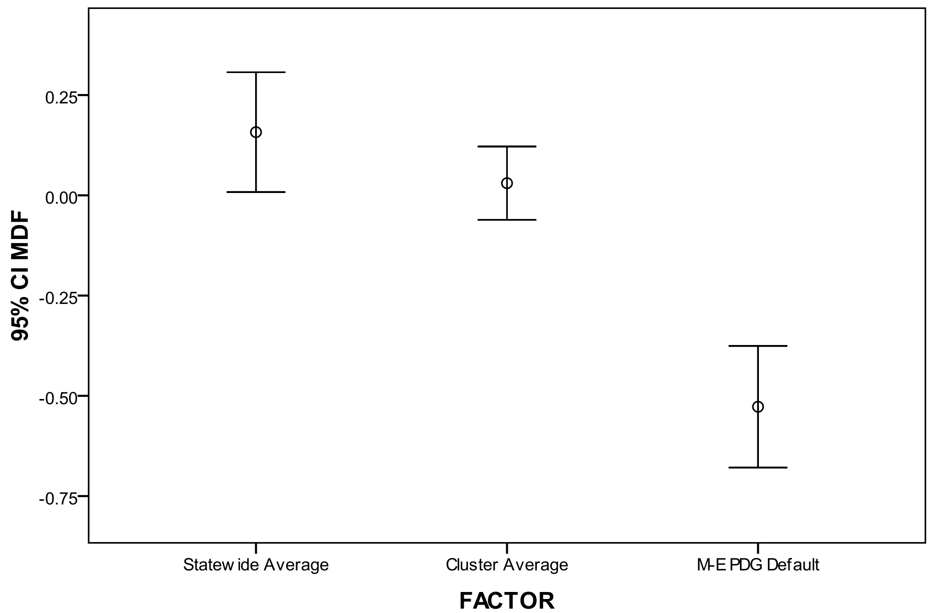


Figure 4.15 Error Bar Chart for Differences in Rigid Performance Life Based on MDF Traffic Inputs

Figure 4.15 reveals that the default M-E PDG confidence interval for pavement life difference varies significantly from the cluster or statewide averages. Tukey's contrast test verified this finding. Since the confidence intervals are within a year of one another, however, there is little difference in pavement life prediction from a practical perspective. As such, statewide average values could be used for this traffic input.

4.5.1.3 Hourly Distribution Factor

Table 4.20 displays the descriptive statistics for the various HDF traffic characterizations. The HDFs seem to have a much more significant impact on predicted pavement performance. The M-E PDG default and statewide averages for HDF exhibit under and over predictions of up to 11 years. While this is suggestive of an outlier, the next worse case seen in the data was around 9 to 10 years within both traffic characterizations. The M-E PDG produced the worst results, having a CI roughly between 2.5 and 5 years under predicting performance. The cluster averages produced the least predicted performance difference from site-specific values. This input had a confidence interval within one-year of site-specific values with maximum performance life differences just less than 5.5 years. Statewide HDF values produced CIs that exceeded at least two years either over or under predicting performance. It was not anticipated that HDF would have this much of an effect on pavement performance due to the effect of slab curling. It might be possible that this model needs to be calibrated. To test the difference of this significance statistically, a one-way ANOVA was performed with the results being displayed in Table 4.21.

Table 4.20 Descriptive Statistics for HDF Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide HDF	36	-0.68	4.15	0.69	-10.08	6.83	-2.08	0.73
Cluster Average HDF	36	-0.20	2.11	0.35	-5.42	3.00	-0.92	0.51
M-E PDG Default HDF	36	3.79	3.39	0.57	-3.58	11.00	2.64	4.94

Table 4.21 One-Way ANOVA Pavement Life Difference Results for HDF Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	433.53	2	216.76	19.58	0.00
Within Groups	1162.59	105	11.07		
Total	1596.12	107			

The one-way ANOVA results validated the observation that there was a distinction in mean performance life difference between the three traffic characterizations. This difference is illustrated in the error bar chart shown in Figure 4.16.

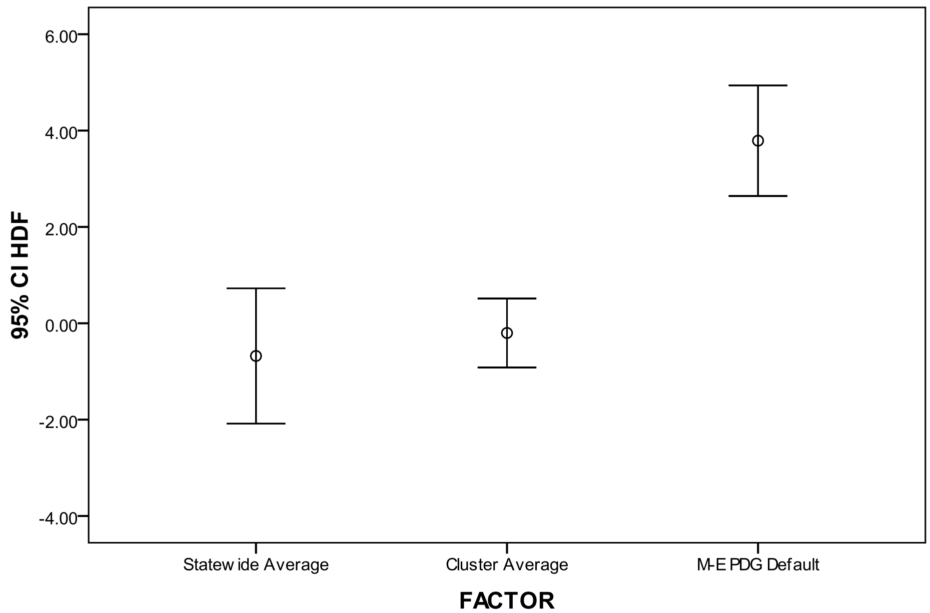


Figure 4.16 Error Bar Chart for Differences in Rigid Performance Life Based on HDF Traffic Inputs

As noted previously, Figure 4.16 reveals that the M-E PDG default significantly under-predicts performance life, as much as four years more with a 95% confidence than using statewide or cluster averages. The cluster average and statewide average do not seem to show a definitive difference, although the cluster average has tighter confident band around zero. Tukey's test confirmed these observations, stating that M-E PDG default HDF values were different than the other traffic characterizations while cluster and statewide averages were not different statistically. The results of these analyses suggest that using cluster averages for this traffic characterization is warranted.

4.5.1.4 Axle Groups per Vehicle

Descriptive statistics for the AGPV traffic characterizations can be found in Table 4.22. The results indicate that variation in AGPV has a slight impact on predicted performance life. The M-E PDG default produced the greatest difference in predicted performance, having maximum under and over prediction values of close to two years. However, the confidence intervals for all traffic characterizations are within half a year from site specific data. The one-way ANOVA results are shown in Table 4.23.

Table 4.22 Descriptive Statistics for AGPV Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average AGPV	36	-0.01	0.50	0.08	-1.00	1.08	-0.18	0.16
Cluster Average AGPV	36	0.04	0.24	0.04	-0.67	0.58	-0.04	0.12
M-E PDG Default AGPV	36	0.06	0.91	0.15	-1.67	2.08	-0.25	0.36

Table 4.23 One-Way ANOVA Pavement Life Difference Results for AGPV Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.07	2	0.04	0.10	0.91
Within Groups	40.13	105	0.38		
Total	40.21	107			

The ANOVA results show that the various AGPV traffic characterization do not have statistically significant difference in predicted performance. Figure 4.17 supports this claim.

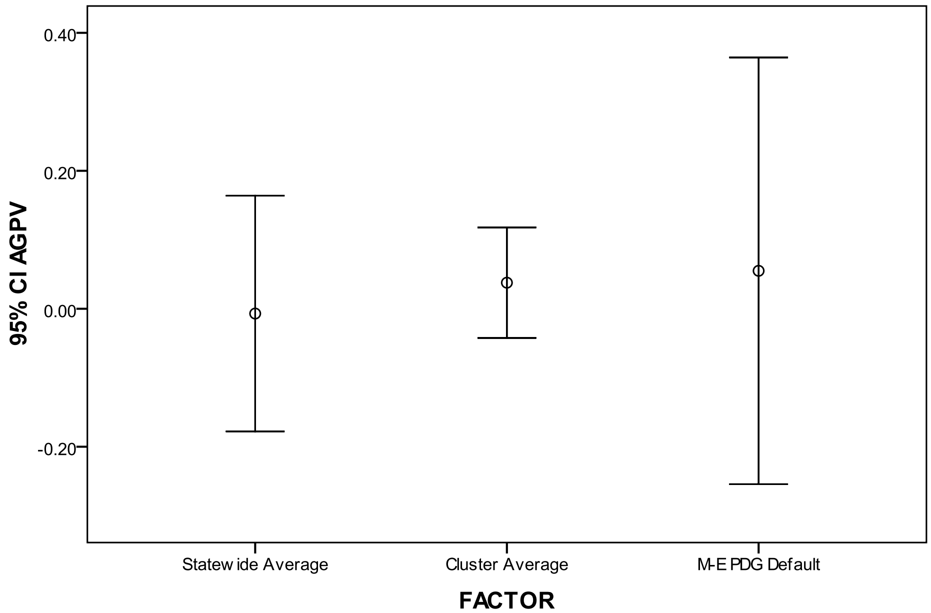


Figure 4.17 Error Bar Chart for Differences in Rigid Performance Life Based on AGPV Traffic Inputs

From Figure 4.17, it is shown that the confidence intervals for the three traffic characterizations overlap one another. The M-E PDG produces the most variation in performance life, having the widest confidence interval. However, from a practical perspective, this interval, which is within half a year of site-specific performance, can be considered negligible. Since there does not seem to be a significant effect, both statistically and practically, between the traffic characterizations, statewide averages could be used.

4.5.1.5 Single Axle Load Spectra

The descriptive statistics for the developed single axle load characterizations are displayed in Table 4.24. The table reveals that single axle load spectra have a moderate impact on predicted pavement performance. Maximum under and over prediction values were around four years, with the M-E PDG default values producing an under prediction exceeding eight years for two sites (Site 9759 and Site 8440). Yet again the M-E PDG default values exhibit the most variation having a performance life difference sample standard deviation nearly twice that of cluster or statewide averages. Its 95% CI also seems to under predict more significantly than the other traffic characterizations, having an interval from nearly zero to around 1.5 years. Statewide and cluster averages seem nearly identical in terms of minimum and maximum performance prediction, sample standard deviation, and 95% CI. Values for these were approximately 4 years, 1.25 years, and bounds of 0.5 years respectively. It should be noted that only seven sites exceeded one year of site specific values. It was unclear as to what was the cause of these more extreme cases. A one-way ANOVA test was performed to statistically evaluate the differences in predicted pavement life between the three traffic characterizations. The results are displayed in Table 4.25.

Table 4.24 Descriptive Statistics for Single Axle Load Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Single Axle Loads	36	0.14	1.25	0.21	-3.92	3.17	-0.29	0.56
Cluster Average Single Axle Loads	36	0.09	1.39	0.23	-4.08	4.17	-0.38	0.56
M-E PDG Default Single Axle Loads	36	0.73	2.45	0.41	-3.83	8.17	-0.10	1.56

Table 4.25 One-Way ANOVA Pavement Life Difference Results for Single Axle LS Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.17	2	4.59	1.45	0.24
Within Groups	332.89	105	3.17		
Total	342.07	107			

The one-way ANOVA did not find a statistical significance between the single axle traffic characterizations. This can be verified by examining Figure 4.18.

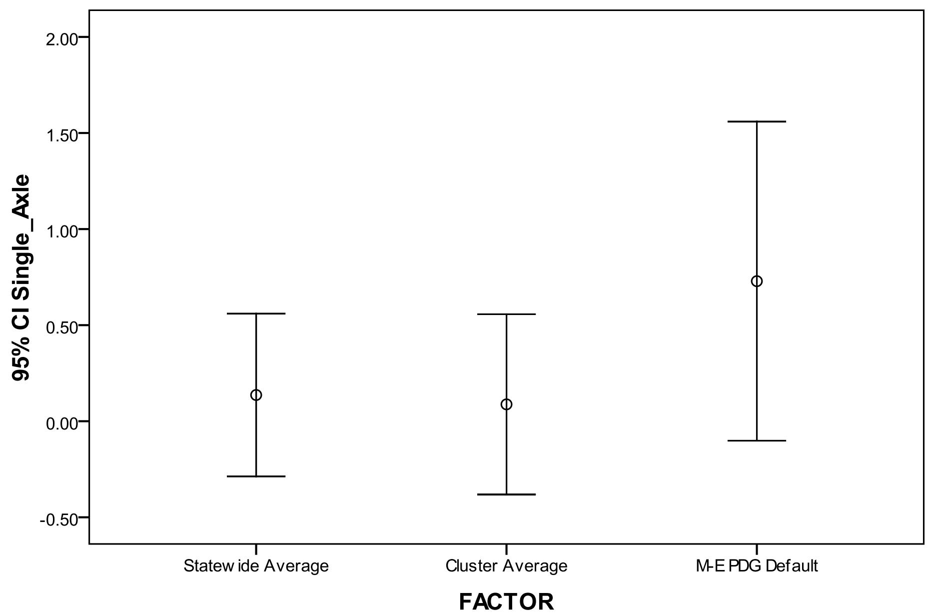


Figure 4.18 Error Bar Chart for Differences in Rigid Performance Life Based on Single Axle Load Traffic Inputs

Figure 4.18 shows that the confidence intervals overlap, which validates the ANOVA finding that there is not a significant difference in predicted pavement performance amongst the three traffic characterizations. Since the statewide and cluster averages produce nearly identical differences in predicted performance life, statewide averages could be used for this traffic input.

4.5.1.6 Tandem Axle Load Spectra

The descriptive statistics for tandem axle load traffic characterizations can be seen in Table 4.26. Originally, it was found that all traffic characterizations produced maximum under or over performance life prediction values in excess of 10 years, which is half the design life. A subsequent outlier analysis was performed on the data to determine the extreme observations that were seen in the data. Four sites were identified, consisting of Site 9189 (I-275@Penn), Site 8049 (Fowlerville), Site 7159 (Battle Creek) and Site 7029 (Grass Lake). Site 7029 is actually responsible for all high over prediction (negative) values. A review of this site indicated that some slight calibration drift existed. This is most likely is responsible for the extreme pavement performance life differences and is most likely an outlier due to the next over prediction value being approximately six years. In analyzing the under prediction (positive) values, at least seven sites had values greater than nine years. The substantial number with this high of variation seems to indicate that the effect is from the hierarchical characterizations themselves rather than extreme and potentially erroneous observations from a few specific sites. The M-E PDG default values produce inferior results having a mean and sample standard deviation pavement performance life difference of almost five years. The confidence interval for this traffic characterization ranges from three to almost seven years. The statewide and cluster average pavement life performance prediction have means and confidence intervals much closer to zero. However, both have high sample standard deviations of around four to five years. The cluster average seems to produce the most comparable results to that of site specific, having a confidence interval within 1.5 years of zero. Cluster averages also have a CI under prediction value one year less than statewide values. The one-way ANOVA analysis to assess the differences in the traffic characterizations can be seen in Table 4.27.

Table 4.26 Descriptive Statistics for Tandem Axle Load Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Tandem Axle Loads	36	0.68	4.75	0.79	-13.00	9.33	-0.93	2.28
Cluster Average Tandem Axle Loads	36	0.14	3.57	0.60	-13.25	8.58	-1.07	1.35
M-E PDG Default Tandem Axle Loads	36	4.90	4.80	0.80	-11.08	12.42	3.27	6.52

Table 4.27 One-Way ANOVA Pavement Life Difference Results for Tandem Axle LS Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	488.80	2	244.40	12.57	0.00
Within Groups	2041.05	105	19.44		
Total	2529.85	107			

The results from the ANOVA analysis reveal that there is a statistically significant difference between the traffic characterizations. The error-bar chart is shown in Figure 4.19.

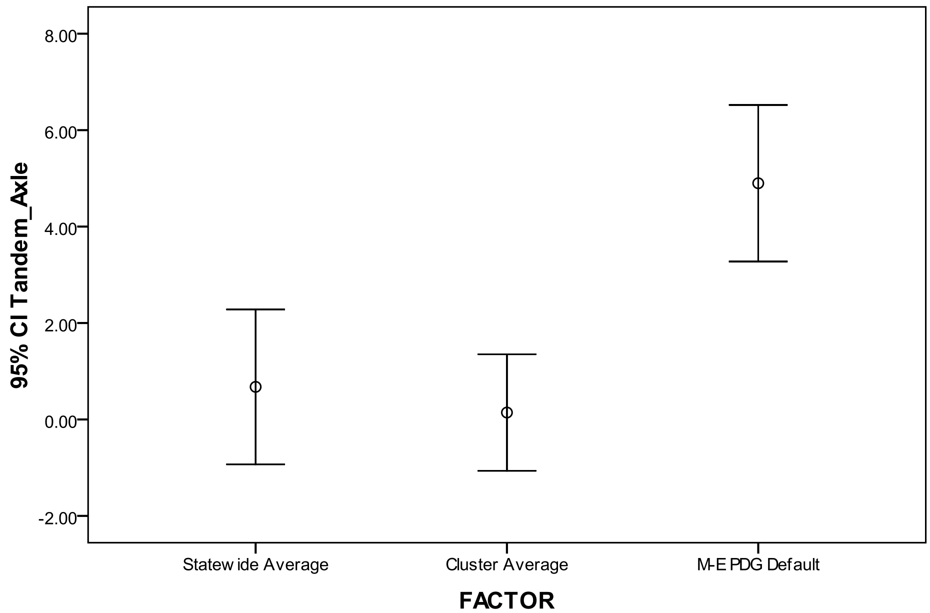


Figure 4.19 Error Bar Chart for Differences in Rigid Performance Life Based on Tandem Axle Load Traffic Inputs

Figure 4.19 illustrates that the M-E PDG default values under predict pavement performance life an average of five years when compared to statewide or cluster traffic characterizations. Cluster and statewide averages seem to produce comparable results. Tukey's contrast confirmed these observations. However, since cluster averages had a mean predicted performance life difference close to zero and a tighter 95% confidence band, one year less under prediction than statewide, it is best that cluster averages be used for this traffic input.

4.5.1.7 Tridem Axle Load Spectra

Table 4.28 summarizes the descriptive statistic summary for mean predicted performance life difference for tridem axle load spectra traffic characterizations.

Table 4.28 reveals that tandem axle loads have an insignificant impact on predicted pavement life performance. The mean, confidence interval, standard deviation, and minimum and maximum performance life difference are all between one to three months. The only exception to this was the M-E PDG default values, in which two sites had predicted performance difference values in excess of one-year. Such a low difference could be attributed to tridem axles contributing a relatively small proportion of overall loading on the pavement. An ANOVA test, shown in Table 4.29, was conducted to verify the statistical significance of this difference.

Table 4.28 Descriptive Statistics for Tridem Axle Load Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Tridem Axle Loads	36	0.004	0.039	0.007	-0.170	0.080	-0.009	0.017
Cluster Average Tridem Axle Loads	34	0.005	0.027	0.005	-0.080	0.080	-0.005	0.014
M-E PDG Default Tridem Axle Loads	36	0.116	0.357	0.060	-0.250	1.830	-0.005	0.236

Table 4.29 One-Way ANOVA Pavement Life Difference Results for Tridem Axle LS Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.29	2	0.15	3.32	0.04
Within Groups	4.55	103	0.04		
Total	4.84	105			

The ANOVA test revealed that at least one of the traffic characterizations was significant from one another. Tukey's contrast was conducted to identify which traffic characterization pair it was. The test contradicted the ANOVA result, finding that there were not any statistically significant differences amongst the traffic characterizations.

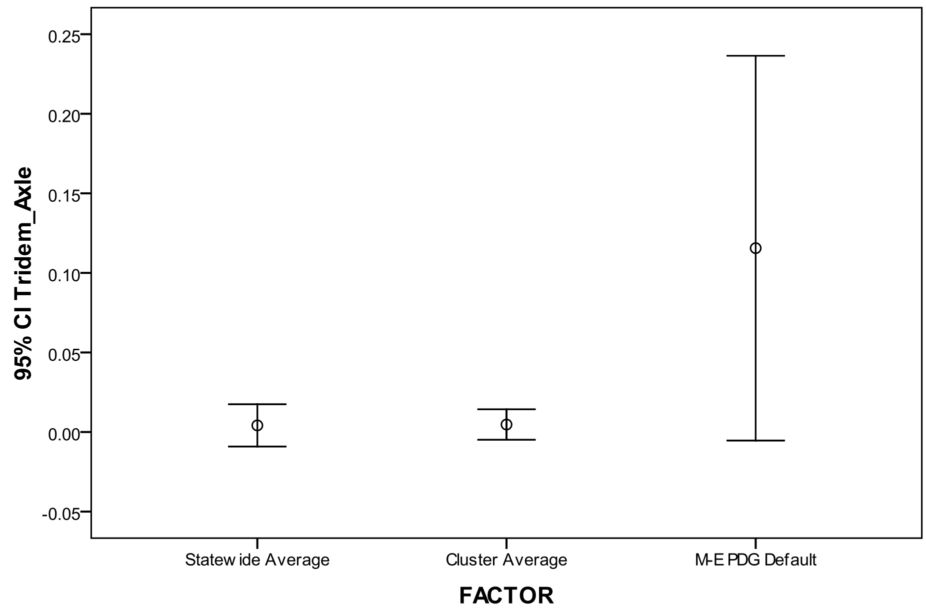


Figure 4.20 Error Bar Chart For Differences in Rigid Performance Life Based on Tridem Axle Load Traffic Inputs

The effects of the two potential erroneous points in the M-E PDG default values are shown in Figure 4.20 by the large increase in the confidence interval band. In contrast, both the statewide and cluster averages, have narrower 95% confidence interval bands that are less than a month difference from zero. The confidence interval bands being within one to three months for all traffic characterizations, suggest that statewide averages could be used for this traffic input.

4.5.1.8 Quad Axle Load Spectra

Summary statistics for the quad axle load spectra predicted pavement performance difference can be seen in Table 4.30.

Similar to the tridem axle load spectra characterizations, the quad axle load spectra characterizations seem to have little impact on predicted pavement performance life. All characterizations have means, standard deviations, 95% confidence intervals, and maximum under and over predicted performance life values of less than a month. Similarly to tridem axles, this is most likely due to quad axles contributing to such a small amount of the overall loadings experienced by the pavement. The ANOVA analysis conducted for this data can be seen in Table 4.31.

Table 4.30 Descriptive Statistics for Quad Axle Load Comparison

Data level	Basic Statistics						95% Confidence Interval	
	N	Mean	Std. Dev.	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Quad Axle Loads	36	0.002	0.013	0.002	0.000	0.080	-0.002	0.007
Cluster Average Quad Axle Loads	33	0.000	0.000	0.000	0.000	0.000	0.000	0.000
M-E PDG Default Quad Axle Loads	36	0.002	0.030	0.005	-0.080	0.080	-0.008	0.012

Table 4.31 One-Way ANOVA Pavement Life Difference Results for Quad Axle LS Input Levels

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.00	2	0.00	0.15	0.86
Within Groups	0.04	102	0.00		
Total	0.04	104			

The ANOVA analysis verifies that there is not a significant difference between traffic characterizations for quad axle load spectra. The error bar chart shown in Figure 4.21 also confirms this as the 95% confidence intervals overlap. Since all traffic characterizations produce the same results as site specific data, a statewide average can be used for this traffic input.

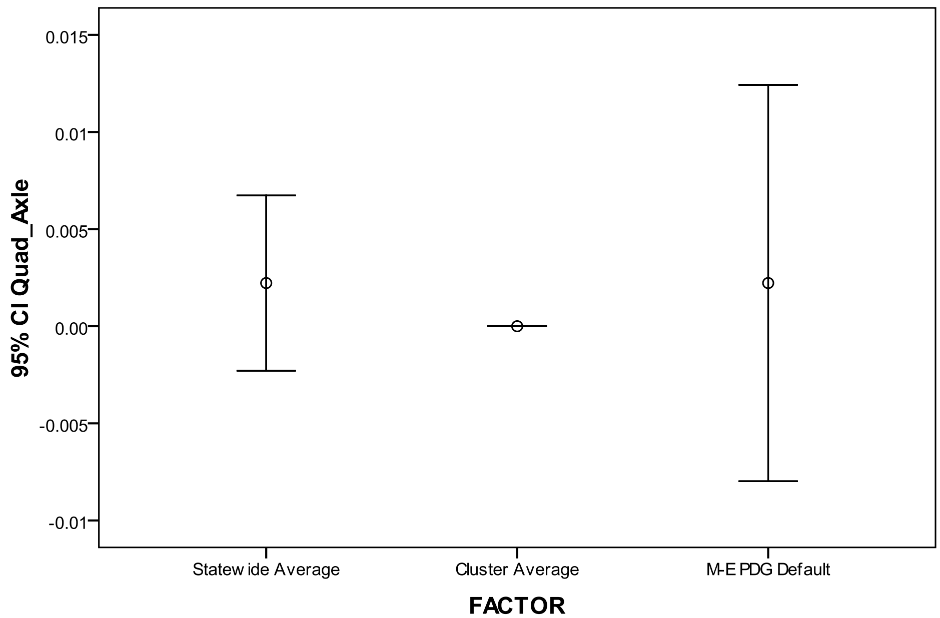


Figure 4.21 Error Bar Chart for Differences in Rigid Performance Life Based on Quad Axle Load Traffic Inputs

4.5.2 **Flexible Pavement Analysis**

Following the rigid analyses, the flexible runs were conducted. Since the flexible runs take a substantially longer time period than rigid pavement to process the rutting and fatigue cracking outputs, up to 15 times longer in some cases, care was taken to efficiently perform runs. From the rigid analysis, it was seen that in nearly every case, the M-E PDG default traffic input produced either the most varying prediction life or had the most substantial average pavement life difference from site specific values. Therefore, it was decided to exclude the M-E PDG default values in flexible pavement design runs.

As previously stated, rutting, and fatigue cracking were shown to be impacted by the various traffic characterizations and are accordingly assessed for the flexible runs. To measure the impact of the traffic characterizations had on these distresses and subsequently pavement performance life, the following analyses were conducted:

- Descriptive statistics to summarize the data
- Paired *t*-test between statewide average performance life difference and cluster average performance life difference
- An error-bar chart with each traffic characterization to visually assess the difference.

Unless there is a strong reason not to, the traffic characterizations suggested for use in rigid design will be recommended for flexible to maintain consistency in the design procedure.

4.5.2.1 Truck Traffic Classification

Rutting

The descriptive statistics for the TTC characterizations' pavement life difference performance based on rutting can be found in Table 4.32.

Table 4.32 Pavement Life Difference Descriptive Statistics Based on Rutting for TTC Characterizations

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average TTC	31	0.665	2.713	0.487	-2.667	11.417	-0.330	1.661
Cluster Average TTC	31	0.535	2.600	0.467	-3.083	10.250	-0.419	1.488

When compared to rigid pavement, the flexible pavement life difference for the TTC characterizations was found to be slightly less variable, with the exception of Site 9759 (Cutlerville). This sight was responsible for the minimum and maximum pavement performance life differences of approximately 11.5 and 10.25 years for statewide and cluster averages. The next maximum value was roughly five years, suggesting that Site 9759 is an outlier. The standard deviation of the data approached almost three years for both TTC traffic characterizations, with confidence interval bounds of approximately 1.5 years or less. The paired *t*-test to determine if the differences in traffic characterizations were statistically significant is shown in Table 4.33.

Table 4.33 Paired *t*-test for Pavement Life Difference Based on Rutting for TTC Characterization

Variable	Paired Differences (Rutting)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
TTC	0.131	1.073	0.193	-0.263	0.525	0.679	30	0.502

The paired *t*-test in Table 4.33 was found to be insignificant. Figure 4.22 shows that the error bars are nearly identical for each traffic characterization, indicating that they have similar distributions.

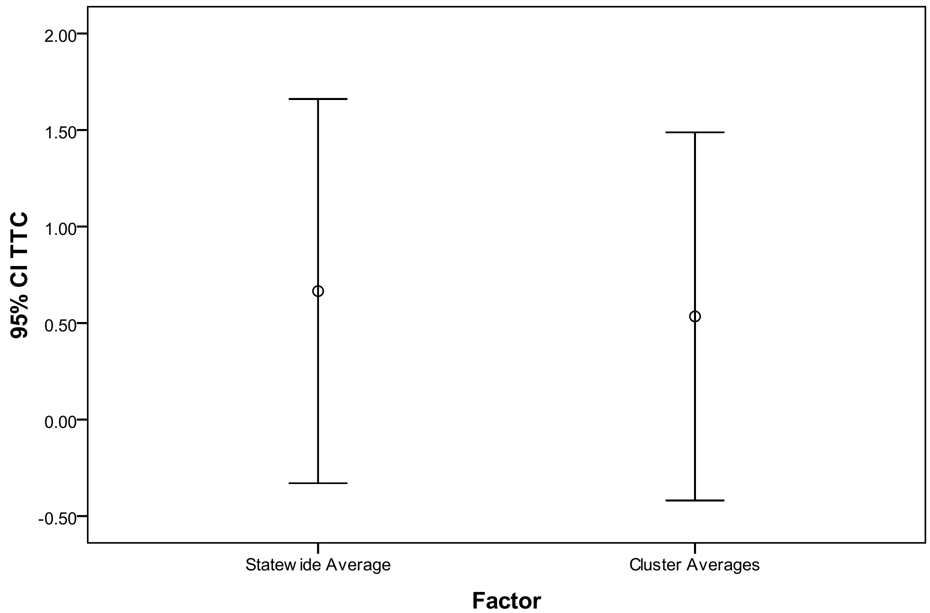


Figure 4.22 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to TTC

<u>Fatigue Cracking</u>

The descriptive statistics for the TTC characterization, pavement life difference performance based on fatigue cracking can be found in Table 4.34. While not as pronounced as rutting performance life difference, the performance life difference values based on fatigue cracking exhibit standard deviations of almost two years, with underestimation of pavement life around six years. There again seems to be no distinction between traffic characterizations for differences in pavement performance life. This is supported by the lack of significance from the paired *t*-test shown in Table 4.35 and the overlapping confidence intervals for pavement life difference between the two traffic characterizations as shown in Figure 4.23.

Table 4.34 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for TTC Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average TTC	31	0.434	1.934	0.347	-1.833	6.333	-0.276	1.143
Cluster Average TTC	31	0.304	1.681	0.302	-2.333	5.667	-0.313	0.920

Table 4.35 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for TTC Characterization

Variable	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
TTC	0.130	1.254	.225	-0.330	0.590	0.576	30	0.569

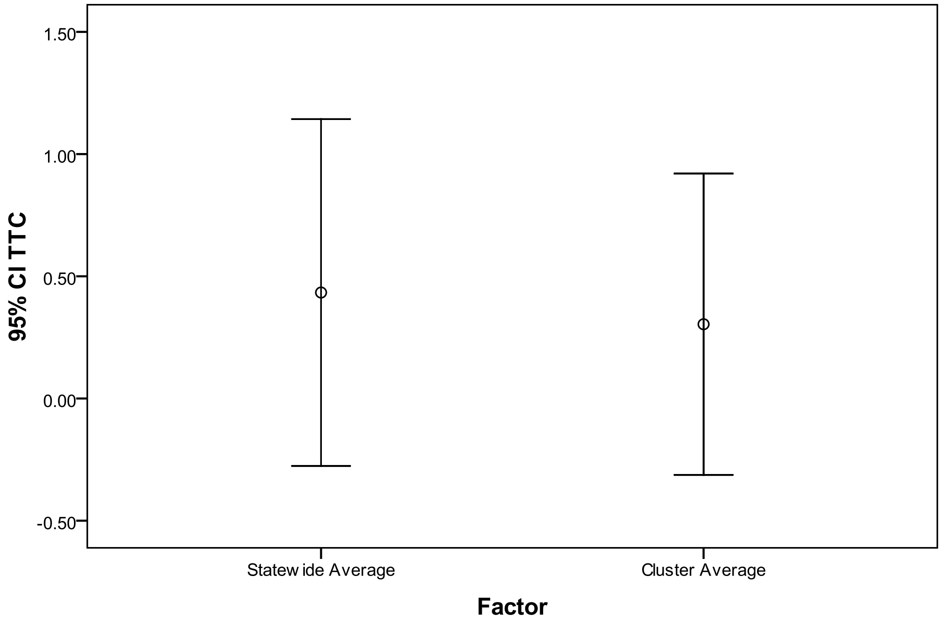


Figure 4.23 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to TTC Characterization

It was found that for both rutting and fatigue cracking distresses, the 95% CI and minimum and maximum performance life difference values were less than that of rigid. However, the cluster average and statewide average TTC characterizations had similar performance for flexible pavement. Since it was suggested that TTC cluster averages be used for rigid pavement, it is recommended that this practice be continued for flexible design for sake of consistency.

4.5.2.2 Monthly Distribution Factor

<u>Rutting</u>

The descriptive statistics for the pavement life difference based on rutting for the two analyzed MDF traffic characterizations is contained in Table 4.36.

Table 4.36 reveals that similar to rigid pavements, MDF traffic characterizations do not have a significant impact on pavement performance. Both statewide and cluster averages have a maximum of one year's difference in pavement life from site-specific values. Additionally, both have standard deviations of less than half a year, indicating very little variation across sites. The standard deviation for cluster averages, however, is half that of statewide averages. The paired *t*-test was run and the results are presented in Table 4.37, to determine if this was significant.

Table 4.36 Pavement Life Difference Descriptive Statistics Based on Rutting for MDF Characterizations

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average MDF	31	0.035	0.470	0.084	-0.917	0.917	-0.138	0.207
Cluster Average MDF	31	0.027	0.227	0.041	-0.750	0.667	-0.056	0.110

Table 4.37 Paired *t*-test for Pavement Life Difference Based on Rutting for MDF Characterization

Variable	Paired Differences (Rutting)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
MDF	0.008	0.449	0.081	-0.156	0.173	0.100	30	0.921

The paired *t*-test revealed that the contrasts between the pavement life differences between the traffic characterizations were not statistically significant. This is reflected in Figure 4.24 as the statewide characterization pavement life difference confidence interval encompasses the cluster average pavement life difference confidence interval.

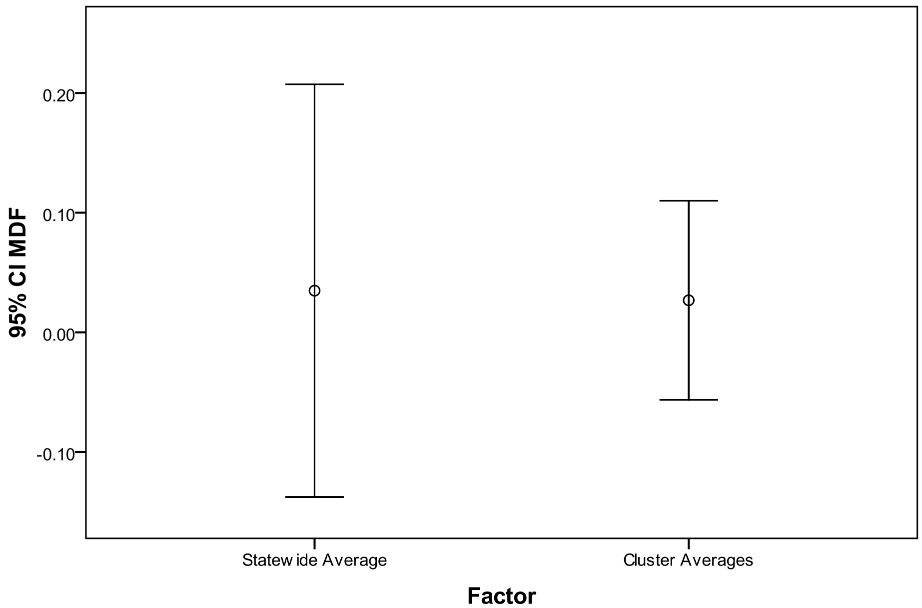


Figure 4.24 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to MDF Characterization

<u>Fatigue Cracking</u>

The descriptive statistics for the pavement life difference based on fatigue cracking for MDF characterizations can be seen in Table 4.38.

Based on Table 4.38, it appears that fatigue cracking is more sensitive to MDF, as maximum pavement life difference underestimates site specific values by almost 2 years. However, the standard deviations are similar to those seen for rutting. The paired *t*-test for the two traffic characterizations can be seen in Table 4.39.

Table 4.39 reveals that the statewide and cluster values for pavement life performance difference are significantly distinct from one another at a 95% confidence. To verify this graphically, the error bar chart for each traffic characterization was created and is shown in Figure 4.25.

Table 4.38 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for MDF Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average MDF	31	0.148	0.444	0.080	-0.583	1.917	-0.015	0.311
Cluster Average MDF	31	0.051	0.336	0.060	-0.417	1.667	-0.072	0.174

Table 4.39 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for MDF Characterization

Variable	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
MDF	0.097	0.265	0.048	0.000	0.194	2.050	30	0.049

Figure 4.25 illustrates that the performance life difference confidence interval for each traffic characterization overlap one another. This suggests that there may be outliers within each grouping that are causing the *t*-test to falsely reject the null hypothesis that the two traffic characterizations are from the same population. Even with this observation, both confidence intervals have 95% confidence bands for performance life difference of less than half a year, which could be considered a negligible impact.

The lack of variability in the performance life difference between the traffic characterizations and generally insignificant impact as a whole for both distresses suggests that statewide averages can be used for this traffic input.

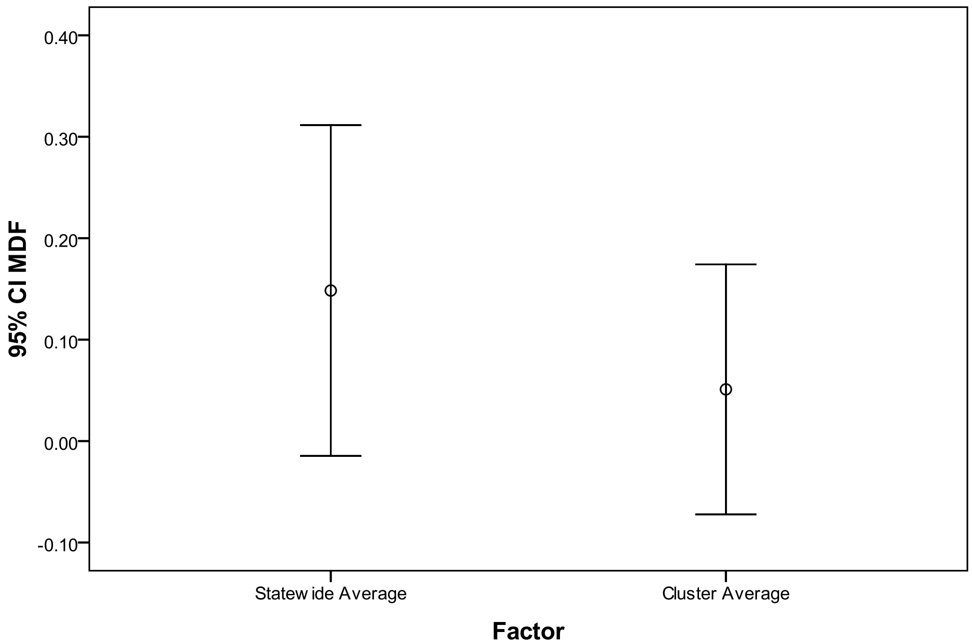


Figure 4.25 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to MDF Characterization

4.5.2.3 Hourly Distribution Factor

The pavement performance life difference was completely unaffected by the HDF traffic characterizations placed in the M-E PDG, unlike rigid pavement. This was true for both rutting and fatigue cracking. Consequently, descriptive statistics, a *t*-test, and an error bar chart are not applicable here. The lack of any variability in the flexible design and significant variability in the rigid design further supports that the HDF model might need to be adjusted. Since this is an extreme contrast to rigid pavement, where cluster averages were suggested for use, it is recommended that statewide values for HDF can be used for flexible pavement analyses.

4.5.2.4 Axle Groups per Vehicle

<u>Rutting</u>

The descriptive statistics for the pavement life differences produced for the AGPV traffic characterizations can be seen in Table 4.40.

Table 4.40 reveals that AGPV has little impact on flexible pavement design life based on rutting. The maximum difference attained at any individual site for either traffic characterization was one year. The standard deviations are also relatively low, at approximately half a year. To assess the difference between the two traffic characterizations, the paired *t*-test was again performed with the results shown in Table 4.41.

Table 4.40 Pavement Life Difference Descriptive Statistics Based on Rutting for AGPV Characterizations

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average AGPV	31	-0.032	0.554	0.100	-1.000	1.083	-0.235	0.172
Cluster Average AGPV	31	-0.041	0.404	0.073	-0.833	.917	-0.189	0.108

Table 4.41 Paired *t*-test for Pavement Life Difference Based on Rutting for AGPV Characterization

Variable	Paired Differences (Rutting)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
AGPV	0.009	0.588	0.106	-0.207	0.225	0.085	30	0.932

Table 4.41 shows that the two traffic characterizations' pavement life performance difference values are not significantly different from one another. A graphical representation of this is shown in Figure 4.26.

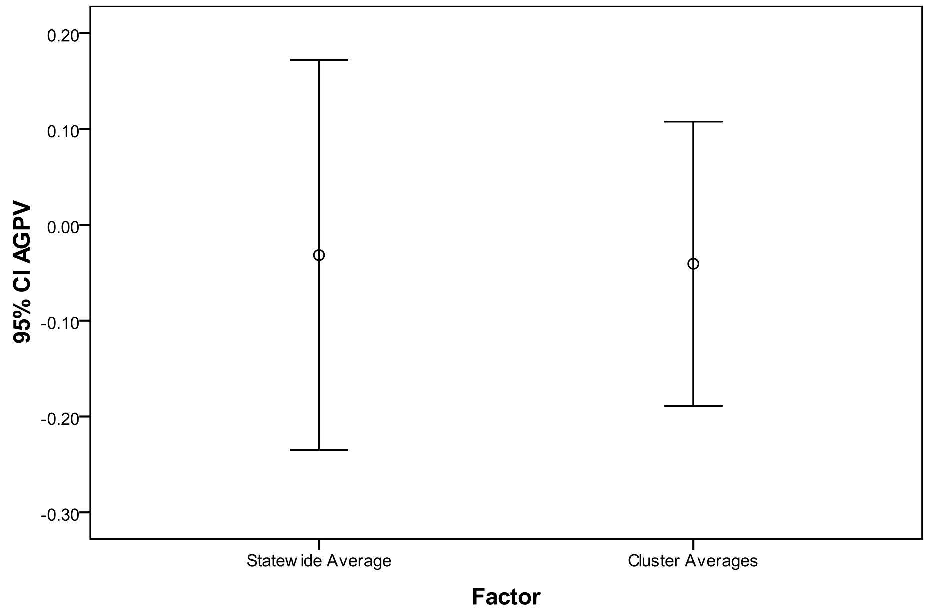


Figure 4.26 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to AGPV Characterization

It is apparent from Figure 4.26 and the results of the *t*-test that the AGPV traffic characterizations do not produce significantly different results from one another and actually have little impact on design life as a whole based on rutting.

<u>Fatigue Cracking</u>

The descriptive statistics for pavement performance life difference based on fatigue cracking for the two AGPV characterizations can be seen in Table 4.42.

Similarly to rutting, the AGPV traffic characterization had little effect on pavement life performance based on fatigue cracking. The maximum pavement performance life difference was less than a year for both traffic characterizations and standard deviations were far less than half a year. While the standard deviations for the AGPV cluster characterization is half that of the statewide average, their 95% confidence intervals are similar. The results of the paired *t*-test to determine of the two characterizations are statistically different is shown in Table 4.43.

Table 4.42 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for AGPV Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average AGPV	31	-0.034	0.334	0.060	-0.833	0.917	-0.156	0.089
Cluster Average AGPV	31	0.005	0.185	0.033	-0.583	0.333	-0.062	0.073

Table 4.43 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for AGPV Characterization

Variable	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
AGPV	-0.039	0.296	0.053	-0.148	0.069	-0.739	30	0.465

The paired t-test indicates that the performance life difference values for the two AGPV traffic characterizations are not statistically different. The confidence intervals shown in the error bar chart in Figure 4.27 corroborates these results.

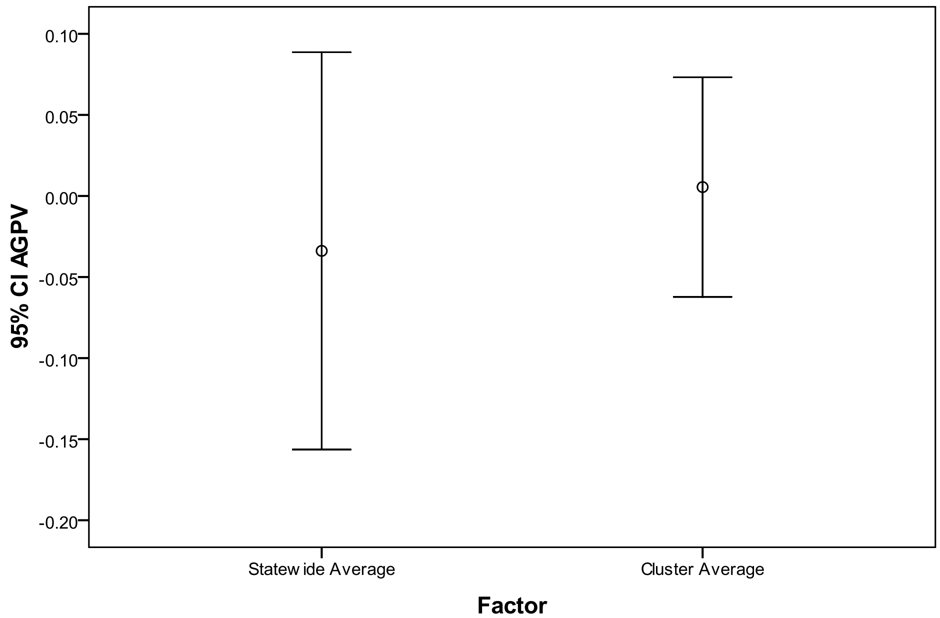


Figure 4.27 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to AGPV Characterization

The AGPV traffic characteristics produce similar results in terms of pavement performance life difference and seemingly exhibit little impact on pavement design by only having a maximum difference of less than two years in life for considering both distresses. As such, statewide averages could be used for this traffic characterization.

4.5.2.5 Single Axle Load Spectra

Rutting

The descriptive statistics for performance life difference based on rutting for the single axle load spectra can be found in Table 70.

From Table 4.44, it appears that there is little difference in predicted pavement performance life between cluster and statewide single axle load traffic characterizations. Both have similar performance life difference means close to -0.137 years, standard deviations around 0.7 years, and maximum under and over performance life difference of 1.00 and 2.00 years respectively. The paired *t*-test performed on these two sets of data also concluded that the two traffic characterizations do not produce performance life difference values that are statistically different from one another as shown in Table 4.45. These identical 95% confidence intervals for the single axle load traffic characterizations shown in Figure 4.28 support these findings.

Table 4.44 Pavement Life Difference Descriptive Statistics Based on Rutting for Single Axle Load Characterizations

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Single Axle Loads	31	-0.137	0.674	0.121	-2.000	1.000	-0.385	0.110
Cluster Average Single Axle Loads	31	-0.121	0.682	0.122	-2.083	1.167	-0.371	0.129

Table 4.45 Paired *t*-test for Pavement Life Difference Based on Rutting for Single Axle Load Spectra Characterizations

Axle type	Paired Differences (Rutting)					t	df	Sig. (2-tailed)
	Descriptive statistics			95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Single Axle Load	-0.017	0.164	0.029	-0.077	0.043	-0.569	30	0.574

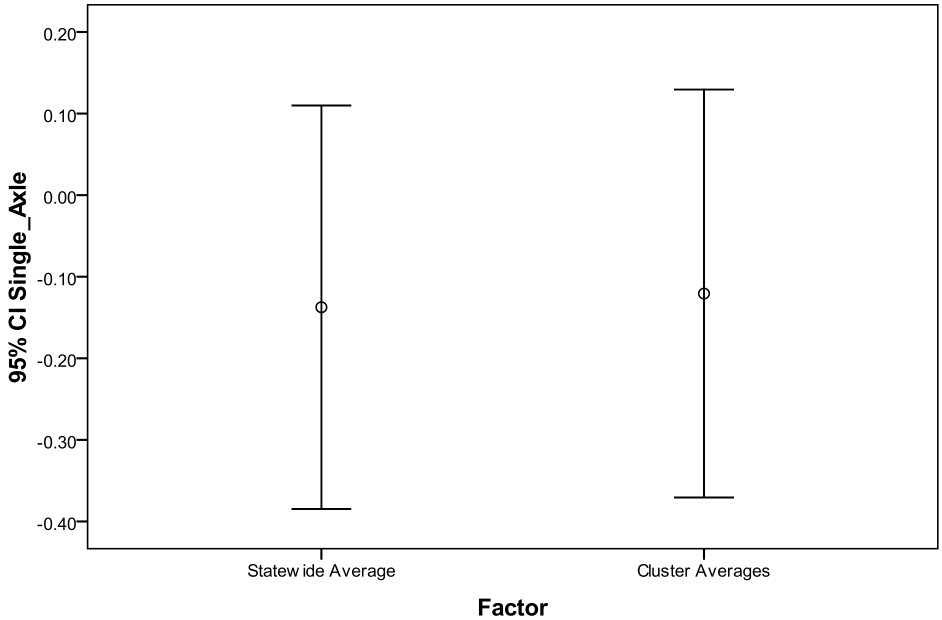


Figure 4.28 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to Single Axle Load Spectra Characterization

<u>Fatigue Cracking</u>

Descriptive statistics for performance life difference based on fatigue cracking for the single axle load traffic characterizations can be found in Table 4.46. Similar to the results produced for rutting, the single axle load traffic characterizations produce nearly identical results to one another. Mean values are around -0.5 years, standard deviations are near 1 year, and under and over prediction of performance life is close to 2 and 3 years respectively. What is different from the rutting results, however, is that fatigue cracking seems to be more sensitive to changes in single axle loadings. Standard deviations and maximum performance life differences based on fatigue cracking seem to be double that of the results for the rutting distress. The results of the paired *t*-test for the statistical difference between the two pavement performance life predictions can be found in Table 4.47.

Table 4.46 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for Single Axle Load Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Single Axle Loads	31	-0.045	1.037	0.186	-2.833	1.917	-0.426	0.335
Cluster Average Single Axle Loads	31	-0.064	1.021	0.183	-2.833	1.833	-0.439	0.310

Table 4.47 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for Single Axle Load Spectra Characterizations

	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Single Axle Load	0.019	0.325	0.058	-0.100	0.138	0.321	30	0.751

The paired *t*-test reveals that the two single axle load traffic characterization do not generate statistically different pavement life performance values at a 95% confidence. Similar to the rutting distress, the confidence intervals for the performance life difference for the two single axle load spectra traffic characterization are nearly identical as shown in Figure 4.29.

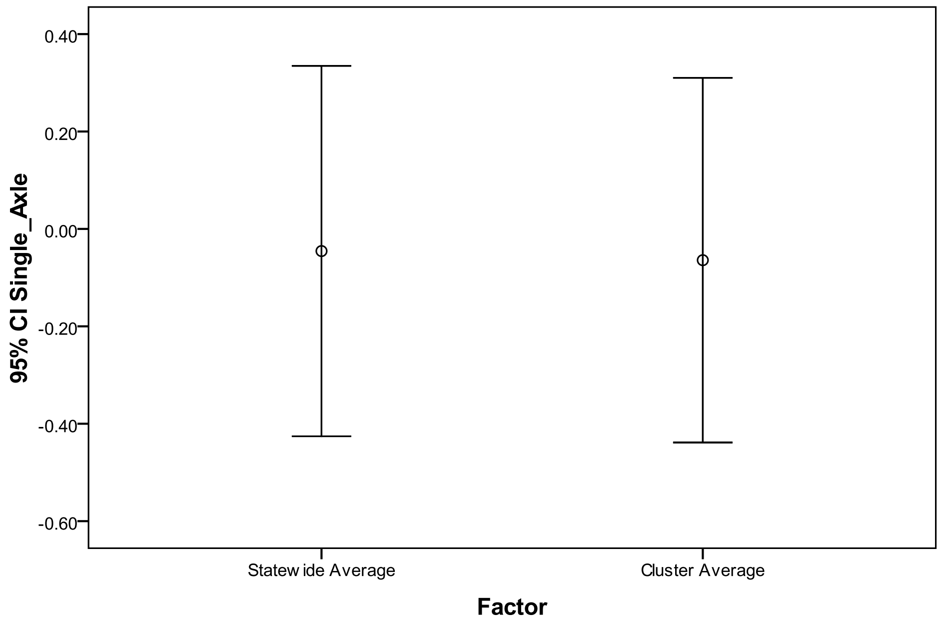


Figure 4.29 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to Single Axle Load Spectra Characterization

The results indicate that the single axle load spectra traffic characterizations produce similar pavement performance life difference results. Additionally, the performance lives based on the distresses seem to be only slightly impacted by the changes in the single axle loadings. These findings suggest that statewide averages single axle loadings could be used for this traffic characteristic.

4.5.2.6 Tandem Axle Load Spectra

Rutting

Summary statistics for the pavement performance life difference based on rutting for tandem axle load spectra traffic characterization is contained in Table 4.48.

The effect of the tandem axle load spectra traffic characterization based on rutting performance life difference is much less pronounced than that for percent slabs cracked in rigid pavement. Unlike maximum pavement life performance differences of over 13 years in rigid pavement, maximum pavement performance life differences in flexible pavement based on rutting are only three years. Standard deviations are also significantly less, from four years in rigid pavement to approximately one year in flexible pavement based on rutting. Between the two tandem axle load spectra traffic characterization, there appears to be little difference. Standard deviation and maximum under and over predicted pavement life all have similar values. The *t*-test to compare the two traffic characterization performance life differences is shown in Table 4.49.

Table 4.48 Pavement Life Difference Descriptive Statistics Based on Rutting for Tandem Axle Load Characterizations

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Tandem Axle Loads	31	0.180	1.134	0.204	-2.250	3.000	-0.236	0.596
Cluster Average Tandem Axle Loads	31	-0.043	0.819	0.147	-2.250	1.917	-0.344	0.257

Table 4.49 Paired *t*-test for Pavement Life Difference Based on Rutting for Tandem Axle Load Spectra Characterizations

	Paired Differences (Rutting)					T	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Tandem Axle Load	0.223	0.783	0.141	-0.064	0.511	1.586	30	0.123

Table 4.49 reveals that the *t*-test concluded, at a 95% confidence, there is not a statistically significant difference pavement performance life between statewide and cluster tandem axle load characterizations. Figure 4.30 verifies this finding as the 95% confidence intervals for each tandem axle load spectra traffic characterization overlaps with each other.

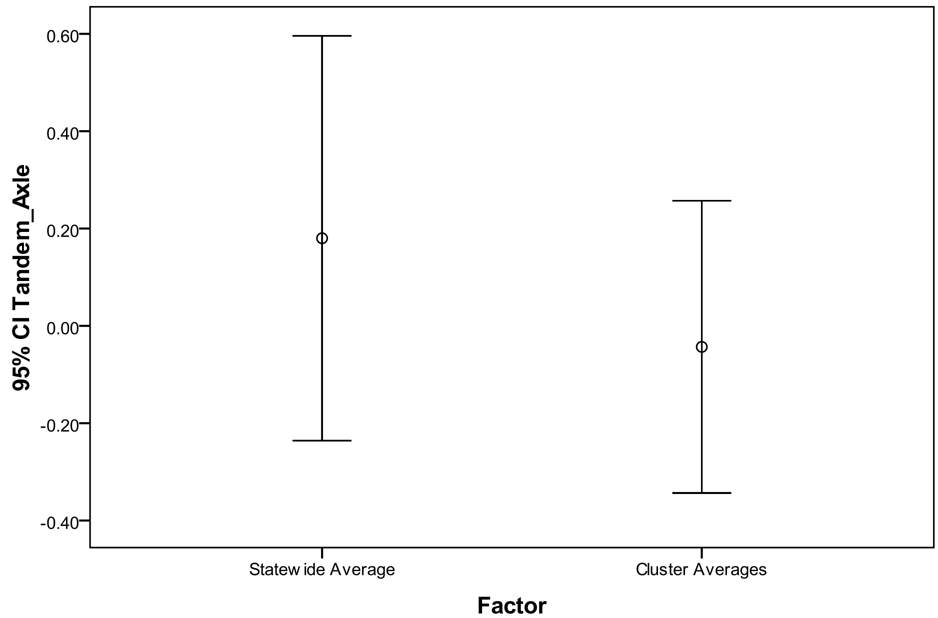


Figure 4.30 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to Tandem Axle Load Spectra Characterization

<u>Fatigue Cracking</u>

The descriptive statistics for pavement performance life difference based on fatigue cracking for the tandem axle load spectra traffic characterization is shown in Table 4.50.

The summary statistics found in Table 4.50 are similar to those for rutting. The standard deviation is around one year with maximum over or under prediction in pavement performance of less than four years. The results between the two traffic characterizations are similar. Minimum and maximum pavement performance life difference are -2 and 4 years respectively and standard deviations are both one year. To test is this observation is statistically significant; the paired *t*-test was conducted and is shown in Table 4.51.

Table 4.50 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for Tandem Axle Load Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Tandem Axle Loads	31	0.575	1.253	0.225	-1.917	3.917	0.116	1.035
Cluster Average Tandem Axle Loads	31	0.215	1.032	0.185	-2.000	3.417	-0.163	0.594

Table 4.51 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for Tandem Axle Load Spectra Characterizations

	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Tandem Axle Load	0.360	1.377	0.247	-0.145	0.865	1.457	30	0.156

Table 4.51 shows that the pavement life performance difference between the two tandem axle load spectra traffic characterizations is not statistically significant. This is again realized through the error bar chart shown in Figure 4.31 as the 95% confidence interval for both traffic characterizations overlap.

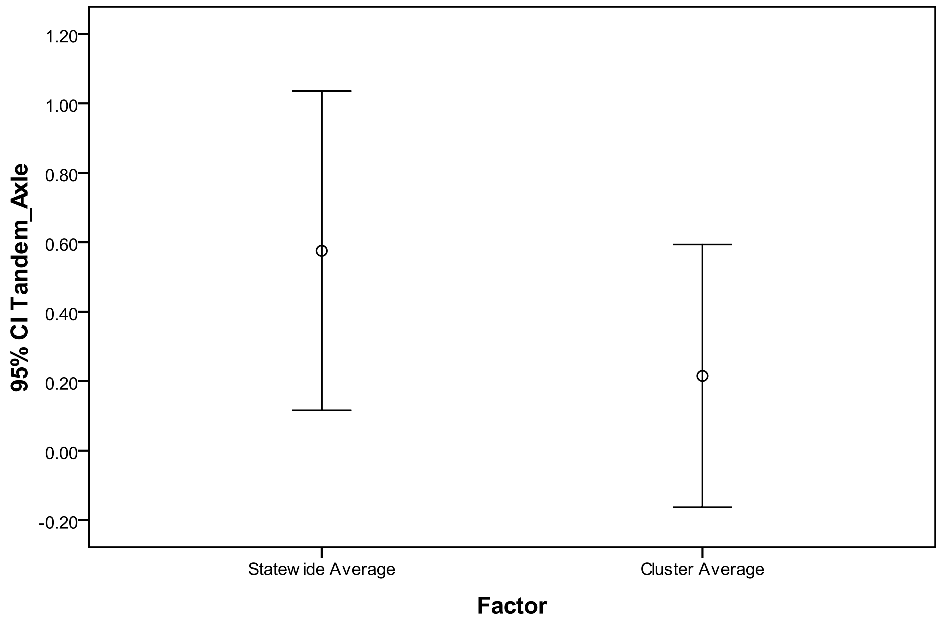


Figure 4.31 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to Tandem Axle Load Spectra Characterization

From Figure 4.31, it does appear that the cluster average for tandem axle load spectra yields predicted performance 95% CI bounds almost half a year less than the statewide values. Accordingly, similar to rigid design, cluster averages should be used for flexible pavement design.

4.5.2.7 Tridem Axle Load Spectra

<u>Rutting</u>

The descriptive statistics for the performance life difference based on rutting for tridem axle load spectra traffic characterizations are shown in Table 4.52.

Table 78 shows that the predicted performance life based on rutting is unaffected by the changes in tandem axle loading spectra from the developed traffic characterizations. The maximum difference in pavement life performance for either traffic characterization is only a third of a year. Standard deviations are a month or less for both as well. The 95% CI for predicted pavement performance is only two weeks within site specific values. The results of the *t*-test to compare the statistical difference between the two traffic characterizations' pavement performance difference values are displayed in Table 4.53.

Table 4.52 Pavement Life Difference Descriptive Statistics Based on Rutting for Tridem Axle Load

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Tridem Axle Loads	31	0.021	0.068	0.012	-0.167	0.167	-0.004	0.046
Cluster Average Tridem Axle Loads	30	0.022	0.084	0.015	-0.083	0.333	-0.009	0.054

\

Table 4.53 Paired *t*-test for Pavement Life Difference Based on Rutting for Tridem Axle Load Spectra Characterizations

	Paired Differences (Rutting)					t	df	Sig. (2-tailed) Std.
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Tridem Axle Load	-0.003	0.050	0.009	-0.022	0.015	-0.003	0.050	0.009

The results of the *t*-test found that the traffic characterizations produce statistically different pavement life performance difference. However the error bar chart shows that the 95% confidence intervals for each traffic characterization overlap as shown in Figure 4.32. Despite this statistical difference, the difference in pavement life performance is negligible.

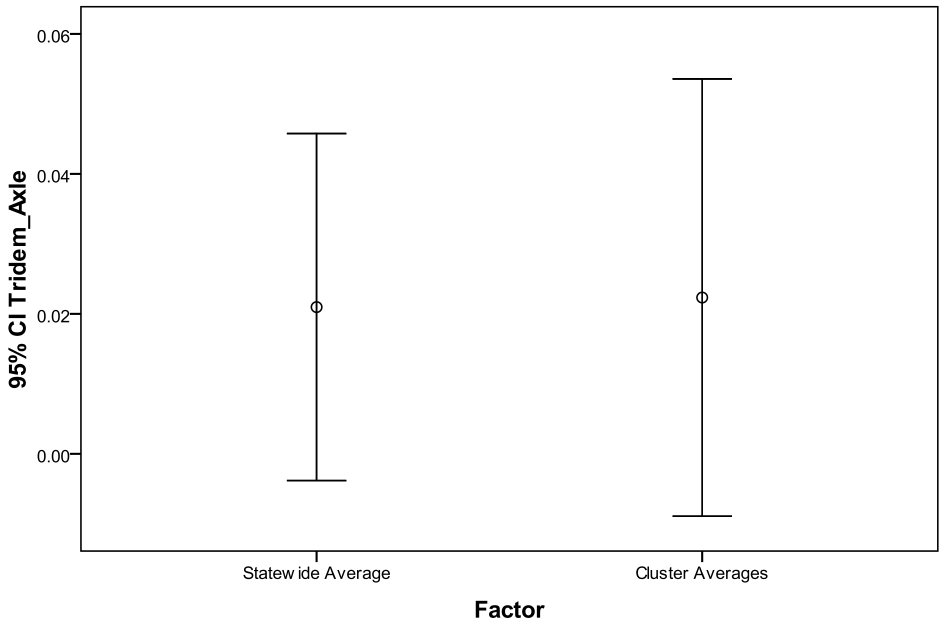


Figure 4.32 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to Tridem Axle Load Spectra Characterization

<u>Fatigue Cracking</u>

The descriptive statistics for the performance life difference based on fatigue cracking for tridem axle load spectra characterizations is shown in Table 4.54.

The results in Table 80 are the same as those seen in the rutting analysis. The standard deviation values are approximately one month and maximum pavement performance life difference is only half a year. The *t*-test results to determine if there is a significant difference between the traffic characterizations is shown in Table 4.55.

Table 4.54 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for Tridem Axle Load Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Tridem Axle Loads	31	0.036	0.111	0.020	-0.167	0.500	-0.004	0.077
Cluster Average Tridem Axle Loads	29	0.011	0.076	0.014	-0.167	0.167	-0.017	0.040

Table 4.55 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for Tridem Axle Load Spectra Characterizations

	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Tridem Axle Load	0.010	0.064	0.012	-0.014	0.035	0.867	28	0.393

The results of the *t*-test in Table 81 reveal that the two tridem axle load traffic characterizations do not produce statistically significant differences in pavement performance life difference values. While the 95% confidence intervals are not the same for each traffic characterization, they still overlap as shown in Figure 4.33. This again substantiates that the pavement life differences produced by the two traffic characterizations are similar.

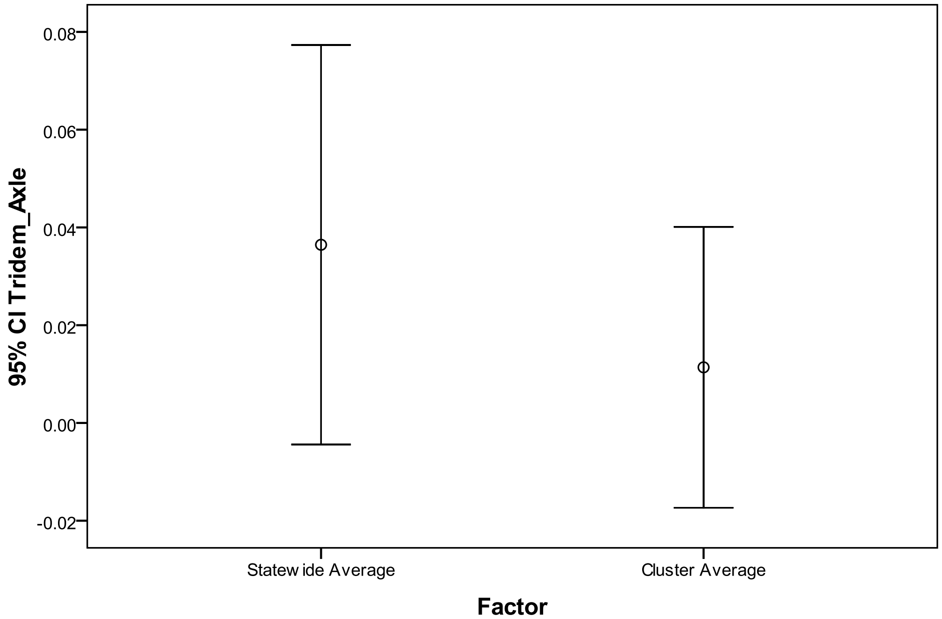


Figure 4.33 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to Tridem Axle Load Spectra Characterization

The results of the tridem axle load spectra traffic characterization has revealed that pavement performance life based on both rutting and fatigue cracking distresses is unaffected by the changes in axle load spectra. Accordingly, the practical distinction in pavement life performance difference between the two traffic cluster is negligible. Again this is probably due to tridem axles contributing to relatively small proportion of the traffic stream. Consequently, statewide average tridem axle load spectra can be used for this traffic characterization.

4.5.2.8 Quad Axle Load Spectra

Rutting

The summary statistics for the performance life difference based on rutting for the quad axle load spectra traffic characterization can be seen in Table 4.56. Unlike tridem axle load spectra, the quad axle load characterizations seem to have a moderate impact on the pavement performance life prediction. This could be due to the high load spectra created by TrafLoad combined with sensitivity to rutting in flexible pavement. The maximum pavement performance life prediction was 4 years using statewide quad axle loadings. The standard deviation was also high for this traffic characterization, having a value close to 2 years. From Table 4.56, it seems that cluster average quad axle load spectra values have lower maximum performance life difference values, ranging from half a year to almost one year. The standard deviation was also lower by half a year. These results suggest that quad axle load spectra cluster averages may capture pavement performance life that is closer to site-specific values. A *t*-test for the differences between traffic characterizations based on performance life difference values was conducted to determine if there was any statistical significance in the values created. The results of the test are shown in Table 4.57.

Table 4.56 Pavement Life Difference Descriptive Statistics Based on Rutting for Quad Axle Load Characterizations

Data level	Group Statistics (Rutting)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Quad Axle Loads	31	0.118	1.824	0.328	-2.750	4.083	-0.551	0.787
Cluster Average Quad Axle Loads	29	-0.114	1.347	0.250	-2.333	3.250	-0.627	0.398

Table 4.57 Paired *t*-test for Pavement Life Difference Based on Rutting for Quad Axle Load Spectra Characterizations

	Paired Differences (Rutting)					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Quad Axle Load	0.060	1.816	0.337	-0.631	0.750	0.177	28	0.861

Table 4.57 reveals that there is not a statistically significant difference in predicted pavement life performance between the two traffic characterizations. Figure 4.34 shows that the confidence intervals for each traffic characterization, which both range less than one year from zero overlap one another which supports the *t*-test.

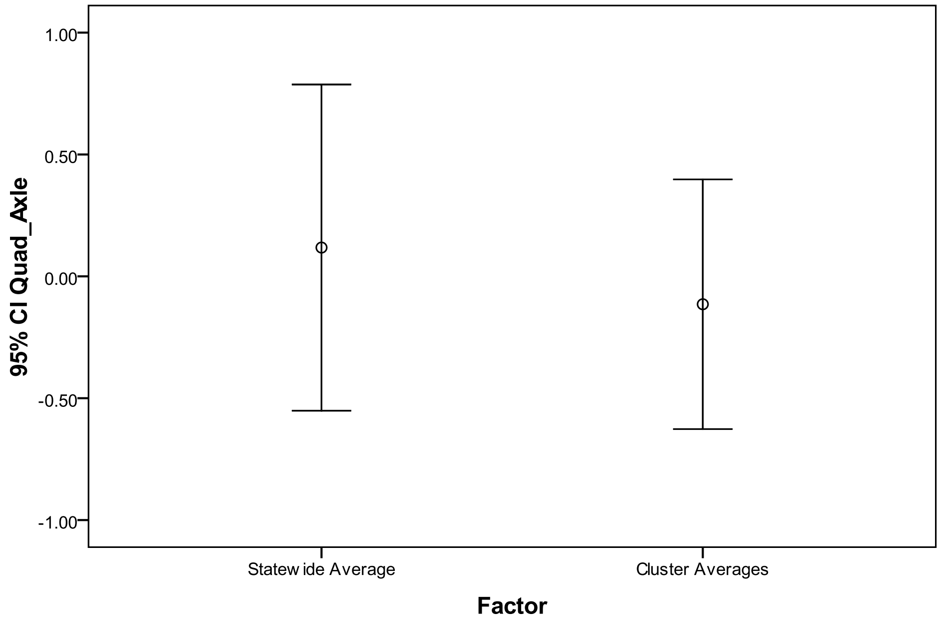


Figure 4.34 Error Bar Chart for Differences in Flexible Performance Life Based on Rutting Due to Quad Axle Load Spectra Characterization

Fatigue Cracking

Descriptive statistics for the performance life difference based on fatigue cracking for quad axle load spectra traffic characterizations can be found in Table 4.58. The descriptive statistics show that that the quad axle load traffic characterization have a lesser effect on pavement performance life difference based on fatigue cracking than that based on rutting. The maximum pavement performance life difference and standard deviation is only two years and approximately half a year, respectively. This is much less than four years and two years as observed for the pavement life difference based on rutting. The cluster average produces slightly better results than that of the statewide average producing a smaller standard deviation and maximum performance life difference one less year. To determine if there was a statistical difference, the paired *t*-test was conducted with results shown in Table 4.59.

Table 4.58 Pavement Life Difference Descriptive Statistics Based on Fatigue Cracking for Quad Axle Load Characterizations

Data level	Group Statistics (Fatigue Cracking)						95% Confidence Interval	
	N	Mean	Std. Deviation	Std. Error Mean	Min Perf. Life Diff.	Max Perf. Life Diff.	Lower	Upper
Statewide Average Quad Axle Loads	31	0.121	0.692	0.124	-1.083	2.000	-0.133	0.375
Cluster Average Quad Axle Loads	28	-0.054	0.504	0.095	-0.833	0.917	-0.249	0.142

Table 4.59 Paired *t*-test for Pavement Life Difference Based on Fatigue Cracking for Quad Axle Load Spectra Characterizations

	Paired Differences (Fatigue Cracking)					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Quad Axle Load	0.140	0.644	0.122	-0.110	0.390	1.147	27	0.262

The *t*-test revealed that the traffic characterizations did not produce statistically different pavement performance life differences. The overlapping 95% confidence intervals shown in Figure 4.35 substantiate the *t*-test. It is also apparent from Figure 4.35 that the cluster average confidence interval is closer and more symmetric around zero than the statewide average.

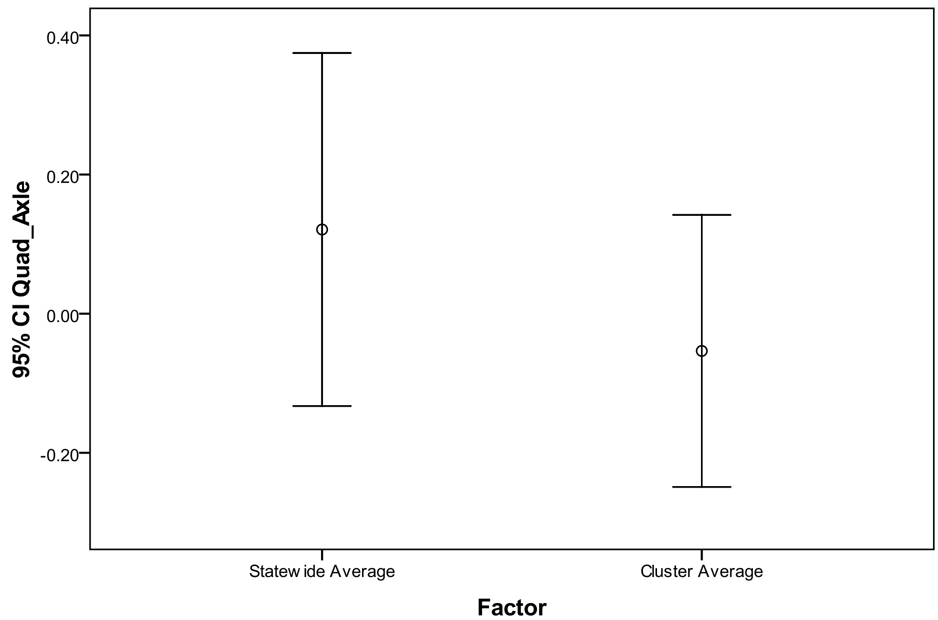


Figure 4.35 Error Bar Chart for Differences in Flexible Performance Life Based on Fatigue Cracking Due to Quad Axle Load Spectra Characterization

The results from the quad analysis reveal that the flexible pavement performance life based on rutting and fatigue cracking is more sensitive to the quad axle load spectra traffic characterizations than was the case for rigid pavement. Statistical analysis indicated that the two quad axle load traffic characterizations did not produce significantly different results in pavement performance life. Consequently, use of statewide quad axle load can be sufficient for flexible design.

4.5.2.9 Summary

Comparisons in the M-E PDG predicted performance life differences between site-specific data and the developed traffic characterizations yielded information on the impact of the traffic input on pavement performance. This led to the selection of the appropriate traffic characterization for each traffic input. The following summarizes the results found in this section. All traffic characterizations not presented here can be found in Appendix H.

- **TTC significantly affects predicted rigid pavement performance and moderately affects flexible pavement performance.** With the exception of cluster averages for rigid pavement, the traffic characterizations had 95% CIs greater than 1 year and maximum performance life differences in excess of 5 years. Since TTC cluster averages for rigid pavement produced, a CI bound half a year less than the other two characterizations and had maximum values less than 5 years, TTC clusters were suggested for use in rigid design. Although there was no observable difference in impact between cluster averages and a statewide values, TTC cluster averages are also recommended for flexible design for consistency. The classification cluster averages are shown in Table 4.60.

Table 4.60 Cluster TTC Averages

	Cluster 1	Cluster 2	Cluster 3
4	1.66	1.68	2.08
5	13.01	27.35	49.78
6	3.27	5.57	6.62
7	0.33	0.95	1.09
8	3.86	4.93	4.27
9	64.35	42.39	22.08
10	6.42	7.90	6.43
11	1.59	1.11	0.41
12	0.41	0.17	0.04
13	5.11	7.95	7.20

- **MDFs had a negligible impact on predicted rigid and flexible pavement performance.** The developed MDF traffic characterizations collectively produced a maximum of 2 years difference in pavement life from site specific values. The 95% confidence intervals were all well within half a year. Consequently, the statewide values displayed in Table 4.61 for these traffic characterizations can be implemented.

Table 4.61 Statewide MDF Averages

Month	VC4	VC5	VC6	VC7	VC8	VC9	VC10	VC11	VC12	VC13
1	0.81	0.81	0.81	0.81	0.90	0.90	0.90	0.87	0.87	0.87
2	0.89	0.89	0.89	0.89	0.95	0.95	0.95	0.89	0.89	0.89
3	0.88	0.88	0.88	0.88	0.98	0.98	0.98	0.88	0.88	0.88
4	0.93	0.93	0.93	0.93	1.01	1.01	1.01	0.96	0.96	0.96
5	1.02	1.02	1.02	1.02	1.06	1.06	1.06	1.05	1.05	1.05
6	1.14	1.14	1.14	1.14	1.12	1.12	1.12	1.16	1.16	1.16
7	1.18	1.18	1.18	1.18	0.98	0.98	0.98	1.07	1.07	1.07
8	1.19	1.19	1.19	1.19	1.08	1.08	1.08	1.10	1.10	1.10
9	1.13	1.13	1.13	1.13	1.03	1.03	1.03	1.07	1.07	1.07
10	1.06	1.06	1.06	1.06	1.05	1.05	1.05	1.11	1.11	1.11
11	0.96	0.96	0.96	0.96	0.96	0.96	0.96	1.00	1.00	1.00
12	0.82	0.82	0.82	0.82	0.87	0.87	0.87	0.83	0.83	0.83

- **HDFs significantly affect predicted rigid pavement performance but have a negligible impact on flexible pavement performance.** Use of statewide and the M-E PDG traffic characterizations defaults produced design life differences in excess of 10 years for rigid pavement. Use of HDF cluster averages, however, produced maximum predicted rigid pavement performance life differences of only 5 years, with a 95% confidence interval within a year of site specific values. Cluster average HDFs should be utilized for this traffic input for rigid pavement. In contrast, HDF characterizations produced absolutely no difference in predicted performance life. Since this difference is substantial between designs, statewide values can be used for flexible pavement. Both cluster averages and statewide average values are shown in Table 4.62.

Table 4.62 HDF Cluster and Statewide Averages

	Cluster 1	Cluster 2	Cluster 3	Statewide Avg
0	2.52	1.78	1.05	1.62
1	2.22	1.64	0.89	1.45
2	2.11	1.66	0.97	1.46
3	2.33	2.00	1.22	1.75
4	2.67	2.59	1.74	2.27
5	3.11	3.68	2.60	3.16
6	3.71	4.49	4.32	4.29
7	4.16	5.24	6.08	5.38
8	4.91	6.06	7.42	6.39
9	5.32	6.51	7.43	6.67
10	5.58	6.60	7.33	6.71
11	5.68	6.50	7.41	6.71
12	5.60	6.31	7.24	6.55
13	5.58	6.16	7.12	6.44
14	5.48	5.89	6.97	6.24
15	5.36	5.54	6.62	5.93
16	5.33	5.01	5.49	5.25
17	4.98	4.44	4.54	4.57
18	4.70	3.94	3.46	3.88
19	4.48	3.39	2.82	3.35
20	4.13	2.95	2.30	2.90
21	3.75	2.64	2.00	2.58
22	3.37	2.42	1.63	2.27
23	2.92	2.17	1.34	1.97

- **AGPV had a negligible impact on predicted rigid and flexible pavement performance.** The maximum performance life difference from site-specific values was only two-years. Additionally 95% confidence intervals for predicted pavement performance life fell well within half a year of zero. Statewide averages can be used for this traffic input and are displayed in Table 4.63.

Table 4.63 AGPV Statewide Averages

Vehicle class	Single	Tandem	Tridem	Quad
4	1.65	0.36	0.00	0.00
5	2.00	0.05	0.00	0.00
6	1.00	1.00	0.00	0.00
7	1.06	0.06	0.58	0.37
8	2.28	0.74	0.00	0.00
9	1.29	1.85	0.00	0.00
10	1.54	1.00	0.33	0.55
11	4.99	0.00	0.00	0.00
12	3.85	0.96	0.00	0.00
13	2.03	1.40	0.36	0.62

- **Single axle load spectra have a moderate effect on predicted rigid and flexible pavement performance.** Cluster averages and statewide averages had CIs within a year, with maximum and minimum are around four years difference for rigid pavement and less than three years for flexible. The M-E PDG defaults were higher than this for both pavement types. Cluster and statewide averages produced comparable results, having maximum over or under prediction values within one year of each other for both pavement types. The 95% CIs were within months of each other indicating that statewide averages could be used for this traffic input. Due to the size of the axle load spectra tables, they were placed in Tables H-11 through H-32 in Appendix H for reference.

- **Tandem axle load significantly impacted predicted rigid pavement performance and had a moderate influence on flexible.** Maximum predicted performance life differences exceeded 10 years for all developed traffic characterizations for rigid pavement. CIs were in excess of one year for statewide and cluster value whereas the M-E PDG defaults had values between 3 to 6 years. However, the maximum under prediction CI bound for cluster averages was almost one year better than that of statewide values. **Consequently TTC cluster averages were suggested for use in pavement design.** Flexible pavement experienced maximum pavement performance life differences of fewer than five years. Confidence intervals for statewide and cluster averages were within two years of zero, Cluster averages produced 95% CIs approximately a quarter of a year better than statewide values, which individually does not warrant their use. **However, to stay consistent with rigid design, cluster values are also recommended for flexible design.**

- **Tridem axle load spectra have a negligible impact on rigid and flexible pavement performance.** With the exception of the M-E PDG defaults on rigid pavement, the remaining traffic characterizations produced maximum pavement life differences of only 0.5 years. The confidence intervals for all traffic characterizations were within months of zero. Consequently, statewide average tridem axle load spectra can be used for this traffic input.

- **Quad axle load spectra do not have significant impact on predicted rigid pavement performance but have a moderate effect on flexible pavement performance.** Little difference in predicted pavement performance life was seen across traffic characterizations for rigid pavement. Means, 95% confidence intervals, standard deviations, and maximum difference were either zero or within months of zero. This suggests statewide averages could be used for this traffic input. Traffic characterizations produced a maximum pavement performance life difference for flexible pavement was approximately four years and was noticed particularly for the rutting distress. The standard deviation and confidence interval was within one for both traffic characterizations. Between traffic characterizations, there was negligible difference in CIs, again warranting use of statewide values.

- **The M-E PDG defaults were inferior inputs to statewide or cluster averages.** In general, statewide or cluster averages produced predicted performance lives that were far closer to the site-specific values than the M-E PDG defaults. Consequently, the M-E PDG defaults are not recommended for use in the state of Michigan.

4.6 SELECTION OF APPROPRIATE TRAFFIC CHARACTERIZATION

Once the appropriate traffic characterizations were identified, it was necessary to determine how they could be implemented in design. For the traffic inputs that only need statewide values, selection of the appropriate traffic input is automatic. However, for the traffic inputs that require cluster averages, the discriminant analysis reviewed in Chapter 3 could be implemented to select the appropriate traffic characteristic. The traffic inputs identified as needing Level II data at a minimum are stated below. Discriminant analysis was conducted for these traffic characterizations to aid in the selection of the appropriate cluster to use in design.

- TTC
- HDF (Rigid only)
- Tandem Axle Load Spectra

While there are many outputs in SPSS as discussed in Chapter 3, the outputs that will be summarized in this section that pertain to the model or functions as a whole include:

- Eigenvalue and canonical correlation
- Wilk’s Lambda test for model significance
- Standardized canonical discriminant function coefficients
- Fisher’s linear discriminant coefficients

4.6.1 **Truck Traffic Classification**

The eigenvalue and canonical correlation for the TTC discriminant functions can be seen in Table 4.64.

Table 4.64 Eigenvalue and Canonical Correlation for TTC Discriminant Functions

Function	4.6.1.1.1 Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.837	88.7	88.7	.934
2	0.874	11.3	100.0	.683

From Table 4.64, it is observed that the first function discriminates the TTC variable sufficiently, as it has a high eigenvalue of 6.837 and a relatively high correlation of 0.93. This function accounts for most of the variance at over 88%. The second function is less discriminatory, having a smaller eigenvalue of 0.874 and weaker correlation of only 0.683, accounting for the rest of the variance. The Wilk's Lambda test for the significance of the model functions is shown in Table 4.65. The Wilk's Lambda test was very significant ($p<<0.05$), and had a Wilk's Labda value of 0.068. Both measures indicate that the model sufficiently discriminates the TTC dependent variable.

Table 4.65 Wilk's Lambda Test for Significance of Model

Test of Function	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	.068	68.515	32	.000
2	.534	16.014	15	.381

Now that the model is shown to be significantly discriminatory, the individual independent values can be explored to determine which variables have the most discriminatory power. The standardized canonical discriminant function coefficients are shown in Table 4.66. It should be noted that the vehicle class percentages are removed in this analysis because if a classification count was available, there is no need to use the clustering algorithm.

Table 4.66 Standardized Canonical Discriminant Function Coefficients

Variables	Function	
	1	2
Region	.522	.559
Functional Class	.296	.188
Food Product Truck %	.081	-1.755
Fabricated Metal Products Truck %	-.870	1.069
Machinery Truck %	-1.082	.038
Rubber and Plastics Truck %	1.385	.995
Furniture and Fixtures Truck %	-.864	-.700
Electrical Equipment Truck %	-.286	-.915
Total Tons	.580	.879
AADTT	-1.025	-.124
Miscellaneous Manufacturing Products Truck %	-.247	.075
Road Class	.135	-.463
Printed Matter Truck %	.663	.653
Paper and Pulp Products Truck %	1.286	.114
Logs, Lumber and Wood Products Truck %	.437	.840
Transportation Equipment Truck %	-.061	-.760

Table 4.66 shows that Rubber and Plastics Products Truck %, Paper and Pulp Products Truck %, AADTT, and Machinery Truck % possess the most discriminatory power for function 1. The Food Product Truck %, Fabricated Metal Products Truck % and Rubber and Plastics Truck % are the most discriminatory variables in Function 2.

The Fisher's linear discriminant coefficients for classifying the TTC dependent variable can be found in Table 4.67.

Table 4.67 Fisher's Linear Discriminant Coefficients for TTC Variable

Variables	TTC		
	1	2	3
Region	3.659	5.841	5.151
Functional Class	-.004	.353	.292
Food Product Truck %	.184	-.318	1.327
Fabricated Metal Products Truck %	3.602	1.440	-.209
Machinery Truck %	3.017	-4.340	-5.021
Rubber and Plastics Truck %	-10.051	-2.118	-3.717
Furniture and Fixtures Truck %	7.900	-2.844	-.346
Electrical Equipment Truck %	5.583	3.042	5.117
Total Tons	5.278E-7	8.601E-7	7.120E-7
AADTT	.004	-.003	-.003
Miscellaneous Manufacturing Products Truck %	-20.924	-25.202	-26.132
Road Class	15.404	15.973	18.157
Printed Matter Truck %	-1.115	12.462	8.533
Paper and Pulp Products Truck %	-.143	1.811	1.887
Logs, Lumber and Wood Products Truck %	.772	1.517	1.107
Transportation Equipment Truck %	.800	.462	1.012
(Constant)	-40.502	-37.882	-38.245

The results of the classification algorithm are displayed in Table 4.68.

Table 4.68 Classified Sites into TTC Clusters Through Discriminant Analysis

		TTC	Predicted Group Membership			Total
			1	2	3	
Original	4.6.1.1.1.1 Count	1	11	0	0	11
		2	0	15	1	16
		3	0	3	6	9
	%	1	100.0	.0	.0	100.0
		2	.0	93.8	6.3	100.0
		3	.0	33.3	66.7	100.0

The results of the classification shown in Table 4.68 reveal that 88.9% of sites were clustered into their original groups. While not as high as the HDF variable, this still provides a significant procedure for identifying the TTC cluster a site belongs to.

4.6.2 **Hourly Distribution Factor**

While the results of HDF have been presented in the example reviewed in Chapter 3, it is stated again for completeness. The eigenvalue and canonical correlation developed for each of the functions is contained in Table 4.69.

Table 4.69 Eigenvalue and Canonical Correlation for HDF Discriminant Functions

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.739	82.8	82.8	.933
2	1.397	17.2	100.0	.763

Table 4.69 reveals that function 1 discriminates the dependent variable well, having a high eigenvalue and a correlation close to 1 (0.93), explaining over 83% of the variance. This second function has less ability to distinguish between clusters, having an eigenvalue of 1.397 and a correlation of only 0.76.

The Wilk's Lambda test to determine if the functions created in the model produce statistically significant results is shown in Table 4.70.

Table 4.70 Wilk's Lambda Test for Significance of HDF Model

Test of Functions	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	.054	71.553	36	.000
2	.417	21.420	17	.208

The Wilk's Lambda test shown in Table 4.70 states that the overall model produces mean discriminant scores for the clusters that are statistically different ($p < 0.05$). The Wilk's Lambda is also close to zero. Consequently the model discriminates well. This and allows for the standardized canonical discriminant function coefficients to be evaluated to determine which predictor variable discriminates HDF the most. These coefficients are shown in Table 4.71.

Table 4.71 reveals that for function 1, Miscellaneous Manufacturing Products Truck %, VC 9%, Total Tons, and Machinery Truck % percentage trucks are the most influential discriminating variables while rubber and plastics truck %, logs lumber and wood truck %, and AADTT are the most influential discriminating variables in function 2.
In order to classify a given site based on the model created, Fisher's linear discriminant coefficients have been created and are displayed in Table 4.72. These coefficients, when inputted into the linear regression equations for each cluster, will create the classification scores that will the future design site into the appropriate HDF cluster as shown in Section 3.5 of this report.

Table 4.71 Standardized Canonical Discriminant Function Coefficients for HDF Model

Variables	Function	
	1	2
Region	.102	-.526
Functional Class	-.694	-.019
Food Product Truck %	.248	-.901
Fabricated Metal Products Truck %	-.695	-.266
Machinery Truck %	1.302	-.353
Rubber and Plastics Truck %	-.987	1.315
Furniture and Fixtures Truck %	-.329	-.159
Electrical Equipment Truck %	1.124	-.487
Total Tons	1.426	-.955
VC 5 %	.982	.577
VC 9 %	1.821	.013
AADTT	-.086	1.159
Miscellaneous Manufacturing Products Truck %	-2.154	.989
Road Class	.904	.175
Printed Matter Truck %	.454	-.338
Paper and Pulp Products Truck %	-.534	1.102
Logs, Lumber and Wood Products Truck %	.434	-1.313
Transportation Equipment Truck %	1.004	.494

Table 4.72 Fisher's Linear Discriminant Coefficients for HDF Variable

Variables	HDF		
	1	2	3
Region	.854	1.353	.507
Functional Class	-1.451	-.675	-.291
Food Product Truck %	-4.838	-4.457	-5.400
Fabricated Metal Products Truck %	-2.927	-.984	-.409
Machinery Truck %	21.080	14.999	10.592
Rubber and Plastics Truck %	-15.924	-14.435	-9.627
Furniture and Fixtures Truck %	-7.998	-4.070	-3.091
Electrical Equipment Truck %	14.782	10.109	5.963
Total Tons	2.880E-6	2.408E-6	1.843E-6
VC 5 %	4.098	3.552	3.440
VC 9 %	5.574	4.723	4.291
AADTT	-.0044	-.0074	-.0042
Miscellaneous Manufacturing Products Truck %	-116.520	-87.319	-60.573
Road Class	32.470	23.673	20.212
Printed Matter Truck %	57.649	53.170	47.277
Paper and Pulp Products Truck %	-1.504	-1.529	-.488
Logs, Lumber and Wood Products Truck %	1.886	2.145	1.250
Transportation Equipment Truck %	4.685	2.697	2.209
(Constant)	-276.774	-189.364	-156.574

The results of the classification algorithm are shown in Table 4.73. Overall, 97.2% of the sites were clustered correctly, making the model very effective for selecting the appropriate HDF value based on the set of available predictor variables.

Table 4.73 Classified Sites into HDF Clusters through Discriminant Analysis

		HDF Clusters	Predicted Group Membership			
			1	2	3	
Original	Count	1	5	0	0	11
		2	0	16	1	17
		3	0	0	14	14
	%	1	100.0	.0	.0	100
		2	.0	94.1	5.9	100
		3	.0	.0	100.0	100

4.6.3 Tandem Axle Load Spectra

The eigenvalue and canonical correlations for the tandem axle load spectra discriminant functions are displayed in Table 4.74. The additional functions are due to their being five clusters for this dependent variable.

Table 4.74 Eigenvalue and Canonical Correlation for Tandem Axle Load Spectra Discriminant Functions

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	4.590	51.3	51.3	.906
2	2.387	26.7	78.0	.840
3	1.488	16.6	94.7	.773
4	0.477	5.3	100.0	.568

Table 4.74 shows that unlike the previous two dependent variables, there is not an equation, which discriminates the tandem axle load spectra clusters definitively. Function 1 and function 2 have the most discriminatory power, having eigenvalue and canonical correlations 2.387 and 4.590, respectively. The Wilk's Lambda test shown in Table 4.75 reveals that the model using all four functions (first row), has any statistical significance in discriminating the tandem axle load spectra at a 95% confidence level ($p < 0.05$). The remaining models do not discriminate as effectively.

Table 4.75 Wilk's Lambda Test for Significance of Model

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.014	99.697	72	.017
2	.080	59.252	51	.200
3	.272	30.580	32	.538
4	.677	9.162	15	.869

The standardized canonical discriminant function coefficients for each function can be seen in Table 4.76. The Total Tons, AADTT, Functional Class, Miscellaneous Manufacturing Truck % and VC 9 % all seem to substantially contribute to the discriminatory power of function 1 and function 2 as well. Total Tons AADTT and VC 9 % are seemingly directly relatable as they are influences or byproducts of the tandem axle loads on the roadways. Food Class Truck %, Electrical Equipment Truck % and VC 9 % influence functions 3 and 4.

Fisher's linear discriminant coefficients for classifying a potential design site are shown in Table 4.77.

Table 4.76 Standardized Canonical Discriminant Function Coefficients

	Function			
	1	2	3	4
Region	.178	.372	.239	.122
Functional Class	1.609	.910	-.149	.281
Food Product Truck %	-.540	-.693	1.841	-2.217
Fabricated Metal Products Truck %	1.201	-.576	-.164	1.261
Machinery Truck %	-.323	1.805	-.867	.926
Rubber and Plastics Truck %	-.395	-.248	-1.518	-.889
Furniture and Fixtures Truck %	-.069	-.150	.299	.385
Electrical Equipment Truck %	1.184	1.404	1.284	1.110
Total Tons	4.264	2.895	.023	1.203
VC 5 %	.911	-.048	.077	-.424
VC 9 %	1.496	.526	1.208	-1.283
AADTT	-3.782	-2.462	.045	.319
Miscellaneous Manufacturing Products Truck %	-1.986	-2.345	-.500	-1.302
Road Class	-.122	-.308	.931	.335
Printed Matter Truck %	-.557	-.033	-.799	.609
Paper and Pulp Products Truck %	.000	.544	.786	-.525
Logs, Lumber and Wood Products Truck %	-.294	-.762	.471	.438
Transportation Equipment Truck %	-.657	-.100	-.014	.004

Table 4.77 Fisher's Linear Discriminant Coefficients for Tandem Axle Load Spectra Variable

	All_Tan_ALS				
	1	2	3	4	5
Region	1.282	2.239	1.189	1.611	2.041
Functional Class	2.461	4.322	2.407	2.281	2.439
Food Product Truck %	-5.417	-4.337	-2.360	-3.045	-1.905
Fabricated Metal Products Truck %	4.683	5.822	4.626	2.298	3.609
Machinery Truck %	-3.413	-5.404	-12.092	-2.438	-7.021
Rubber and Plastics Truck %	-8.241	-11.219	-9.401	-8.291	-13.481
Furniture and Fixtures Truck %	4.969	3.750	5.006	3.681	6.634
Electrical Equipment Truck %	5.472	13.573	5.070	6.119	11.379
Total Tons	1.952E-6	3.692E-6	1.837E-6	1.826E-6	2.079E-6
VC 5 %	2.615	2.965	2.771	2.608	2.658
VC 9 %	2.974	3.710	3.334	3.200	3.400
AADTT	-.018	-.038	-.019	-.019	-.020
Miscellaneous Manufacturing Products Truck %	-31.062	-70.104	-21.781	-31.707	-41.838
Road Class	8.367	8.441	10.925	8.363	14.280
Printed Matter Truck %	22.003	6.732	11.655	16.561	9.506
Paper and Pulp Products Truck %	1.240	2.187	1.740	2.244	2.647
Logs, Lumber and Wood Products Truck %	.657	.104	.884	.316	.884
Transportation Equipment Truck %	-1.598	-2.516	-1.802	-1.456	-1.634
(Constant)	-108.356	-151.896	-126.900	-117.762	-143.980

The results of the classification analysis can be seen in Table 4.78.

Table 4.78 Classified Sites into Tandem Axle Load Spectra Clusters through Discriminant Analysis

		Tandem Clusters	Predicted Group Membership					Total
			1	2	3	4	5	
Original	Count	1	2	0	1	1	0	4
		2	0	8	0	0	0	8
		3	0	1	10	0	0	11
		4	1	0	0	6	1	8
		5	0	0	0	0	5	5
	%	1	50.0	.0	25.0	25.0	.0	100.0
		2	.0	100.0	.0	.0	.0	100.0
		3	.0	9.1	90.9	.0	.0	100.0
		4	12.5	.0	.0	75.0	12.5	100.0
		5	.0	.0	.0	.0	100.0	100.0

The classification algorithm correctly clustered 86.1% of the sites. Since the number of sites is small, having 5 groups does not leave a large sample size in each cluster. This could also contribute to the inaccuracies of the discriminant scheme. Even with this detriment, the tandem axle load spectra cluster can still be selected with reasonable accuracy.

4.6.4 Summary and Use of Discriminant Analysis

The Fisher linear discriminant coefficients developed and presented in this section can be used to classify a given future design site based on the independent variables accessible to the MDOT prior to design of the roadway. For the variables mentioned in the beginning of this section which require such cluster averages to improve design quality, the proper selection of the appropriate traffic cluster is crucial. The procedure reviewed in Section 3.5 (Chapter 3) can be applied for any of the four traffic characterizations reviewed in this section for the proper selection of the needed traffic characteristic.

CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS

The conclusions are divided into two parts: (i) traffic data coverage, and (ii) traffic input characterization.

5.1 CONCLUSIONS

5.1.1 **Data Coverage**

In order to establish traffic patterns within the state, raw weigh-in-motion (WIM) and classification data from 44 WIM stations maintained in the state of Michigan were quality checked and processed using TrafLoad. During this process, the question of how much data to collect, (i.e. length of time) was raised. Thus the effect of length of data coverage, one week per month (OWPM) vs. continuous site-specific, was explored in this study. The OWPM pavement performance life was both under and over estimated, but had a maximum difference of 3.33 years with a 95% confidence of approximately 0.5 to 1.5 years overestimation of pavement design life. Certain traffic elements known to be the most variable from the traffic input perspective seemed to have little effect on the OWPM pavement performance life. The only exception to this was the continuous AADTT value for rigid pavement. Use of OWPM data in conjunction with continuous AADTT resulted in values that were closer to site specific. **However, if the data retrieval takes minimal effort from WIM or classification stations, it is recommended that continuous traffic data be used wherever available.**

5.1.2 **Traffic Inputs Characterization**

The following hierarchical traffic inputs were used in the M-E PDG:

- Level I – Converted WIM and classification data to the M-E PDG format using TrafLoad.
- Level II – Utilized cluster analysis to form groups with similar traffic characteristics. The group traffic characteristics were averaged to create a Level II traffic inputs.
- Level III – Average traffic characteristics from all Michigan sites were used as Level III data.

5.1.2.1 Findings based on the Cluster Analysis

The development of Level II inputs established the following findings:

- It was anticipated that the MDOT will know the AADTT at a site. Therefore, AADTT was grouped into low, medium, and high traffic volume. Low was under 1000 AADTT, medium was from 1000 to 3000 AADTT, and high was greater than 3000 AADTT for the design lane in one direction. Twenty-three sites had low AADTT, 12 had medium AADTT, and the remaining six had high AADTT.

- Truck traffic classification (TTC) clustering identified three specific traffic patterns centered on VC 5 and VC 9. The first traffic clustering was dominated by VC 9 and to a lesser extent by VC 5. The second cluster had somewhat equal distribution of VC 5 and VC 9. The third cluster was dominated by VC5 and to a lesser extent by VC 9.

- Monthly distribution factors were divided into three groups: VC 4-7, VC 8-10, and VC 11-13 (i.e., single-unit, tractor-trailer combination, and multi-trailer combination). Although three, four, and five MDF clusters were formed for VC 4-7, VC 8-10, and VC 11-13, respectively, all exhibited a similar trend of high peaks in the summer and low peaks in the winter months. Furthermore, VC 8-10 groups exhibited a uniform MDF distribution throughout the year as compared to other groups. This indicates a little seasonal variation in this group.

- Hourly distribution factors were grouped into three clusters. The first cluster showed a uniform HDF distribution throughout the day implying the presence of a large number of through-trucks. The second cluster exhibited rush-hour peak implying that a majority of the truck volume exists between 9 am to 5 pm. The third cluster was bounded by the clusters one and two.

- The single, tandem, tridem, and quad AGPVs had three, three, four, and five clusters, respectively. However, for all practical purposes a little difference could be seen between the groups.

- The single axle load spectra were grouped into three clusters, which peaked at 4-7 and 9-14 kips. The analysis also revealed that individual VCs were found to have similar axle load distributions across all sites. It was also observed that the prevalence of one peak over another was dependent on the percentages of VC 5 and VC 9 in the traffic stream at a site. The sites with a large number of VC 5 exhibited a peak at 4-7 kips whereas the sites with majority of VC 9 showed a peak at 9-14 kips.

- The tandem axle load spectra exhibited five distinct clusters. Clusters 1-3 showed presence of lighter axles as compared to clusters 4 and 5. Two peaks observed in the spectra correspond to unloaded (9-14 kips) and loaded (30-35 kips) trucks.

- The tridem axle load spectra were grouped into three clusters. In general, the clusters had a large proportion of lighter axles around 12 kips followed by a small peak at 40-45 kips.

- The quad axle load spectra had shown four clusters. Peak values for the quad axle load spectra occur at 15-20, 50-60 and 104 kips. Perhaps the most important finding in the analysis of quad axles is the presence of a 104 kip load, which is about 15% heavier than quad axle load in cluster 3. Presence of such a high load on one quad axle could be an artifact of data processing of the TrafLoad. It appears that a truck having two successive quad axles (e.g., trucks with eight axles) are being combined into one axle by the TrafLoad. Consequently, the results for quad axle loads in this report should be used with caution. It should be noted that the number of quad axles in the traffic stream is less than 1% as compared to single, tandem and tridem axle configuration.

5.1.2.2 General Findings

Additionally, following observations were made based on the analyses of the traffic inputs:

- **In general, insignificant seasonal (month to month) variations existed in axle load spectra for the most vehicle classes** except the vehicle classes (VC 4, VC 7, VC 8, VC 11, and VC 12) that constitute a very low percentage of the traffic volume and are on roads with low AADTT.
- **The impact of directional difference in axle load spectra for most vehicle classes is negligible.** Only VC 10 and VC 13 exhibited directional difference. This is most likely local nature of these specific VC trips (for e.g., traveling to and from a logging site or gravel pit). This is an important observation as it substantiates the need to analyze only a single direction.

- **The single axle load spectra for different vehicle classes at all sites were found to be similar based on cluster analysis.** This finding suggests that average value of single axle load spectra across different sites can be used with minimal error.

- **The single axle load distribution depends on the percentages of VC 5 and VC 9 in the traffic stream.** The sites with higher proportions of VC 5 peak at 3-6 kips while sites with higher proportions VC 9 peak at 11-13 kips.

- **The tandem axle load distributions depend on the axle load spectra of VC 9** only.

- **The tridem and quad axle load spectra are a function of VC 10 and VC 13.** This is due to the fact that VC 10 and VC 13 are the only axles which have tridem and quad.

5.1.2.3 Significant Traffic Inputs

For pavement design, it is recognized that site specific data be used wherever available. For sites in which site-specific data is not available, it is necessary to know whether Level II or Level III data are acceptable at a minimum for design. To investigate the impact of traffic input levels on predicted pavement performance for flexible and rigid pavements, the M-E PDG was used. As a result of this investigation, selection of the appropriate traffic characterization for each traffic input was made. The following is the summary of findings:

- **TTC significantly impacts predicted rigid pavement performance and moderately affects flexible pavement performance.** Thus, TTC clusters (Level II) is suggested for use in case of the rigid pavement design. Although there was no apparent difference in impact between cluster averages and statewide values in case of flexible pavement design, it suggested using **TTC cluster averages (Level II)** for sake of consistency.

- **MDFs have negligible impact on predicted rigid and flexible pavement performance.** The developed MDF traffic characterizations collectively produced a maximum difference of 2 years in pavement life from site specific values. Therefore, it is recommended that a **statewide average (Level III)** be used.

- **HDF significantly impacts rigid pavement performance but has a negligible impact on flexible pavement performance.** Consequently, cluster average (Level II) HDFs should be utilized for rigid pavement design. In contrast, for flexible pavement, HDF characterizations produced absolutely no difference in predicted performance life. Therefore, **statewide averages (Level III)** for HDF can be used for flexible pavement design.
- **AGPV had a negligible impact on predicted rigid and flexible pavement performance.** Therefore, it is suggested that **statewide averages (Level III)** be used for this traffic input.

- **Single axle load spectra have a moderate effect on predicted rigid and flexible pavement performance.** Cluster and statewide averages produced comparable results, having maximum over or under prediction within one year of each other for both pavement types. The 95% CIs for both of these traffic characterizations were also within months of each other. Therefore, it is recommended that **statewide averages (Level III)** be used for this traffic input.

- **Tandem axle load significantly impacted rigid pavement performance and had a moderate influence on flexible pavement performance.** Therefore, **cluster averages (Level II)** are suggested for both rigid and flexible pavement designs.

- **Tridem axle load spectra do not have a significant impact on rigid and flexible pavement performance.** Consequently, **statewide average** tridem axle load spectra (Level III) can be used for this traffic input.

- **Quad axle load spectra have a negligible impact on predicted rigid pavement performance** but have a moderate effect on flexible pavement performance. Therefore, **statewide average** quad axle load spectra (Level III) can be used.

- **The M-E PDG defaults traffic inputs don't accurately reflect the local traffic conditions in the state of Michigan.** In general, statewide or cluster averages produced performance lives that were closer to the site-specific values than the M-E PDG defaults. Consequently, the M-E PDG defaults are not recommended for use in the state of Michigan, with the exception of quad axle loads.

The summary of the above conclusions and suggested recommendations are summarized below:

Traffic Characteristic	Impact on Pavement Performance		Suggested Input Levels (when Level I is unavailable)	
	Rigid Pavement	Flexible Pavement	Rigid Pavement	Flexible Pavement
TTC	Significant	Moderate	Level II	
HDF	Significant	Negligible	Level II	Level III
MDF	Negligible		Level III	
AGPV	Negligible		Level III	
Single ALS	Moderate		Level III	
Tandem ALS	Significant	Moderate	Level II	
Tridem ALS	Negligible	Negligible	Level III	
Quad ALS	Negligible	Moderate	Level III	

5.1.2.4 Establishing Traffic Inputs for a Site

Once the appropriate input levels for each of the traffic characteristic were established, it was necessary to determine how these could be implemented in design. For the traffic inputs where site specific (Level I) data or only statewide values (Level III) need to be used, selection of the appropriate traffic input is obvious. However, for the traffic inputs that require cluster averages, the discriminant analysis as presented in Chapters 3 and 4 could be employed to select the appropriate traffic characteristic cluster. The discriminant analysis algorithm can be adopted for the following traffic inputs which require Level II data:

- TTC
- HDF (Rigid only)
- Tandem Axle Load Spectra

Discriminant coefficients developed for each of these traffic characteristics will assist in the selection of the appropriate traffic characteristics for design purposes. The following information will be needed to implement the discriminant analysis results:

- Vehicle freight commodity truck percentage for the following commodities
    - Food Products
    - Fabricated Metal Products
    - Transportation Products
    - Logs, Lumber and Wood Products
    - Machinery
    - Rubber and Plastics

    - Paper and Pulp Products
    - Furniture and Fixtures
    - Miscellaneous Manufacturing Products
    - Printed Matter
    - Electrical Equipment
- Road class
- Geographic region
- AADTT
- VC 5%
- VC 9%
- Functional class (rural/urban)
- Roadway annual tonnage

The use of appropriate inputs into the linear regression equations developed in this research will identify the suitable traffic input cluster for use in the M-E PDG.

5.2 RECOMMENDATIONS

It is recommended, wherever possible, to expand the geographic coverage of traffic characteristics in Michigan. When a new WIM or classification needs to be installed, it should be located in areas where limited traffic data is available. Short duration and continuous counts should be shared between agencies to ensure wider and recurrent data collection coverage. Effective communication between traffic data collection personnel and pavement design engineers is recommended for addressing the traffic input requirement for the M-E PDG. Additionally, the following specific traffic data collection efforts should be considered as recommended by the Traffic Monitoring Guide (TMG):

- The short duration volume coverage count program should provide comprehensive coverage across the roadway infrastructure on a cycle of 6 years. Short duration classification counts should account for at least 25-30% of all volume counts being conducted wherever possible. In addition, at least one vehicle classification count should be made on each route annually.
- To obtain 95% confidence and 10% error in the precision of the traffic factors formed within a seasonal group; five to eight continuous counters should be established per group. New seasonal factors should be compared to the ones formed and placed into the appropriate group.
- At least six continuous vehicle classification counters be established for each factor group. Continuous counts should be placed on different functional classes and different geographic regions within the state. Emphasis should be placed on roads that are primarily local or long hauls. When new sites are added, the data should be compared and placed into the appropriate existing factor groups.
- For all sites within a Truck Weight Road Group (TWRG), a minimum of six should be monitored, with at least one of the WIM sites operating continuously and recording two or more lanes of traffic. The amount of permanent WIM stations and discontinuous portable systems is a function of the number of TWRGs created, the accuracy at which the measured weights are taken, and the budget of the state agency.

With proper coverage of existing groups and a gradual expansion into unmonitored areas within the state through movement of permanent devices, the data collection program could be more robust. In addition to above mentioned general suggestions, based on the results of this study following are the specific recommendations to improve traffic-related data collection to facilitate use of the M-E PDG design process in the state of Michigan:

1. The clusters for different traffic inputs were determined based on the traffic data collected at specific WIM and classification sites distributed in the state. In addition, the most of traffic data were collected between years 2005 to 2007. However, there will be a need to revise these clusters if following updates or changes are anticipated:

    a. Addition of a significant number of new classification and WIM sites at different geographical locations or change in the status of existing site (e.g., down- or up-grading from WIM to classification or vice versa).
    b. Significant change in the land use in the vicinity of the existing WIM locations.
    c. Change in the WIM technology for a number of locations. For example if less accurate piezo sensors are replaced with more accurate quartz or bending plate sensors.
    d. If MDOT anticipates the above mentioned updates or changes in the foreseeable future (e.g., 5 or 10 years), then there will be a need to revise the clusters for all traffic inputs.

2. Based on the clustering, the existing statewide locations for WIM sites were reviewed and the following specific WIM additions are recommended for the various regions in the state:

    a. Superior Region:
        - Because of the presence of heavy to very heavy axle loads, an additional WIM site between Shingleton and Strongs along M-28 is recommended.
        - Integrate the axle load and gross-vehicle weight (GVW) from the bridge site (2109) with the existing WIM data.
        - The WIM sites (1199 and 2029) were added to the network after the study had commenced. These sites are appropriate for WIM data collection and will further enhance the WIM data coverage for the superior region.
        - To capture interstate truck traffic (between Michigan and Wisconsin), an addition WIM site should be considered in future west of WIM site 1199.
    b. North Region:
        - The current WIM site distribution seems adequate with the addition of WIM site 3069 to cover the west side of the region.
        - An additional WIM sites should be considered in future on the eastern side along M-32.
    c. Grand Region:
        - The cluster analysis revealed light to medium axle loadings in this region. Therefore, the current WIM site distribution seems adequate at this point in time.

d. Bay Region:
   - This region also contains light to medium axle loadings. Addition of WIM site 6449 is appropriate as it will provide additional data on I-75 between Bay and Metro regions.
   - The current WIM site distribution seems adequate at this point in time.
e. Metro Region:
   - Integrate the axle load and gross-vehicle weight (GVW) between sites 6109 and 6469.
   - Additional site 9699 seems appropriate.
f. University Region:
   - The cluster analysis supports the downgrading of WIM site 8829 to count site.
g. Southwest Region:
   - The locations of additional WIM sites 7219, 7319, and 7169 seem appropriate.
   - Additional WIM site is recommended in future north of Battle Creek on I-69 either in Southwest or University region because of evidence of heavy axle loads in that vicinity.

3. Currently, MDOT is using AASHTO 93 guide for designing flexible and rigid pavements. The AASHTO 93 guide only requires ESALs as the traffic input. However, ESALs are determined based on average truck factors (TF). The TF calculations involve the use of axle load spectra for different axle configurations depending on vehicle class. Therefore, MDOT also needs axle load spectra for all axle configurations for AASHTO 93 guide. However, more detailed axle load spectra are needed for the M-E PDG to characterize the axle loadings. In addition, several other traffic related inputs are necessary for the M-E PDG. In fact, MDOT is already collecting all the required traffic-related data at various locations in the state. Additional resources are anticipated to process the already collected traffic data to the required level for the M-E PDG. Therefore, if MDOT wants to adopt the M-E PDG design process considering its benefits, it is strongly recommended to improve and enhance its data processing capabilities (converting raw traffic data to the M-E PDG format). It is recommended that for the short-term, MDOT can use TrafLoad software to achieve data processing objectives. In the interim period, MDOT should use the findings of this study to obtain the necessary traffic inputs for the M-E PDG. In the long-term, in-house data processing capabilities should be developed to address the goal.

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Appendix A
Infrastructure and Methodology

A. Processing of Raw Data in TrafLoad

The following presents the algorithms present within the TrafLoad software for developing the various traffic characteristics for use in the M-E PDG. These algorithms are presented in presented in Part 4 of the TrafLoad manual but are reviewed here for understanding and completeness (3). The TrafLoad accepts “W-records” (7-cards) as well as “C-records” (4-cards). The MDOT maintains this formatting as discussed in Section 6 of the TMG (5). For this analysis only the outer lane was used despite TrafLoad’s capabilities of processing multiple lanes. Multiple lanes were not utilized as pavement design focuses on the outer lane since it carries the majority of truck traffic.

A.1 Average Annual Daily Truck Traffic

The AADTT was computed in the following manner:

1. For each day of week, *w*, vehicle class, *i*, month, *m*, and each hour of the day, *h*, obtain an hourly count, $HVOL_{iwm}$.
2. For each day of week, *w*, vehicle class, *i*, month, *m*, sum up the hourly counts and average those summations for the same day of week (Max n=5) within a given month. This provides an average AADTT value for each vehicle class and each day of week for every month, $MADW_{iwm}$, as shown in Equation 3.1.

$$MADW_{iwm} = \frac{1}{n}\sum_{p=1}^{n}\sum_{h=1}^{24} HVOL_{iwmph} \qquad \text{(A.1)}$$

3. Average each $MADW_{iwm}$ for each month and then average these seven day of week values together to create an AADTT for each vehicle class, $AADTT_i$, as shown in Equation 3.2.

$$AADTT_i = \frac{1}{7}\sum_{w=1}^{7}\frac{1}{12}\sum_{m=1}^{12} MADW_{iwm} \tag{A.2}$$

4. Sum each vehicle class to obtain an overall AADTT for a site, $AADTT_t$, as shown in Equation 3.3.

$$AADTT_t = \sum_{i=4}^{13} AADTT_i \tag{A.3}$$

A.2 Truck Traffic Classification

The calculation of individual truck classification is an extension of AADTT. The percentage of each truck class is found by dividing the individual vehicle class $AADTT_i$, by the total AADTT, $AADTT_t$ as shown in Equation 3.4.

$$TTC_i = \frac{AADTT_i}{AADTT_t} \tag{A.4}$$

A.3 Monthly Distribution Factor

The monthly distribution factor is computed in the following manner:

1. For each $MADW_{iwm}$ calculated in Equation 3.2, average the seven day of week AADTT values for each month, m, and each vehicle class, i, as shown in Equation 3.5. This yields an AADTT value for each month and each vehicle class, $MADTT_{im}$.

$$MADTT_{im} = \frac{1}{7}\sum_{w=1}^{7} MADW_{iwm} \tag{A.5}$$

2. For each vehicle class, i, and each month, m, obtain a monthly distribution factor for each vehicle class and month, MDF_{im}, by dividing the $MADTT_{im}$ by the overall vehicle class $AADTT_i$ found in Equation 3.5. Equation 3.6 displays this calculation.

$$MDF_{im} = \frac{MADTT_{im}}{AADTT_i} \tag{A.6}$$

3. For this analysis, it was decided to group single-unit trucks (VC 4-7), tractor-single trailer combinations (VC-8-10) and multi-trailer combinations (VC 11-13) for MDF creation for simplification of calculations as suggested by research. To create the MDFs for these groups, a weighted average, based on AADTT of the number of vehicle classes within each group, k, was performed for each group, g, as shown in Equation 3.7.

$$MDF_{img} = \sum^{k} MDF_{im} * \frac{AADTT_i}{AADTT_g} \tag{A.7}$$

A.4 Hourly Distribution Factor

The HDFs are created through the following steps:

1. Sum hourly volume counts $HVOL_h$ for each hour for all days in which data was collected. Average this hourly summation by the number of days collected, x, for all 24 hours to yield an average volume count for each hour of the day, $HVOLTOT_h$, as shown in Equation 3.8.

$$HVOLTOT_h = \frac{1}{x}\sum_{i=1}^{x} HVOL_h \qquad \text{(A.8)}$$

2. Sum the averaged hourly volume counts, $HVOLTOT_h$, to have a total volume count, *TOTVOL*, as shown in Equation 3.9.

$$TOTVOL = \sum_{h=0}^{23} HVOLTOT_h \qquad \text{(A.9)}$$

3. Calculate the hourly HDFs, HDF_h, by dividing the average hourly volume counts, $HVOLTOT_h$, by the total average volume count, *TOTVOL* as shown in Equation 3.10.

$$HDF_h = \frac{HVOLTOT_h}{TOTVOL} \qquad \text{(A.10)}$$

A.5 Axle Groups Per Vehicle

The axle groups per vehicle for each vehicle class, *i*, and each axle group, *j*, (single, tandem, tridem, quad), $AGPV_{ij}$, are established by summing all axle groups for all truck records in each vehicle class and axle type, A_{ij}, and dividing by the number of vehicles in the record for that vehicle class, V_i. This calculation is shown in Equation 3.11.

$$AGPV_{ij} = \frac{\sum_{1}^{y} A_{ij}}{V_i} \qquad \text{(A.11)}$$

A.6 Axle Load Spectra

The following outlines the basic procedure for the creation of axle load distributions.

1. For each vehicle class, *i*, axle type, *j*, day of week, *w*, month, *m*, and load bin, *l*, and particular day within month, *p*, (max 5 for any day of week) calculate the number of axle load repetitions, AR_{ijwmlp}. Sum these repetitions across all load bins as shown in Equation 3.12 to form a total amount of axles for a given vehicle class, axle type, day of week, month and particular day of month, ART_{ijwmp}.

$$ART_{ijwmp} = \sum_{j=1}^{39} AR_{ijwmlp} \tag{A.12}$$

2. For each vehicle class, *i*, axle type, *j*, day of week, *w*, month, *m*, and load bin, *l*, and particular day within month calculate the frequency of axles, ALS_{ijwmlp}, by dividing the load bin repetition, AR_{ijwmlp}, by the overall repetitions, ART_{ijwmp}. This calculation is shown in Equation 3.13.

$$ALS_{ijwmlp} = \frac{AR_{ijwmlp}}{ART_{iwmlp}} \tag{A.13}$$

3. For each vehicle class, *i*, axle type, *j*, month, *m*, and load bin, *l*, form a monthly axle load frequency for each day of week, $MALSW_{ijwml}$, by averaging the particular same days of week within a month as shown in Equation 3.14.

$$MALSW_{ijwml} = \frac{1}{n} \sum_{p=1}^{n} ALS_{ijwmlp} \tag{A.14}$$

The conversion of an overall monthly axle load spectra from the day of week values involves a significant number of adjustment calculations. Refer to Chapter 3.3 of Part 4 in the TrafLoad manual for guidance on these calculations.

It was deemed advantageous to cluster axle load spectra for single, tandem, tridem and quad axle configurations *as a whole*, with all vehicle classes combined. M-E PDG actually multiplies its damage factors based on the combined distribution of all single, tandem, tridem and quad axles and not by individual vehicle classes. Additionally, a review of the data revealed that little month-to-month variation in axle load spectra existed. As such, the following reviews the calculations for combining and averaging axle load spectra across different vehicle classes:

1. For each month, *m*, axle type, *j*, and load bin, *l*, calculate the total amount of repetitions for each vehicle class, $TOTREP_{ijml}$. This is done by multiplying together the AADTT of the site, MDF for the given month, MDF_m, AGPV for the vehicle class and axle type, $AGPV_{ij}$, the TTC for the vehicle class, TTC_i, and the axle load frequency for that month, vehicle class, axle type and load bin. This calculation can be seen in Equation 3.15.

$$TOTREP_{ijml} = AADTT * MDF_m * AGPV_{ij} * TTC_i * ALS_{ijl} \quad \text{(A.15)}$$

2. For each month, *m*, axle type, *j*, and load bin *l*, sum the total repetitions across all vehicle classes, AR_{mjl}, as shown in Equation 3.16.

$$AR_{mjl} = \sum_{k=4}^{13} TOTREP_{ijl} \quad \text{(A.16)}$$

3. For each month, m, and axle type, j, sum the total repetitions found in step 2 across all load bins, ART_{mj}, as shown in Equation 3.17.

$$ART_{mj} = \sum_{j=1}^{39} AR_{ij} \tag{A.17}$$

4. For each axle type, j, month, m, and load bin, l, form a monthly axle load frequency, ALS_{ijwml}, by dividing the total repetitions found in Step 2, AR_{mjl}, by the cumulative repetitions from Step 3, ART_{mj}. This calculation is shown in Equation 3.18.

$$ALS_{mjl} = \frac{AR_{mjl}}{ART_{mj}} \tag{A.18}$$

5. Annual axle load spectra were created by taking simple averages of each of the cumulative monthly axle load spectra for each axle type, $AALS_{jl}$, as displayed in Equation 3.19.

$$AALS_{jl} = \frac{1}{12} \sum_{m=1}^{12} ALS_{mjl} \tag{A.19}$$

Table A1. Comprehensive MDOT WIM Sites for Weight and Traffic Recording

Site No.	Site Name	Control Section	Year Initiated (Latest Date Calibrated)	Duration of Data	Instrument Type	Road Class
1459	Bark River	21021	2000 (Oct-06)	Oct. 2006 - Oct. 2007 (WIM) Nov. 2005 - Oct. 2007 (Class)	WIM (Quartz)	Federal (US-2)
1529	Norway	22023	1998	Nov. 2005 - Oct. 2007	WIM (Piezo BL)	Federal (US-2)
2229	Rapid River	21025	2006 (Oct-06)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-2)
~~3069~~	~~Kalkaska~~	~~40012~~	~~2007~~	~~Oct 2007 only~~	~~WIM (Quartz)~~	~~Interstate (I-196)~~
4049	Vanderbilt	69014	2000	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-75)
4129	Houghton Lake	72013	1998 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-127)
4149	Prudenville	72061	2002	Nov. 2005 - Oct. 2007	WIM (Piezo BL)	Interstate (I-75)
4229	Augres	6073	1997	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	Federal (U.S.-23)
4249	Omer	6072	2002 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Bending)	Federal (U.S.-23)
5019	St. Johns	19034	2005 (Oct-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-127)
5059	Hudsonville	70024	1996 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-196)

Site No.	Site Name	Control Section	Year Initiated (Latest Date Calibrated)	Duration of Data	Instrument Type	Road Class
5249	Morley	59012	1993	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	Federal (US-131)
5289	Muskegon	61072	2001 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-31)
5299	Ionia	34044	1993 (Dec-06)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-96)
6019*	Carsonville	74062	1999 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Bending)	State (M-46)
~~6119~~	~~Birch Run MC~~	~~25032~~	~~2007~~	~~Oct. 2007 only~~	~~WIM (Quartz)~~	~~Interstate (I-75)~~
6129	Birch Run	73171	2005 (Apr-06)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-75)
6309	Clio	25102	1993	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	State (M-57)
~~6349~~	~~Flint~~	~~25032~~	~~2000~~	~~Nov. 2005 - Oct. 2007~~	~~WIM (Piezo BLC)~~	~~Federal (I-75)~~
6369	Capac	77024	1993	Nov. 2005 - Oct. 2007	WIM (Piezo BL)	Interstate (I-69)
6429	Kawkawlin	9035	1999 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-75)
6469	Port Huron	77111	2000 (Jan-07)	Oct. 2006 - Oct. 2007	WIM (Quartz)	Interstate (I-94)
6479	Bay City	9101	1993	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	Federal (US-10)

Site No.	Site Name	Control Section	Year Initiated (Latest Date Calibrated)	Duration of Data	Instrument Type	Road Class
7029	Grass Lake	38103	1998 (May-06)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-94)
7109	Schoolcraft	39011	2000	Nov. 2005 - Oct. 2007	WIM	Federal (US-131)
7159	Battle Creek	13082	2000	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	Interstate (I-94)
~~7169~~	~~Marshall~~	~~13083~~	~~2007~~	~~Jul. 2007 - Oct. 2007~~	~~WIM (Quartz)~~	~~Interstate (I-94)~~
~~7179~~	~~Coloma~~	~~11017~~	~~2000~~	~~Nov. 2005 - Oct. 2007~~	~~WIM (Piezo BLC)~~	~~Interstate (I-94)~~
7269	Coldwater	12033	2001 (May-06)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-69)
8029	Mason	33031	2007	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-127)
8049	Fowlerville	47066	1999	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-96)
8129	Jonesville	30062	2000 (Feb-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-12)
8209	South Hill	63022	2000	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	Interstate (I-96)
8219	Howell	47065	1998 (Feb-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-96)
8229	Brighton	47014	2000	Nov. 2005 - Oct. 2007	WIM	Federal (US-23)

Site No.	Site Name	Control Section	Year Initiated (Latest Date Calibrated)	Duration of Data	Instrument Type	Road Class
8249	Luna Pier	58151	2001	Nov. 2005 - Mar. 2007	WIM (Piezo BL)	Interstate (I-75)
8440	Puritan	82053	2003 (Feb-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-24)
8689	Dundee	58034	2000	Nov. 2005 - Apr. 2006	WIM (Piezo)	Federal (US-23)
8729	Lambertville	58034	1994 (Feb-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Federal (US-23)
8829	Ypsilanti	81062	2000	Nov. 2005 - Oct. 2007	WIM (Piezo BLC)	Interstate (I-94)
9189	275 @ Penn	82291	1993	Nov. 2005 - Oct. 2007	WIM (Piezo BL)	Interstate (I-275)
9209	275 @ Cherry Hill	82292	1998 (Feb-07)	Nov. 2005 - Oct. 2007	WIM (Quartz)	Interstate (I-275)
9369	Kalamazoo			Nov. 2005 - Sept. 2006	WIM	Interstate (I-94)
9759	Cutlerville	41064	2004 (Jan-07)	Nov. 2005 - Oct. 2007	WIM (Bending)	State (M-6)

*Note sites with an “X” indicates data was not used in continuous analyses. Sites which are shaded were excluded from the OWPM analyses.

Table A2. Comprehensive MDOT Classification Sites for Traffic Recording

Site Number	Site Name	Control Section	Year Initiated (Latest Date Calibrated)	Duration of Data	Instrument Type	Road Class
2029	Brevort	49023	2006	Jun. 2006 - Oct. 2007	Classification (Piezo BL)	Federal (US-2)
2209	Deerton	2041	2004	Nov. 2005 - Oct. 2007	Classification (Piezo BL)	State (M-28)
3269	Branch	53022	2006	Jun. 2007 - Oct. 2007	Classification (Piezo BL)	Federal (US-10)
7069	Homer	13022	2006	Jul. 2006 - October 2007	Classification (Piezo BL)	State (M-60)
7289	Bangor	80041	2000	May 2006 - Oct. 2007	Classification (Piezo BLC)	State (M-43)
7329	White Pigeon	78022	1998	Oct. 2006 - Oct. 2007	Classification (Piezo BLC)	State (US-12)
9799	Cicotte	82194	2002	Nov. 2005 - Oct. 2007	Classification (Piezo BL)	Interstate (I-75)

*Note sites with an “X” indicates data was not used in continuous analyses. Sites which are shaded were excluded from the OWPM analyses.

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Table A3. Rigid Pavement ESAL and Pavement Thickness Values

Site No.	Single Axle	Tandem Axle	Tridem Axle	Quad Axle	SUM 20 Years @ 2% Growth	DNPS Thickness	M-E PDG Design Thickness
1459	2172216	2419078	305077	2300860	7197230	9.69	9.50
1529	1189919	2374549	102721	1835485	5502674	9.27	9.50
2229	1584790	3324002	85350	1062749	6056891	9.42	10.00
4049	2043999	3908479	259823	2019664	8231966	9.91	10.00
4129	1225273	1737103	147002	1804114	4913493	9.10	9.50
4149	1974023	3137984	243686	4889068	10244761	10.27	10.00
4229	607238	1057828	43990	511471	2220527	7.92	8.50
4249	774123	1165415	65817	726294	2731649	8.22	8.50
5019	2540309	4611972	195729	1987539	9335550	10.11	10.50
5059	4274143	8404008	300907	2332698	15311756	10.95	10.50
5249	8781049	8703620	534227	6629017	24647914	11.81	11.00
5289	2199834	4444503	362400	2473118	9479855	10.14	10.00
5299	5671647	11853774	231379	11690442	29447242	12.14	11.50
6019	272400	320834	50800	346661.4	990695	6.80	8.00
6129	5585871	10012390	505411	4404974	20508646	11.47	11.00
6309	407161	460754.9	84192	603563.8	1555672	7.42	8.00
6369	4698867	18296312	1007032	2926993	26929205	11.97	11.50
6429	3491803	5533331	342242	4414095	13781471	10.77	10.50
6469	4449347	9621073	797768	2303226	17171413	11.15	11.00
6479	2972393	6859762	606714	5316599	15755468	11.00	10.50
7029	16522270	56553279	823196	7750872	81649617	14.21	13.50
7109	3118434	7516762	266543	958709.5	11860448	10.51	10.50
7159	18920867	92343192	1439046	6899957	119603063	15.06	14.00
7269	8975981	28369349	250117	62377.52	37657824	12.61	12.50
8029	2567164	5240522	234909	6045904	14088499	10.81	10.00
8049	5932727	14283983	369192	3433317	24019219	11.76	11.50
8129	1369815	2484214	220574	876640.8	4951243	9.11	9.50
8209	10792223	21502554	2347176	34738139	69380093	13.86	12.00
8219	4668050	8604780	326639	2932765	16532234	11.08	11.00
8229	7012327	15215070	889919	6527671	29644987	12.15	11.50
8440	644628	387405.7	24359	143656.7	1200049	7.06	8.00
8729	11649705	27894101	709527	6163891	46417223	13.03	12.50
8829	9225828	30425920	884983	13991981	54528713	13.36	12.50
9189	10013577	32774533	1274339	21655852	65718300	13.74	12.50
9209	10015609	18425231	883006	13122223	42446069	12.85	11.50
9759	691073	854270.3	53198	352034.1	1950575	7.74	8.50

Table A4. Flexible Pavement ESAL and Pavement Thickness Values

Site No.	Single Axle	Tandem Axle	Tridem Axle	Quad Axle	SUM 20 Years @ 2% Growth	DNPS Thickness	M-E PDG Design Thickness
1459	2172216	2419078	305077	2300860	7197230	9.69	9.50
1529	1189919	2374549	102721	1835485	5502674	9.27	9.50
2229	1584790	3324002	85350	1062749	6056891	9.42	10.00
4049	2043999	3908479	259823	2019664	8231966	9.91	10.00
4129	1225273	1737103	147002	1804114	4913493	9.10	9.50
4149	1974023	3137984	243686	4889068	10244761	10.27	10.00
4229	607238	1057828	43990	511471	2220527	7.92	8.50
4249	774123	1165415	65817	726294	2731649	8.22	8.50
5019	2540309	4611972	195729	1987539	9335550	10.11	10.50
5059	4274143	8404008	300907	2332698	15311756	10.95	10.50
5249	8781049	8703620	534227	6629017	24647914	11.81	11.00
5289	2199834	4444503	362400	2473118	9479855	10.14	10.00
5299	5671647	11853774	231379	11690442	29447242	12.14	11.50
6019	272400	320834	50800	346661	990695	6.80	8.00
6129	5585871	10012390	505411	4404974	20508646	11.47	11.00
6309	407161	460755	84192	603564	1555672	7.42	8.00
6369	4698867	18296312	1007032	2926993	26929205	11.97	11.50
6429	3491803	5533331	342242	4414095	13781471	10.77	10.50
6469	4449347	9621073	797768	2303226	17171413	11.15	11.00
6479	2972393	6859762	606714	5316599	15755468	11.00	10.50
7029	16522270	56553279	823196	7750872	81649617	14.21	13.50
7109	3118434	7516762	266543	958709	11860448	10.51	10.50
7159	18920867	92343192	1439046	6899957	1.2E+08	15.06	14.00
7269	8975981	28369349	250117	62378	37657824	12.61	12.50
8029	2567164	5240522	234909	6045904	14088499	10.81	10.00
8049	5932727	14283983	369192	3433317	24019219	11.76	11.50
8129	1369815	2484214	220574	876641	4951243	9.11	9.50
8209	10792223	21502554	2347176	34738139	69380093	13.86	12.00
8219	4668050	8604780	326639	2932765	16532234	11.08	11.00
8229	7012327	15215070	889919	6527671	29644987	12.15	11.50
8440	644628	387406	24359	143657	1200049	7.06	8.00
8729	11649705	27894101	709527	6163891	46417223	13.03	12.50
8829	9225828	30425920	884983	13991981	54528713	13.36	12.50
9189	10013577	32774533	1274339	21655852	65718300	13.74	12.50
9209	10015609	18425231	883006	13122223	42446069	12.85	11.50
9759	691073	854270	53198	352034	1950575	7.74	8.50

Table A5. Pearson Correlation Coefficients for Predictor Variables (1 of 2)

Predictor Variable	Pearson Criteria	TTC	Single AGPV	Tandem AGPV	Tridem AGPV	Quad AGPV	HDF
Road Class	Pearson Corr.	.507**	.074	.187	.272	.276	.366*
	Sig. (2-tailed)	.001	.686	.298	.109	.114	.019
	N	41	32	33	36	34	41
Region	Pearson Corr.	-.458**	-.384*	-.704**	-.439**	-.378*	-.308*
	Sig. (2-tailed)	.003	.030	.000	.007	.027	.050
	N	41	32	33	36	34	41
AADTT	Pearson Corr.	-.637**	-.116	-.466**	-.386*	-.163	-.621**
	Sig. (2-tailed)	.000	.526	.006	.020	.358	.000
	N	41	32	33	36	34	41
VC 5 %	Pearson Corr.	.884**	-.081	.220	.255	.098	.660**
	Sig. (2-tailed)	.000	.661	.219	.133	.581	.000
	N	41	32	33	36	34	41
VC 9%	Pearson Corr.	-.912**	.101	-.304	-.255	-.165	-.781**
	Sig. (2-tailed)	.000	.583	.086	.133	.352	.000
	N	41	32	33	36	34	41
Functional Class	Pearson Corr.	.032	-.340	-.476**	-.239	-.054	.266
	Sig. (2-tailed)	.853	.057	.005	.161	.761	.117
	N	36	32	33	36	34	36
Food Products Truck %	Pearson Corr.	-.600**	-.114	-.584**	-.493**	-.058	-.510**
	Sig. (2-tailed)	.000	.533	.000	.002	.746	.001
	N	36	32	33	36	34	36
Fabricated Metal Products Truck %	Pearson Corr.	-.703**	-.007	-.600**	-.399*	-.200	-.458**
	Sig. (2-tailed)	.000	.968	.000	.016	.256	.005
	N	36	32	33	36	34	36

Transportation Equipment Truck %	Pearson Corr.	-.499**	-.058	-.159	.053	-.381*	-.372*
	Sig. (2-tailed)	.002	.752	.377	.757	.026	.025
	N	36	32	33	36	34	36
Logs Lumber and Wood Products Truck %	Pearson Corr.	.312	.067	.508**	.346*	.047	.067
	Sig. (2-tailed)	.064	.716	.003	.038	.791	.698
	N	36	32	33	36	34	36
Machinery Truck %	Pearson Corr.	-.650**	-.102	-.403*	-.192	-.156	-.577**
	Sig. (2-tailed)	.000	.577	.020	.261	.378	.000
	N	36	32	33	36	34	36
Rubber and Plastics Truck %	Pearson Corr.	-.592**	-.010	-.489**	-.481**	-.079	-.483**
	Sig. (2-tailed)	.000	.955	.004	.003	.659	.003
	N	36	32	33	36	34	36
Furniture and Fixtures Truck %	Pearson Corr.	-.499**	.220	-.036	-.024	.013	-.454**
	Sig. (2-tailed)	.002	.225	.843	.890	.944	.005
	N	36	32	33	36	34	36
Miscellaneous Manufacturing Products Truck %	Pearson Corr.	-.496**	-.025	-.272	-.179	-.076	-.467**
	Sig. (2-tailed)	.002	.893	.125	.295	.667	.004
	N	36	32	33	36	34	36
Printed Matter Truck %	Pearson Corr.	-.519**	-.038	-.520**	-.414*	-.159	-.404*
	Sig. (2-tailed)	.001	.838	.002	.012	.370	.015
	N	36	32	33	36	34	36
Electrical Equipment Truck %	Pearson Corr.	-.504**	.005	-.399*	-.260	-.181	-.450**
	Sig. (2-tailed)	.002	.977	.021	.126	.307	.006
	N	36	32	33	36	34	36
Paper and Pulp Products Truck %	Pearson Corr.	.213	.255	.550**	.515**	.130	.054
	Sig. (2-tailed)	.211	.159	.001	.001	.465	.756
	N	36	32	33	36	34	36
Total Tons	Pearson Corr.	-.580**	.039	-.206	-.321	.021	-.675**
	Sig. (2-tailed)	.000	.834	.250	.057	.905	.000
	N	36	32	33	36	34	36

Table A5. Pearson Correlation Coefficients for Predictor Variables (2 of 2)

Predictor Variable	Pearson Criteria	MDF 4-7	MDF 8-10	MDF 11-13	All Single Axle Load Spectra	All Tandem Axle Load Spectra	All Tridem Axle Load Spectra	All Quad Axle Load Spectra
Road Class	Pearson Corr.	.029	-.089	.124	.608**	-.081	.405*	.014
	Sig. (2-tailed)	.869	.590	.531	.000	.639	.017	.938
	N	35	39	28	36	36	34	33
Region	Pearson Corr.	-.576**	-.168	-.481**	-.441**	-.194	-.436*	-.072
	Sig. (2-tailed)	.000	.307	.009	.007	.256	.010	.691
	N	35	39	28	36	36	34	33
AADTT	Pearson Corr.	-.176	-.048	-.272	-.668**	.213	-.513**	.015
	Sig. (2-tailed)	.312	.774	.161	.000	.211	.002	.936
	N	35	39	28	36	36	34	33
VC 5 %	Pearson Corr.	-.108	-.042	.440*	.828**	-.214	.185	.168
	Sig. (2-tailed)	.538	.800	.019	.000	.209	.296	.349
	N	35	39	28	36	36	34	33
VC 9%	Pearson Corr.	-.017	-.033	-.383*	-.838**	.264	-.338	-.166
	Sig. (2-tailed)	.923	.840	.044	.000	.120	.051	.355
	N	35	39	28	36	36	34	33
Functional Class	Pearson Corr.	-.504**	-.056	-.342	-.039	-.382*	-.069	.104
	Sig. (2-tailed)	.004	.749	.075	.820	.022	.700	.563
	N	31	35	28	36	36	34	33
Food Products Truck %	Pearson Corr.	-.239	-.304	-.377*	-.414*	.093	-.526**	.042
	Sig. (2-tailed)	.195	.076	.048	.012	.588	.001	.816
	N	31	35	28	36	36	34	33

Fabricated Metal Products Truck %	Pearson Corr.	-.214	-.339*	-.410*	-.559**	-.072	-.387*	-.196
	Sig. (2-tailed)	.248	.046	.030	.000	.677	.024	.275
	N	31	35	28	36	36	34	33
Transportation Equipment Truck %	Pearson Corr.	.064	-.290	.085	-.426**	.001	-.307	-.034
	Sig. (2-tailed)	.733	.091	.668	.010	.995	.078	.853
	N	31	35	28	36	36	34	33
Logs Lumber and Wood Products Truck %	Pearson Corr.	.538**	.403*	.590**	.320	.288	.428*	.416*
	Sig. (2-tailed)	.002	.016	.001	.057	.089	.011	.016
	N	31	35	28	36	36	34	33
Machinery Truck %	Pearson Corr.	-.060	-.204	-.122	-.463**	.306	-.460**	.173
	Sig. (2-tailed)	.749	.239	.536	.004	.069	.006	.336
	N	31	35	28	36	36	34	33
Rubber and Plastics Truck %	Pearson Corr.	-.312	-.333	-.345	-.509**	-.027	-.408*	-.159
	Sig. (2-tailed)	.088	.051	.072	.002	.878	.017	.378
	N	31	35	28	36	36	34	33
Furniture and Fixtures Truck %	Pearson Corr.	.189	.070	-.063	-.470**	.263	-.306	.212
	Sig. (2-tailed)	.309	.689	.748	.004	.121	.079	.236
	N	31	35	28	36	36	34	33
Miscellaneous Manufacturing Products Truck %	Pearson Corr.	-.071	-.372*	.016	-.310	.204	-.341*	.062
	Sig. (2-tailed)	.705	.028	.935	.066	.233	.049	.730
	N	31	35	28	36	36	34	33
Printed Matter Truck %	Pearson Corr.	-.223	-.251	-.433*	-.343*	.008	-.465**	.100
	Sig. (2-tailed)	.228	.145	.021	.041	.963	.006	.580
	N	31	35	28	36	36	34	33

Electrical Equipment Truck %	Pearson Corr.	-.199	-.388*	-.195	-.373*	.071	-.282	-.134
	Sig. (2-tailed)	.284	.021	.319	.025	.680	.106	.456
	N	31	35	28	36	36	34	33
Paper and Pulp Products Truck %	Pearson Corr.	.588**	.309	.629**	.158	.520**	.273	-.018
	Sig. (2-tailed)	.000	.071	.000	.358	.001	.118	.921
	N	31	35	28	36	36	34	33
Total Tons	Pearson Corr.	.107	-.195	-.032	-.523**	.228	-.429*	.441*
	Sig. (2-tailed)	.566	.262	.870	.001	.181	.011	.010
	N	31	35	28	36	36	34	33

Table A6. Pearson Correlation Coefficients for Predictor Variables (1 of 2)

Site	Road Class	Road Class Code	Region	Reg. Code	Funct. Class *Based on TMG	Funct. Class Code	AADTT Value	Class 5%	Class 9%	Food Products (20) Truck %	Fabricated Metal Products (34) Truck %
1459	US	2	Superior	1	2	1	357.9	40.88	24.9	2.13	0.97
1529	US	2	Superior	1	2	1	294.7	41.5	28.1	1.2	0.69
2029	US	2	Superior	1			201.3	8.64	58.27		
2209	M	3	Superior	1			88.4	20.02	47.96		
2229	US	2	Superior	1	2	1	436.4	27.52	45.19	1.75	1.12
4049	I	1	North	2	1	1	522.9	27.98	34.19	2.07	1.5
4129	US	2	North	2	5	1	386.3	45.66	27.28	0.53	0.84
4149	I	1	North	2	1	1	669.2	41.62	29.62	2.2	2.08
4229	US	2	Bay	3	2	1	150.5	32.69	28.9	0.12	2.13
4249	US	2	Bay	3	2	1	325.7	45.07	21.05	0.66	0.87
5019	US	2	University	4	12	2	832.8	23.6	49.27	0.95	0.5
5059	I	1	Grand	5	11	2	1425.1	21.36	52.41	4.54	5.59
5249	US	2	Grand	5	5	1	1221.6	35.36	43.74	2.6	1.93
5289	US	2	Grand	5	12	2	974.6	34.8	33.09	1.67	0.57
5299	I	1	Grand	5	1	1	2188.1	16.39	54.46	6.6	5.33
6019	M	3	Bay	3	2	1	111.5	67.09	10.22	1.1	0
6129	I	1	Bay	3	1	1	1547.9	20.23	50.52	2.47	1.68
6309	M	3	Bay	3	6	1	122.9	48.25	17.25	0.38	0.02
6369	I	1	Metro	6	1	1	1695	17.2	64	4.23	5.7
6429	I	1	Bay	3	1	1	846.4	30.61	35.14	1.31	1.22
6469	I	1	Metro	6	11	2	1451.6	15.81	54.81	3.29	7.81
6479	US	2	Bay	3	5	1	899	24.23	36.8	2.24	1.3

7029	I	1	University	4	1	1	3569.2	10.93	71.43	10.77	5.93
7069	M	3	Southwest	7			431.3	6.26	71.23		
7109	US	2	Southwest	7	2	1	976.1	43.69	37.28	4.17	4.81
7159	I	1	Southwest	7	1	1	5435.4	13.75	73.13	9.47	4.89
7269	I	1	Southwest	7	1	1	3100.6	9.14	80.54	3.2	3.82
7329	US	2	Southwest	7			236.7	26.53	45.37		
8029	US	2	University	4	5	1	809.2	26.66	41.45	1.3	0.44
8049	I	1	University	4	1	1	1809	17.23	59.86	6.16	5.12
8129	US	2	University	4	2	1	412.1	27.49	43.92	5.77	7.47
8209	I	1	Metro	6	11	2	2802.1	22.57	40.9	4.95	2.18
8219	I	1	University	4	11	2	1894.6	19.34	55.62	6.33	5.52
8229	US	2	University	4	12	2	1881.4	23.46	50.08	4.15	2.12
8440	US	2	Metro	6	14	2	277.1	70.23	12.67	7.15	4.11
8729	US	2	University	4	5	1	3171	12.53	66.74	6.97	6.5
8829	I	1	Metro	6	11	2	2235.9	17.14	59	13.1	7.26
9189	I	1	Metro	6	11	2	2780.7	11.75	61.24	6.34	4.26
9209	I	1	Metro	6	11	2	3106	23.51	46.79	6.98	4.64
9759	M	3	Grand	5	14	2	321.2	47.7	26.74	4.29	2.12
9799	I	1	Metro	6			3049.8	5.97	70.58		

Table A6. Predictor Variable Values for all Sites (2 of 2)

Site	Trans Equip. (37) Truck %	Logs, Lumber and Wood Prod. (24) Truck %	Mach. (35) Truck %	Rubber and Plastics (30) Truck %	Paper and Pulp Prod. (26) Truck %	Furn. and Fixtures (25) Truck %	Misc. Manuf. Prod. (39) Truck %	Printed Matter (27) Truck %	Elect. Equip. (36) Truck %	Total Tons
1459	1.43	12.83	1.69	0.29	13.56	1.52	0.15	0.26	0.7	3146990
1529	1.03	7.89	1.1	0.22	12.69	0.93	0.11	0.17	0.54	3158069
2029										
2209										
2229	1.77	17.33	1.79	0.3	12.52	0.87	0.21	0.2	0.53	6307396
4049	5.66	16.72	0.68	0.45	7.78	1.26	0.07	0.22	0.41	13597092
4129	3.02	11.22	0.15	0.21	1.41	0.17	0.02	0.09	0.14	2894113
4149	5.2	12.28	0.46	0.43	8.08	1.35	0.09	0.31	0.39	9347661
4229	2.42	8.8	0.08	0.14	4.21	0.01	0.02	0.05	0.03	974087
4249	0.99	5.6	0.04	0.21	0.03	0.01	0.02	0.02	0.03	1949968
5019	2.29	7.59	0.2	0.58	1.33	0.53	0.02	0.14	0.36	4138620
5059	3.15	5.3	1.17	3.6	2.39	0.99	0.11	0.15	1.76	8721490
5249	2.4	15.88	0.67	1.39	1.67	0.45	0.04	0.11	0.58	9088585
5289	0.52	3.4	0.33	0.03	0.75	0.02	0.05	0.05	0.08	7456050
5299	5.27	2.92	2.19	2.13	1.96	1.83	0.09	0.65	0.8	18190390
6019	0.03	0.93	0	0.03	0.01	0	0	0	0	82501
6129	3.08	6.2	0.22	0.67	2.99	0.57	0.08	0.22	0.38	23171358
6309	0	0.25	0.01	0.08	0.01	0	0.01	0.01	0.03	150056
6369	14.24	3.95	2.98	1.87	4.78	1.81	0.39	0.33	0.71	13865399

6429	2.79	7.48	0.24	0.25	4.02	0.68	0.05	0.16	0.21	15384190
6469	15.88	2.53	1.65	2.2	0.9	0.9	0.61	0.54	2.27	8513307
6479	1.75	4.08	0.04	1.21	0.82	0.22	0.09	0.18	0.41	6216048
7029	9.99	2.8	4.02	4.66	3.08	1.43	1.43	0.77	3.51	56205672
7069										
7109	5.64	4.03	0.77	2.03	1.69	0.78	0.28	0.19	0.73	9705593
7159	8.42	2.67	3.49	4.07	2.65	1.2	1.26	0.64	2.74	68281346
7269	2.13	1.3	1.08	2	1.03	0.34	0.13	0.29	2.54	16366546
7329										
8029	0.37	3.6	0.05	0.92	0.96	0.07	0	0.35	0.14	2049416
8049	2.48	2.64	1.56	2.1	1.67	1.38	0.07	0.74	0.95	15409242
8129	2.01	3.37	1.23	3.67	1.5	0.77	0.33	0.88	4.32	3619224
8209	1.33	4.9	1.06	1.53	1.26	0.72	0.02	0.74	0.55	16018865
8219	2.69	2.61	1.6	1.98	1.7	1.41	0.06	0.75	0.96	15147592
8229	2.58	7.34	0.36	1.13	2.38	0.46	0.05	0.43	0.54	11413115
8440	2.95	1.88	1.43	1.88	1.24	0.03	0.27	0.6	1.86	343602
8729	3.54	2.2	2.16	2.08	3.02	1.48	0.23	0.77	1.42	22374002
8829	3.6	4.18	4.03	3.68	2.22	1.84	1.02	1.52	2.63	26902544
9189	2.4	0.94	2.91	1.44	1.4	0.61	0.32	0.28	1.58	11259455
9209	1.1	4.56	1.95	2.33	1.51	0.99	0.2	1.15	1.5	21160283
9759	2.2	1.98	0.68	2.1	1.02	1.01	0.04	0.25	0.23	9314743

Appendix B

Analyses Results

Table B1. Difference in AADTT between OWPM and Continuous Data

Site	AADTT (OWPM)	AADTT (Full)	Difference	Percentage Difference
1459	356.3	357.9	1.6	0.45
1529	271.4	294.7	23.3	7.91
2209*	84.3	88.4	4.1	4.64
2229	433.1	436.4	3.3	0.76
4049	504.6	522.9	18.3	3.50
4129	362	386.3	24.3	6.29
4149	595.1	669.2	74.1	11.07
4229	148.1	150.5	2.4	1.59
4249	318	325.7	7.7	2.36
5019	814.4	832.8	18.4	2.21
5059	1385.7	1425.1	39.4	2.76
5249	1205	1221.6	16.6	1.36
5289	946.5	974.6	28.1	2.88
5299	2075.4	2188.1	112.7	5.15
6019*	102.8	111.5	8.7	7.80
6129	1469.4	1547.9	78.5	5.07
6309	119.7	122.9	3.2	2.60
6369	1707.6	1695	-12.6	-0.74
6429	821.2	846.4	25.2	2.98
6479	869.1	899	29.9	3.33
7029	3534.9	3569.2	34.3	0.96
7109	890	976.1	86.1	8.82
7159	5331.9	5435.4	103.5	1.90
7269	3035.4	3100.6	65.2	2.10
8029	784.2	809.2	25	3.09
8049	1744.7	1809	64.3	3.55
8129	387.6	412.1	24.5	5.95
8209	2742	2802.1	60.1	2.14
8219	1830.3	1894.6	64.3	3.39
8229	1850	1881.4	31.4	1.67
8440	274.7	277.1	2.4	0.87
8729	3052.9	3171	118.1	3.72
8829	2185.2	2235.9	50.7	2.27
9189	2705.2	2780.7	75.5	2.72
9209	2992.2	3106	113.8	3.66
9759	317.2	321.2	4	1.25
9799*	3024.8	3049.8	25	0.82

*Indicates data was not used in the statistical analyses

Table B2. Difference in TTC between OWPM and Continuous Data

Site	VC Category	TTC (OWPM)	TTC (Full)	Difference
1459	VC 11-13	13.61	13.55	-0.06
1529	VC 11-13	11.27	10.76	-0.52
2209*	VC 11-13	30.60	29.98	-0.63
2229	VC 11-13	9.44	9.40	-0.05
4049	VC 11-13	15.18	14.90	-0.28
4129	VC 11-13	8.15	8.10	-0.05
4149	VC 11-13	9.91	9.07	-0.84
4229	VC 11-13	13.50	13.36	-0.15
4249	VC 11-13	12.20	11.97	-0.23
5019	VC 11-13	7.96	7.94	-0.02
5059	VC 11-13	5.46	5.53	0.07
5249	VC 11-13	7.16	7.26	0.10
5289	VC 11-13	5.08	5.36	0.27
5299	VC 11-13	10.04	13.19	3.15
6019*	VC 11-13	75.10	76.05	0.96
6129	VC 11-13	11.92	12.03	0.11
6309	VC 11-13	7.02	7.65	0.63
6369	VC 11-13	5.58	5.53	-0.05
6429	VC 11-13	10.17	9.81	-0.36
6479	VC 11-13	13.02	13.14	0.11
7029	VC 11-13	5.15	5.15	0.00
7109	VC 11-13	4.49	4.34	-0.15
7159	VC 11-13	4.31	4.35	0.05
7269	VC 11-13	3.15	3.14	-0.01
8029	VC 11-13	6.89	7.06	0.17
8049	VC 11-13	6.02	6.04	0.02
8129	VC 11-13	10.60	10.60	0.00
8209	VC 11-13	16.22	15.32	-0.90
8219	VC 11-13	5.89	5.92	0.03
8229	VC 11-13	8.19	8.44	0.25
8440	VC 11-13	0.87	0.87	-0.01
8729	VC 11-13	9.13	8.93	-0.19
8829	VC 11-13	7.91	8.10	0.20
9189	VC 11-13	8.75	8.99	0.24
9209	VC 11-13	4.29	4.27	-0.02
9759	VC 11-13	1.86	2.21	0.35
9799*	VC 11-13	12.95	12.90	-0.05
1459	VC 4-7	51.08	51.47	0.39
1529	VC 4-7	49.96	52.09	2.12
2209*	VC 4-7	58.48	59.16	0.68
2229	VC 4-7	34.38	33.66	-0.72

Site	VC Category	TTC (OWPM)	TTC (Full)	Difference
4049	VC 4-7	34.56	34.94	0.38
4129	VC 4-7	51.93	52.11	0.18
4149	VC 4-7	40.95	46.00	5.04
4229	VC 4-7	44.63	43.79	-0.84
4249	VC 4-7	52.80	53.05	0.26
5019	VC 4-7	28.93	29.29	0.36
5059	VC 4-7	32.89	32.81	-0.08
5249	VC 4-7	41.22	40.88	-0.34
5289	VC 4-7	45.20	45.32	0.12
5299	VC 4-7	22.11	21.34	-0.76
6019*	VC 4-7	20.23	19.19	-1.04
6129	VC 4-7	26.01	26.25	0.24
6309	VC 4-7	62.16	61.35	-0.80
6369	VC 4-7	22.08	20.50	-1.58
6429	VC 4-7	35.67	36.80	1.14
6479	VC 4-7	34.01	34.32	0.30
7029	VC 4-7	16.51	16.37	-0.14
7109	VC 4-7	46.82	50.22	3.40
7159	VC 4-7	17.73	17.28	-0.45
7269	VC 4-7	12.26	12.18	-0.07
8029	VC 4-7	32.56	33.07	0.51
8049	VC 4-7	22.34	22.50	0.17
8129	VC 4-7	33.95	35.02	1.06
8209	VC 4-7	28.70	29.04	0.34
8219	VC 4-7	24.51	25.19	0.68
8229	VC 4-7	32.04	31.63	-0.41
8440	VC 4-7	80.41	80.19	-0.23
8729	VC 4-7	16.77	16.88	0.11
8829	VC 4-7	23.10	22.78	-0.31
9189	VC 4-7	19.05	18.93	-0.12
9209	VC 4-7	35.11	35.51	0.39
9759	VC 4-7	63.75	63.73	-0.02
9799*	VC 4-7	80.71	80.72	0.01
1459	VC 8-10	35.31	34.98	-0.33
1529	VC 8-10	38.76	37.16	-1.61
2209*	VC 8-10	10.91	10.86	-0.05
2229	VC 8-10	56.18	56.94	0.77
4049	VC 8-10	50.26	50.16	-0.10
4129	VC 8-10	39.92	39.79	-0.13
4149	VC 8-10	49.13	44.93	-4.20
4229	VC 8-10	41.86	42.86	0.99
4249	VC 8-10	35.00	34.97	-0.03
5019	VC 8-10	63.11	62.78	-0.34

Site	VC Category	TTC (OWPM)	TTC (Full)	Difference
5059	VC 8-10	61.65	61.66	0.01
5249	VC 8-10	51.62	51.86	0.24
5289	VC 8-10	49.72	49.32	-0.40
5299	VC 8-10	67.86	65.47	-2.39
6019*	VC 8-10	4.67	4.75	0.08
6129	VC 8-10	62.07	61.72	-0.35
6309	VC 8-10	30.83	31.00	0.17
6369	VC 8-10	72.34	73.97	1.64
6429	VC 8-10	54.16	53.39	-0.77
6479	VC 8-10	52.96	52.55	-0.42
7029	VC 8-10	78.35	78.48	0.14
7109	VC 8-10	48.69	45.44	-3.25
7159	VC 8-10	77.96	78.36	0.40
7269	VC 8-10	84.59	84.68	0.09
8029	VC 8-10	60.56	59.87	-0.68
8049	VC 8-10	71.64	71.45	-0.19
8129	VC 8-10	55.44	54.38	-1.06
8209	VC 8-10	55.08	55.64	0.56
8219	VC 8-10	69.60	68.89	-0.71
8229	VC 8-10	59.77	59.93	0.17
8440	VC 8-10	18.71	18.95	0.23
8729	VC 8-10	74.11	74.18	0.08
8829	VC 8-10	69.00	69.11	0.12
9189	VC 8-10	72.20	72.08	-0.12
9209	VC 8-10	60.60	60.22	-0.38
9759	VC 8-10	34.39	34.06	-0.33
9799*	VC 8-10	6.33	6.38	0.05

*Indicates data was not used in the statistical analyses

Table B3. Difference in MDF between OWPM and Continuous Data

Site	VC 4-7 MDF Difference	VC 8-10 MDF Difference	VC 11-13 MDF Difference
1459	0.0697	0.0682	0.1134
1529	0.1341	0.0623	0.1104
2209*	0.1009	0.0797	0.1231
2229	0.0805	0.0651	0.1007
4049	0.1385	0.0602	0.0885
4129	0.1330	0.0820	0.1236
4149	0.4164	0.0699	0.1053
4229	0.1481	0.0874	0.0806
4249	0.0694	0.0673	0.1271
5019	0.0614	0.0482	0.1575
5059	0.0664	0.0693	0.0886
5249	0.1335	0.0557	0.2269
5289	0.0792	0.0637	0.1646
5299	0.0835	0.0719	0.2256
6019*	0.1088	0.1253	0.2078
6129	0.0587	0.0617	0.1043
6309	0.0986	0.1150	0.2860
6369	0.0832	0.0810	0.0844
6429	0.0877	0.0868	0.1224
6479	0.2177	0.0677	0.1424
7029	0.0915	0.0673	0.0903
7109	0.2239	0.0749	0.1101
7159	0.2586	0.0832	0.0998
7269	0.0651	0.0682	0.0820
8029	0.0856	0.0737	0.1322
8049	0.1053	0.1284	0.1549
8129	0.1254	0.1184	0.2056
8209	0.0882	0.0704	0.1415
8219	0.0830	0.0892	0.1247
8229	0.1304	0.0749	0.1008
8440	0.0788	0.0843	0.7386
8729	0.0566	0.0734	0.1047
8829	0.2180	0.0743	0.1209
9189	0.1310	0.0708	0.3796
9209	0.0798	0.0940	0.1519
9759	0.0841	0.0776	0.1090
9799*	0.0833	0.0903	0.1267

*Indicates data was not used in the statistical analyses

Table B4. Difference in HDF between OWPM and Continuous Data

Site	HDF Difference
1459	0.0831
1529	0.1190
2209*	0.1091
2229	0.0600
4049	0.0797
4129	0.0671
4149	0.1513
4229	0.0877
4249	0.0472
5019	0.0622
5059	0.0289
5249	0.0548
5289	0.0365
5299	0.0594
6019*	0.1543
6129	0.2012
6309	0.1051
6369	0.0639
6429	0.1429
6479	0.0391
7029	0.0232
7109	0.1127
7159	0.0259
7269	0.0232
8029	0.0376
8049	0.0415
8129	0.0562
8209	0.1318
8219	0.0554
8229	0.0396
8440	0.0776
8729	0.0337
8829	0.0321
9189	0.0257
9209	0.0263
9759	0.0813
9799*	0.0478

*Indicates data was not used in the statistical analyses

Table B5. Difference in AGPV between OWPM and Continuous Data

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
1459	4	1.36	0.64	0.00	0.00	1.37	0.63	0.00	0.00	0.01	-0.01	0.00	0.00
1529	4	1.29	0.71	0.00	0.00	1.28	0.72	0.00	0.00	-0.01	0.01	0.00	0.00
2229	4	1.52	0.48	0.00	0.00	1.48	0.52	0.00	0.00	-0.04	0.04	0.00	0.00
4049	4	1.27	0.73	0.00	0.00	1.28	0.72	0.00	0.00	0.01	-0.01	0.00	0.00
4129	4	1.49	0.51	0.00	0.00	1.49	0.51	0.00	0.00	0.00	0.00	0.00	0.00
4149	4	1.31	0.69	0.00	0.00	1.33	0.67	0.00	0.00	0.02	-0.02	0.00	0.00
4229	4	1.60	0.40	0.00	0.00	1.62	0.38	0.00	0.00	0.02	-0.02	0.00	0.00
4249	4	1.60	0.40	0.00	0.00	1.62	0.38	0.00	0.00	0.02	-0.02	0.00	0.00
5019	4	1.54	0.46	0.00	0.00	1.55	0.45	0.00	0.00	0.01	-0.01	0.00	0.00
5059	4	1.65	0.35	0.00	0.00	1.64	0.36	0.00	0.00	-0.01	0.01	0.00	0.00
5249	4	1.68	0.32	0.00	0.00	1.72	0.32	0.00	0.00	0.04	0.00	0.00	0.00
5289	4	1.72	0.28	0.00	0.00	1.67	0.33	0.00	0.00	-0.05	0.05	0.00	0.00
5299	4	1.75	0.25	0.00	0.00	1.74	0.26	0.00	0.00	-0.01	0.01	0.00	0.00
6129	4	1.67	0.33	0.00	0.00	1.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00
6309	4	1.49	0.51	0.00	0.00	1.41	0.59	0.00	0.00	-0.08	0.08	0.00	0.00
6369	4	1.68	0.32	0.00	0.00	1.68	0.32	0.00	0.00	0.00	0.00	0.00	0.00
6429	4	1.39	0.61	0.00	0.00	1.41	0.59	0.00	0.00	0.02	-0.02	0.00	0.00
6469*	4	1.77	0.23	0.00	0.00	1.76	0.24	0.00	0.00	-0.01	0.01	0.00	0.00
6479	4	1.62	0.38	0.00	0.00	1.60	0.40	0.00	0.00	-0.02	0.02	0.00	0.00
7029	4	1.76	0.24	0.00	0.00	1.76	0.24	0.00	0.00	0.00	0.00	0.00	0.00
7109	4	1.65	0.35	0.00	0.00	1.65	0.35	0.00	0.00	0.00	0.00	0.00	0.00
7159	4	1.70	0.30	0.00	0.00	1.71	0.29	0.00	0.00	0.01	-0.01	0.00	0.00
7269	4	1.77	0.23	0.00	0.00	1.76	0.24	0.00	0.00	-0.01	0.01	0.00	0.00
8029	4	1.38	0.62	0.00	0.00	1.39	0.61	0.00	0.00	0.01	-0.01	0.00	0.00
8049	4	1.63	0.37	0.00	0.00	1.66	0.34	0.00	0.00	0.03	-0.03	0.00	0.00
8129	4	1.80	0.20	0.00	0.00	1.79	0.21	0.00	0.00	-0.01	0.01	0.00	0.00
8209	4	1.83	0.17	0.00	0.00	1.83	0.17	0.00	0.00	0.00	0.00	0.00	0.00
8219	4	1.79	0.21	0.00	0.00	1.79	0.21	0.00	0.00	0.00	0.00	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
8229	4	1.79	0.21	0.00	0.00	1.79	0.21	0.00	0.00	0.00	0.00	0.00	0.00
8440	4	1.78	0.23	0.00	0.00	1.78	0.23	0.00	0.00	0.00	0.00	0.00	0.00
8729	4	1.74	0.26	0.00	0.00	1.72	0.28	0.00	0.00	-0.02	0.02	0.00	0.00
8829	4	1.81	0.19	0.00	0.00	1.81	0.19	0.00	0.00	0.00	0.00	0.00	0.00
9189	4	1.87	0.13	0.00	0.00	1.87	0.13	0.00	0.00	0.00	0.00	0.00	0.00
9209	4	1.88	0.12	0.00	0.00	1.88	0.12	0.00	0.00	0.00	0.00	0.00	0.00
9759	4	1.80	0.20	0.00	0.00	1.80	0.20	0.00	0.00	0.00	0.00	0.00	0.00
1459	5	2.00	0.05	0.00	0.00	2.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
1529	5	2.00	0.03	0.00	0.00	2.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
2229	5	2.00	0.07	0.00	0.00	2.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
4049	5	2.01	0.08	0.00	0.00	2.01	0.09	0.00	0.00	0.00	0.01	0.00	0.00
4129	5	2.00	0.09	0.00	0.00	2.00	0.10	0.00	0.00	0.00	0.01	0.00	0.00
4149	5	2.01	0.05	0.00	0.00	2.01	0.06	0.00	0.00	0.00	0.01	0.00	0.00
4229	5	2.00	0.03	0.00	0.00	2.00	0.02	0.00	0.00	0.00	-0.01	0.00	0.00
4249	5	2.00	0.08	0.00	0.00	2.01	0.09	0.00	0.00	0.01	0.01	0.00	0.00
5019	5	2.01	0.11	0.00	0.00	2.01	0.11	0.00	0.00	0.00	0.00	0.00	0.00
5059	5	2.00	0.03	0.00	0.00	2.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
5249	5	2.00	0.01	0.00	0.00	2.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
5289	5	2.00	0.04	0.00	0.00	2.00	0.05	0.00	0.00	0.00	0.01	0.00	0.00
5299	5	2.00	0.06	0.00	0.00	2.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
6129	5	2.00	0.07	0.00	0.00	2.00	0.08	0.00	0.00	0.00	0.01	0.00	0.00
6309	5	2.00	0.02	0.00	0.00	2.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
6369	5	2.01	0.05	0.00	0.00	2.01	0.06	0.00	0.00	0.00	0.01	0.00	0.00
6429	5	2.00	0.12	0.00	0.00	2.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
6469*	5	2.00	0.03	0.00	0.00	2.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
6479	5	2.00	0.03	0.00	0.00	2.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
7029	5	2.01	0.05	0.00	0.00	2.01	0.06	0.00	0.00	0.00	0.01	0.00	0.00
7109	5	2.00	0.02	0.00	0.00	2.00	0.01	0.00	0.00	0.00	-0.01	0.00	0.00
7159	5	2.00	0.04	0.00	0.00	2.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
7269	5	2.00	0.09	0.00	0.00	2.01	0.09	0.00	0.00	0.01	0.00	0.00	0.00
8029	5	2.00	0.05	0.00	0.00	2.00	0.04	0.00	0.00	0.00	-0.01	0.00	0.00
8049	5	2.00	0.03	0.00	0.00	2.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
8129	5	2.00	0.04	0.00	0.00	2.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
8209	5	2.00	0.02	0.00	0.00	2.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
8219	5	2.00	0.04	0.00	0.00	2.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
8229	5	2.00	0.02	0.00	0.00	2.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
8440	5	2.00	0.01	0.00	0.00	2.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
8729	5	2.01	0.06	0.00	0.00	2.00	0.06	0.00	0.00	-0.01	0.00	0.00	0.00
8829	5	2.00	0.01	0.00	0.00	2.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
9189	5	2.00	0.03	0.00	0.00	2.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
9209	5	2.00	0.02	0.00	0.00	2.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
9759	5	2.00	0.04	0.00	0.00	2.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1459	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
1529	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2229	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4049	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4129	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4149	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4229	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4249	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
5019	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
5059	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
5249	6	1.01	1.00	0.00	0.00	1.02	1.00	0.00	0.00	0.01	0.00	0.00	0.00
5289	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
5299	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6129	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6309	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6369	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
6429	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6469*	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6479	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7029	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7109	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7159	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7269	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8029	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8049	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8129	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8209	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8219	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8229	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8440	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8729	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8829	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9189	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9209	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9759	6	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
1459	7	1.02	0.02	0.43	0.55	1.02	0.02	0.51	0.47	0.00	0.00	0.08	-0.08
1529	7	1.01	0.01	0.34	0.66	1.01	0.01	0.36	0.63	0.00	0.00	0.02	-0.03
2229	7	1.01	0.01	0.39	0.60	1.01	0.02	0.38	0.61	0.00	0.01	-0.01	0.01
4049	7	1.04	0.04	0.66	0.30	1.03	0.03	0.57	0.39	-0.01	-0.01	-0.09	0.09
4129	7	1.16	0.16	0.75	0.09	1.15	0.15	0.78	0.07	-0.01	-0.01	0.03	-0.02
4149	7	1.06	0.06	0.77	0.17	1.05	0.05	0.76	0.19	-0.01	-0.01	-0.01	0.02
4229	7	1.04	0.04	0.41	0.55	1.03	0.03	0.42	0.56	-0.01	-0.01	0.01	0.01
4249	7	1.01	0.01	0.59	0.40	1.02	0.02	0.55	0.43	0.01	0.01	-0.04	0.03
5019	7	1.13	0.13	0.47	0.40	1.11	0.11	0.46	0.43	-0.02	-0.02	-0.01	0.03
5059	7	1.01	0.01	0.63	0.36	1.01	0.01	0.58	0.40	0.00	0.00	-0.05	0.04

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
5249	7	1.24	0.10	0.57	0.32	1.25	0.12	0.55	0.32	0.01	0.02	-0.02	0.00
5289	7	1.00	0.00	0.63	0.37	1.01	0.01	0.63	0.36	0.01	0.01	0.00	-0.01
5299	7	1.12	0.12	0.68	0.20	1.10	0.09	0.68	0.22	-0.02	-0.03	0.00	0.02
6129	7	1.10	0.10	0.55	0.35	1.08	0.08	0.61	0.31	-0.02	-0.02	0.06	-0.04
6309	7	1.01	0.01	0.52	0.47	1.01	0.01	0.53	0.46	0.00	0.00	0.01	-0.01
6369	7	1.07	0.07	0.57	0.36	1.06	0.06	0.63	0.31	-0.01	-0.01	0.06	-0.05
6429	7	1.12	0.12	0.69	0.20	1.09	0.09	0.70	0.20	-0.03	-0.03	0.01	0.00
6469*	7	1.05	0.05	0.56	0.39	1.05	0.05	0.64	0.31	0.00	0.00	0.08	-0.08
6479	7	1.02	0.02	0.62	0.36	1.02	0.02	0.62	0.36	0.00	0.00	0.00	0.00
7029	7	1.23	0.23	0.63	0.14	1.22	0.22	0.63	0.15	-0.01	-0.01	0.00	0.01
7109	7	1.08	0.08	0.70	0.22	1.09	0.09	0.65	0.26	0.01	0.01	-0.05	0.04
7159	7	1.04	0.04	0.47	0.49	1.03	0.03	0.45	0.52	-0.01	-0.01	-0.02	0.03
7269	7	1.05	0.05	0.72	0.23	1.07	0.07	0.63	0.31	0.02	0.02	-0.09	0.08
8029	7	1.05	0.05	0.67	0.28	1.03	0.03	0.67	0.30	-0.02	-0.02	0.00	0.02
8049	7	1.07	0.07	0.65	0.28	1.08	0.08	0.59	0.33	0.01	0.01	-0.06	0.05
8129	7	1.05	0.05	0.54	0.42	1.02	0.02	0.50	0.48	-0.03	-0.03	-0.04	0.06
8209	7	1.04	0.04	0.58	0.38	1.05	0.05	0.58	0.37	0.01	0.01	0.00	-0.01
8219	7	1.07	0.07	0.56	0.37	1.07	0.07	0.55	0.38	0.00	0.00	-0.01	0.01
8229	7	1.05	0.05	0.73	0.22	1.05	0.05	0.72	0.23	0.00	0.00	-0.01	0.01
8440	7	1.15	0.15	0.58	0.27	1.13	0.13	0.58	0.30	-0.02	-0.03	0.00	0.03
8729	7	1.04	0.04	0.69	0.27	1.04	0.04	0.69	0.27	0.00	0.00	0.00	0.00
8829	7	1.03	0.03	0.57	0.41	1.03	0.03	0.57	0.41	0.00	0.00	0.00	0.00
9189	7	1.03	0.03	0.49	0.48	1.03	0.03	0.49	0.48	0.00	0.00	0.00	0.00
9209	7	1.03	0.03	0.69	0.28	1.02	0.02	0.71	0.27	-0.01	-0.01	0.02	-0.01
9759	7	1.02	0.02	0.45	0.53	1.02	0.02	0.39	0.59	0.00	0.00	-0.06	0.06
1459	8	2.51	0.51	0.00	0.00	2.50	0.51	0.00	0.00	-0.01	0.00	0.00	0.00
1529	8	2.54	0.48	0.00	0.00	2.55	0.48	0.00	0.00	0.01	0.00	0.00	0.00
2229	8	2.41	0.60	0.00	0.00	2.41	0.61	0.00	0.00	0.00	0.01	0.00	0.00
4049	8	2.46	0.57	0.00	0.00	2.45	0.58	0.00	0.00	-0.01	0.01	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
4129	8	2.29	0.72	0.00	0.00	2.27	0.75	0.00	0.00	-0.02	0.03	0.00	0.00
4149	8	2.30	0.73	0.00	0.00	2.29	0.73	0.00	0.00	-0.01	0.00	0.00	0.00
4229	8	2.34	0.67	0.00	0.00	2.35	0.67	0.00	0.00	0.01	0.00	0.00	0.00
4249	8	2.41	0.68	0.00	0.00	2.40	0.69	0.00	0.00	-0.01	0.01	0.00	0.00
5019	8	2.12	0.89	0.00	0.00	2.13	0.89	0.00	0.00	0.01	0.00	0.00	0.00
5059	8	2.25	0.76	0.00	0.00	2.25	0.76	0.00	0.00	0.00	0.00	0.00	0.00
5249	8	2.35	0.69	0.00	0.00	2.37	0.69	0.00	0.00	0.02	0.00	0.00	0.00
5289	8	2.32	0.69	0.00	0.00	2.32	0.69	0.00	0.00	0.00	0.00	0.00	0.00
5299	8	2.19	0.82	0.00	0.00	2.19	0.82	0.00	0.00	0.00	0.00	0.00	0.00
6129	8	2.25	0.76	0.00	0.00	2.26	0.76	0.00	0.00	0.01	0.00	0.00	0.00
6309	8	2.45	0.56	0.00	0.00	2.45	0.56	0.00	0.00	0.00	0.00	0.00	0.00
6369	8	2.41	0.67	0.00	0.00	2.41	0.67	0.00	0.00	0.00	0.00	0.00	0.00
6429	8	2.17	0.84	0.00	0.00	2.17	0.85	0.00	0.00	0.00	0.01	0.00	0.00
6469*	8	2.20	0.82	0.00	0.00	2.20	0.83	0.00	0.00	0.00	0.01	0.00	0.00
6479	8	2.29	0.72	0.00	0.00	2.27	0.74	0.00	0.00	-0.02	0.02	0.00	0.00
7029	8	2.42	0.69	0.00	0.00	2.28	0.78	0.00	0.00	-0.14	0.09	0.00	0.00
7109	8	2.25	0.78	0.00	0.00	2.25	0.78	0.00	0.00	0.00	0.00	0.00	0.00
7159	8	2.14	0.87	0.00	0.00	2.14	0.88	0.00	0.00	0.00	0.01	0.00	0.00
7269	8	2.11	0.91	0.00	0.00	2.10	0.91	0.00	0.00	-0.01	0.00	0.00	0.00
8029	8	2.20	0.81	0.00	0.00	2.21	0.80	0.00	0.00	0.01	-0.01	0.00	0.00
8049	8	2.17	0.84	0.00	0.00	2.17	0.84	0.00	0.00	0.00	0.00	0.00	0.00
8129	8	2.23	0.78	0.00	0.00	2.22	0.79	0.00	0.00	-0.01	0.01	0.00	0.00
8209	8	2.27	0.74	0.00	0.00	2.26	0.75	0.00	0.00	-0.01	0.01	0.00	0.00
8219	8	2.15	0.86	0.00	0.00	2.15	0.86	0.00	0.00	0.00	0.00	0.00	0.00
8229	8	2.20	0.82	0.00	0.00	2.19	0.83	0.00	0.00	-0.01	0.01	0.00	0.00
8440	8	2.32	0.69	0.00	0.00	2.32	0.69	0.00	0.00	0.00	0.00	0.00	0.00
8729	8	2.21	0.81	0.00	0.00	2.21	0.82	0.00	0.00	0.00	0.01	0.00	0.00
8829	8	2.22	0.79	0.00	0.00	2.22	0.79	0.00	0.00	0.00	0.00	0.00	0.00
9189	8	2.22	0.80	0.00	0.00	2.22	0.80	0.00	0.00	0.00	0.00	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
9209	8	2.24	0.78	0.00	0.00	2.23	0.78	0.00	0.00	-0.01	0.00	0.00	0.00
9759	8	2.24	0.77	0.00	0.00	2.24	0.77	0.00	0.00	0.00	0.00	0.00	0.00
1459	9	1.55	1.71	0.01	0.00	1.56	1.71	0.01	0.00	0.01	0.00	0.00	0.00
1529	9	1.55	1.71	0.01	0.00	1.55	1.71	0.01	0.00	0.00	0.00	0.00	0.00
2229	9	1.39	1.80	0.01	0.00	1.41	1.79	0.01	0.00	0.02	-0.01	0.00	0.00
4049	9	1.47	1.75	0.01	0.00	1.48	1.75	0.01	0.00	0.01	0.00	0.00	0.00
4129	9	1.44	1.76	0.01	0.00	1.44	1.76	0.01	0.00	0.00	0.00	0.00	0.00
4149	9	1.44	1.77	0.01	0.00	1.43	1.78	0.01	0.00	-0.01	0.01	0.00	0.00
4229	9	1.22	1.88	0.01	0.00	1.24	1.87	0.00	0.00	0.02	-0.01	-0.01	0.00
4249	9	1.56	1.70	0.01	0.00	1.56	1.70	0.01	0.00	0.00	0.00	0.00	0.00
5019	9	1.28	1.85	0.01	0.00	1.28	1.85	0.01	0.00	0.00	0.00	0.00	0.00
5059	9	1.25	1.87	0.00	0.00	1.25	1.87	0.00	0.00	0.00	0.00	0.00	0.00
5249	9	1.23	1.88	0.00	0.00	1.23	1.88	0.00	0.00	0.00	0.00	0.00	0.00
5289	9	1.22	1.88	0.01	0.00	1.22	1.88	0.01	0.00	0.00	0.00	0.00	0.00
5299	9	1.20	1.90	0.00	0.00	1.20	1.90	0.00	0.00	0.00	0.00	0.00	0.00
6129	9	1.28	1.85	0.00	0.00	1.29	1.85	0.00	0.00	0.01	0.00	0.00	0.00
6309	9	1.32	1.82	0.01	0.00	1.34	1.81	0.01	0.00	0.02	-0.01	0.00	0.00
6369	9	1.25	1.87	0.00	0.00	1.24	1.88	0.00	0.00	-0.01	0.01	0.00	0.00
6429	9	1.42	1.77	0.01	0.00	1.42	1.78	0.01	0.00	0.00	0.01	0.00	0.00
6469*	9	1.18	1.91	0.00	0.00	1.17	1.91	0.00	0.00	-0.01	0.00	0.00	0.00
6479	9	1.22	1.88	0.00	0.00	1.23	1.88	0.00	0.00	0.01	0.00	0.00	0.00
7029	9	1.21	1.89	0.00	0.00	1.21	1.89	0.00	0.00	0.00	0.00	0.00	0.00
7109	9	1.26	1.87	0.00	0.00	1.26	1.87	0.00	0.00	0.00	0.00	0.00	0.00
7159	9	1.18	1.91	0.00	0.00	1.18	1.91	0.00	0.00	0.00	0.00	0.00	0.00
7269	9	1.22	1.89	0.00	0.00	1.22	1.89	0.00	0.00	0.00	0.00	0.00	0.00
8029	9	1.32	1.83	0.00	0.00	1.32	1.84	0.00	0.00	0.00	0.01	0.00	0.00
8049	9	1.23	1.88	0.00	0.00	1.23	1.88	0.00	0.00	0.00	0.00	0.00	0.00
8129	9	1.30	1.84	0.00	0.00	1.30	1.84	0.01	0.00	0.00	0.00	0.01	0.00
8209	9	1.20	1.90	0.00	0.00	1.20	1.90	0.00	0.00	0.00	0.00	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
8219	9	1.20	1.90	0.00	0.00	1.20	1.90	0.00	0.00	0.00	0.00	0.00	0.00
8229	9	1.23	1.88	0.00	0.00	1.23	1.88	0.00	0.00	0.00	0.00	0.00	0.00
8440	9	1.19	1.90	0.01	0.00	1.19	1.89	0.01	0.00	0.00	-0.01	0.00	0.00
8729	9	1.28	1.86	0.00	0.00	1.28	1.86	0.00	0.00	0.00	0.00	0.00	0.00
8829	9	1.22	1.89	0.00	0.00	1.22	1.89	0.00	0.00	0.00	0.00	0.00	0.00
9189	9	1.19	1.90	0.00	0.00	1.20	1.90	0.00	0.00	0.01	0.00	0.00	0.00
9209	9	1.16	1.92	0.00	0.00	1.16	1.92	0.00	0.00	0.00	0.00	0.00	0.00
9759	9	1.15	1.92	0.00	0.00	1.15	1.92	0.00	0.00	0.00	0.00	0.00	0.00
1459	10	1.45	1.00	0.29	0.61	1.47	1.00	0.31	0.59	0.02	0.00	0.02	-0.02
1529	10	1.28	0.99	0.32	0.64	1.27	0.97	0.30	0.66	-0.01	-0.02	-0.02	0.02
2229	10	1.26	1.00	0.31	0.65	1.26	1.00	0.32	0.63	0.00	0.00	0.01	-0.02
4049	10	1.52	1.01	0.39	0.49	1.51	1.01	0.40	0.47	-0.01	0.00	0.01	-0.02
4129	10	1.64	1.02	0.28	0.58	1.64	1.01	0.28	0.58	0.00	-0.01	0.00	0.00
4149	10	1.58	1.01	0.23	0.66	1.57	1.00	0.24	0.65	-0.01	-0.01	0.01	-0.01
4229	10	1.60	1.06	0.26	0.62	1.68	1.06	0.23	0.63	0.08	0.00	-0.03	0.01
4249	10	1.53	1.02	0.34	0.55	1.53	1.03	0.34	0.55	0.00	0.01	0.00	0.00
5019	10	1.91	1.02	0.22	0.59	1.90	1.02	0.22	0.59	-0.01	0.00	0.00	0.00
5059	10	1.47	1.01	0.44	0.42	1.47	1.01	0.47	0.40	0.00	0.00	0.03	-0.02
5249	10	1.60	0.90	0.29	0.53	1.61	0.90	0.29	0.53	0.01	0.00	0.00	0.00
5289	10	1.26	1.00	0.19	0.77	1.25	1.00	0.22	0.74	-0.01	0.00	0.03	-0.03
5299	10	1.79	1.03	0.22	0.53	1.80	1.03	0.21	0.53	0.01	0.00	-0.01	0.00
6129	10	1.81	1.02	0.27	0.53	1.79	1.02	0.28	0.52	-0.02	0.00	0.01	-0.01
6309	10	1.32	0.90	0.27	0.78	1.32	0.94	0.31	0.70	0.00	0.04	0.04	-0.08
6369	10	1.40	1.01	0.63	0.27	1.41	1.00	0.61	0.28	0.01	-0.01	-0.02	0.01
6429	10	1.65	1.01	0.32	0.56	1.64	1.01	0.33	0.56	-0.01	0.00	0.01	0.00
6469*	10	1.43	1.00	0.69	0.21	1.44	1.00	0.69	0.20	0.01	0.00	0.00	-0.01
6479	10	1.28	1.00	0.28	0.66	1.28	0.99	0.28	0.67	0.00	-0.01	0.00	0.01
7029	10	1.52	1.05	0.26	0.57	1.51	1.05	0.27	0.56	-0.01	0.00	0.01	-0.01
7109	10	1.64	1.01	0.27	0.58	1.61	1.01	0.30	0.56	-0.03	0.00	0.03	-0.02

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
7159	10	1.58	1.05	0.36	0.45	1.57	1.06	0.36	0.44	-0.01	0.01	0.00	-0.01
7269	10	1.73	1.08	0.62	0.09	1.72	1.08	0.63	0.09	-0.01	0.00	0.01	0.00
8029	10	1.62	0.98	0.17	0.75	1.62	0.98	0.18	0.73	0.00	0.00	0.01	-0.02
8049	10	1.78	1.00	0.22	0.56	1.80	1.00	0.23	0.55	0.02	0.00	0.01	-0.01
8129	10	1.33	0.99	0.35	0.57	1.32	0.99	0.35	0.57	-0.01	0.00	0.00	0.00
8209	10	1.61	0.95	0.28	0.60	1.61	0.94	0.28	0.60	0.00	-0.01	0.00	0.00
8219	10	1.89	1.01	0.24	0.50	1.90	1.01	0.24	0.51	0.01	0.00	0.00	0.01
8229	10	1.51	0.99	0.32	0.60	1.52	0.99	0.32	0.60	0.01	0.00	0.00	0.00
8440	10	1.37	0.98	0.53	0.42	1.37	0.98	0.49	0.45	0.01	0.01	-0.04	0.03
8729	10	1.69	1.01	0.35	0.43	1.69	1.02	0.35	0.43	0.00	0.01	0.00	0.00
8829	10	1.39	0.93	0.25	0.73	1.37	0.94	0.25	0.72	-0.02	0.01	0.00	-0.01
9189	10	1.37	0.95	0.34	0.62	1.37	0.95	0.34	0.62	0.00	0.00	0.00	0.00
9209	10	1.51	0.97	0.33	0.61	1.52	0.97	0.34	0.60	0.01	0.00	0.01	-0.01
9759	10	1.78	1.04	0.27	0.48	1.77	1.03	0.27	0.48	-0.01	-0.01	0.00	0.00
1459	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1529	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2229	11	4.99	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
4049	11	5.00	0.00	0.00	0.00	4.99	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
4129	11	4.99	0.00	0.00	0.00	4.97	0.01	0.00	0.00	-0.02	0.01	0.00	0.00
4149	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4229	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4249	11	4.96	0.02	0.00	0.00	4.97	0.02	0.00	0.00	0.01	0.00	0.00	0.00
5019	11	5.00	0.00	0.00	0.00	4.99	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
5059	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5249	11	5.01	0.00	0.00	0.00	5.00	0.01	0.00	0.00	-0.01	0.01	0.00	0.00
5289	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5299	11	5.00	0.00	0.00	0.00	4.99	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
6129	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6309	11		0.00	0.00	0.00	5.00	0.00	0.00	0.00		0.00	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
6369	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6429	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6469*	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6479	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7029	11	4.99	0.00	0.00	0.00	4.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7109	11	4.91	0.05	0.00	0.00	4.88	0.06	0.00	0.00	-0.03	0.01	0.00	0.00
7159	11	5.00	0.00	0.00	0.00	4.99	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
7269	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8029	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8049	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8129	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8209	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8219	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8229	11	4.99	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
8440	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8729	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8829	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9189	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9209	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9759	11	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1459	12	4.00	1.00	0.00	0.00	3.86	1.07	0.00	0.00	-0.14	0.07	0.00	0.00
1529	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2229	12	2.77	1.61	0.00	0.00	2.86	1.57	0.00	0.00	0.09	-0.04	0.00	0.00
4049	12	4.00	1.00	0.00	0.00	3.92	1.04	0.00	0.00	-0.08	0.04	0.00	0.00
4129	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4149	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4229	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4249	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
5019	12	3.99	1.01	0.00	0.00	3.99	1.00	0.00	0.00	0.00	-0.01	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
5059	12	3.99	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.01	0.00	0.00	0.00
5249	12	4.20	0.96	0.00	0.02	4.36	0.89	0.00	0.05	0.16	-0.07	0.00	0.03
5289	12	4.00	1.00	0.00	0.00	3.97	1.01	0.00	0.00	-0.03	0.01	0.00	0.00
5299	12	4.00	1.00	0.00	0.00	3.99	1.00	0.00	0.00	-0.01	0.00	0.00	0.00
6129	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6309	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6369	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6429	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6469*	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6479	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7029	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7109	12	3.99	0.99	0.01	0.00	3.98	1.01	0.00	0.00	-0.01	0.02	-0.01	0.00
7159	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7269	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8029	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8049	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8129	12	4.00	1.00	0.00	0.00	3.98	1.01	0.00	0.00	-0.02	0.01	0.00	0.00
8209	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8219	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8229	12	4.00	1.00	0.00	0.00	3.99	1.00	0.00	0.00	-0.01	0.00	0.00	0.00
8440	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8729	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
8829	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9189	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9209	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9759	12	4.00	1.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
1459	13	2.34	1.29	0.49	0.54	2.35	1.29	0.48	0.53	0.01	0.00	-0.01	-0.01
1529	13	2.02	1.61	0.52	0.30	1.99	1.63	0.54	0.28	-0.03	0.02	0.02	-0.02
2229	13	2.07	1.54	0.51	0.36	2.08	1.52	0.49	0.38	0.01	-0.02	-0.02	0.02

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
4049	13	3.07	1.42	0.41	0.42	2.78	1.42	0.42	0.47	-0.29	0.00	0.01	0.05
4129	13	1.84	1.62	0.53	0.53	1.88	1.60	0.52	0.54	0.04	-0.02	-0.01	0.01
4149	13	2.08	1.44	0.40	0.62	2.09	1.42	0.38	0.64	0.01	-0.02	-0.02	0.02
4229	13	2.12	1.60	0.22	0.68	2.13	1.61	0.21	0.67	0.01	0.01	-0.01	-0.01
4249	13	1.88	1.62	0.31	0.65	1.85	1.64	0.32	0.64	-0.03	0.02	0.01	-0.01
5019	13	2.11	1.60	0.47	0.53	2.10	1.58	0.45	0.55	-0.01	-0.02	-0.02	0.02
5059	13	1.99	1.52	0.31	0.65	2.01	1.52	0.30	0.65	0.02	0.00	-0.01	0.00
5249	13	1.61	0.90	0.27	0.82	1.59	0.91	0.27	0.83	-0.02	0.01	0.00	0.01
5289	13	1.66	1.48	0.37	0.64	1.67	1.48	0.36	0.65	0.01	0.00	-0.01	0.01
5299	13	0.89	0.59	0.14	0.87	0.57	0.38	0.09	0.92	-0.32	-0.21	-0.05	0.05
6129	13	2.25	1.53	0.39	0.53	2.35	1.53	0.38	0.53	0.10	0.00	-0.01	0.00
6309	13	1.63	1.42	0.46	0.61	1.61	1.37	0.50	0.63	-0.02	-0.05	0.04	0.02
6369	13	2.55	1.38	0.53	0.43	2.52	1.38	0.55	0.43	-0.03	0.00	0.02	0.00
6429	13	1.98	1.57	0.37	0.57	1.97	1.57	0.37	0.57	-0.01	0.00	0.00	0.00
6469*	13	2.43	1.21	0.43	0.59	2.44	1.24	0.43	0.58	0.01	0.03	0.00	-0.01
6479	13	1.74	1.55	0.33	0.67	1.74	1.54	0.33	0.68	0.00	-0.01	0.00	0.01
7029	13	2.97	1.46	0.23	0.61	2.88	1.47	0.24	0.62	-0.09	0.01	0.01	0.01
7109	13	2.02	1.80	0.41	0.45	2.03	1.81	0.41	0.45	0.01	0.01	0.00	0.00
7159	13	2.92	1.53	0.30	0.56	2.90	1.53	0.29	0.57	-0.02	0.00	-0.01	0.01
7269	13	2.34	1.55	0.55	0.28	2.35	1.57	0.56	0.28	0.01	0.02	0.01	0.00
8029	13	2.07	1.35	0.30	0.71	2.10	1.38	0.28	0.70	0.03	0.03	-0.02	-0.01
8049	13	2.14	1.51	0.30	0.59	2.16	1.49	0.30	0.61	0.02	-0.02	0.00	0.02
8129	13	2.02	1.57	0.36	0.69	2.05	1.59	0.32	0.71	0.03	0.02	-0.04	0.02
8209	13	1.47	1.12	0.28	0.86	1.50	1.10	0.27	0.86	0.03	-0.02	-0.01	0.00
8219	13	1.99	1.43	0.31	0.64	2.00	1.43	0.32	0.66	0.01	0.00	0.01	0.02
8229	13	2.19	1.55	0.37	0.59	2.20	1.55	0.37	0.59	0.01	0.00	0.00	0.00
8440	13	1.55	1.31	0.27	0.72	1.41	1.02	0.27	0.86	-0.15	-0.29	-0.01	0.14
8729	13	1.98	1.19	0.26	0.68	1.97	1.24	0.26	0.67	-0.01	0.05	0.00	-0.01
8829	13	2.22	1.31	0.22	0.76	2.16	1.30	0.22	0.76	-0.06	-0.01	0.00	0.00

Site	Truck Class	OWPM				Continuous				Difference			
		Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad	Single	Tandem	Tridem	Quad
9189	13	1.71	1.25	0.31	0.79	1.71	1.24	0.31	0.79	0.00	-0.01	0.00	0.00
9209	13	1.70	1.27	0.27	0.77	1.68	1.27	0.26	0.78	-0.02	0.00	-0.01	0.01
9759	13	2.00	1.59	0.36	0.57	1.97	1.56	0.35	0.60	-0.03	-0.03	-0.01	0.03

*Indicates data was not used in the statistical analyses

Table B6. **Difference in Average Axle Load between OWPM and Continuous Data**

Site	Vehicle Class	Axle Type	OWPM Load	Continuous Load	Difference	Percent Difference
1459	5	Single	6939.64	6980.13	40.49	0.580
1529	5	Single	7682.85	7716.43	33.58	0.435
2229	5	Single	6990.02	6982.93	-7.08	-0.101
4049	5	Single	7696.80	7613.54	-83.26	-1.094
4129	5	Single	6284.20	6251.69	-32.51	-0.520
4149	5	Single	7395.43	7361.79	-33.64	-0.457
4229	5	Single	8587.01	8884.02	297.01	3.343
4249	5	Single	6578.41	6565.58	-12.83	-0.195
5019	5	Single	7229.61	7223.57	-6.04	-0.084
5059	5	Single	7945.23	7974.80	29.57	0.371
5249	5	Single	8132.68	8407.24	274.57	3.266
5289	5	Single	7222.63	7228.43	5.79	0.080
5299	5	Single	7680.70	7728.21	47.51	0.615
6129	5	Single	7898.58	7832.64	-65.94	-0.842
6309	5	Single	8478.08	8452.25	-25.82	-0.306
6369	5	Single	6700.49	6670.56	-29.93	-0.449
6429	5	Single	7251.92	7233.41	-18.51	-0.256
6469*	5	Single	7655.85	7630.93	-24.92	-0.327
6479	5	Single	8234.65	8182.53	-52.12	-0.637
7029	5	Single	7529.22	7489.05	-40.17	-0.536
7109	5	Single	7142.63	7036.93	-105.69	-1.502
7159	5	Single	8416.23	8391.68	-24.55	-0.293
7269	5	Single	8248.19	8227.67	-20.52	-0.249
8029	5	Single	7928.51	7832.84	-95.67	-1.221
8049	5	Single	9405.26	8642.41	-762.85	-8.827
8129	5	Single	7562.60	7536.66	-25.94	-0.344
8209	5	Single	8344.43	8362.03	17.60	0.210
8219	5	Single	8095.19	8119.13	23.94	0.295
8229	5	Single	8014.27	7992.92	-21.35	-0.267
8440	5	Single	7465.98	7477.83	11.85	0.158
8729	5	Single	7590.47	7633.83	43.36	0.568
8829	5	Single	8303.73	8367.05	63.33	0.757
9189	5	Single	8212.15	8223.44	11.29	0.137
9209	5	Single	8371.61	8316.27	-55.34	-0.665
9759	5	Single	7551.40	7624.53	73.13	0.959
1459	5	Tandem	8441.87	8479.85	37.98	0.448
1529	5	Tandem	7363.93	7493.52	129.58	1.729
2229	5	Tandem	8039.70	8058.67	18.97	0.235
4049	5	Tandem	8239.53	8324.15	84.62	1.017
4129	5	Tandem	8415.00	8356.80	-58.20	-0.696

Site	Vehicle Class	Axle Type	OWPM Load	Continuous Load	Difference	Percent Difference
4149	5	Tandem	7547.95	7519.32	-28.63	-0.381
4229	5	Tandem	7506.75	7653.13	146.38	1.913
4249	5	Tandem	8289.03	8435.53	146.50	1.737
5019	5	Tandem	8514.80	8456.53	-58.27	-0.689
5059	5	Tandem	8846.08	8949.62	103.53	1.157
5249	5	Tandem	9345.80	9689.57	343.77	3.548
5289	5	Tandem	8871.67	8888.63	16.97	0.191
5299	5	Tandem	8463.53	8511.55	48.02	0.564
6129	5	Tandem	8824.60	8813.90	-10.70	-0.121
6309	5	Tandem	8562.35	8241.57	-320.78	-3.892
6369	5	Tandem	6853.95	6916.10	62.15	0.899
6429	5	Tandem	8842.40	8787.13	-55.27	-0.629
6469*	5	Tandem	8443.75	8456.32	12.57	0.149
6479	5	Tandem	8010.30	7970.08	-40.22	-0.505
7029	5	Tandem	8578.63	8670.72	92.08	1.062
7109	5	Tandem	6862.25	6851.22	-11.03	-0.161
7159	5	Tandem	7349.95	7413.28	63.33	0.854
7269	5	Tandem	7775.58	7737.73	-37.85	-0.489
8029	5	Tandem	7838.63	7823.23	-15.40	-0.197
8049	5	Tandem	7816.75	7742.33	-74.42	-0.961
8129	5	Tandem	8613.83	8768.67	154.83	1.766
8209	5	Tandem	7252.50	7297.88	45.38	0.622
8219	5	Tandem	8690.72	8657.17	-33.55	-0.388
8229	5	Tandem	7732.93	7742.57	9.63	0.124
8440	5	Tandem	8076.48	7850.20	-226.28	-2.883
8729	5	Tandem	8060.58	8037.97	-22.62	-0.281
8829	5	Tandem	6916.33	6899.08	-17.25	-0.250
9189	5	Tandem	7704.32	7633.28	-71.03	-0.931
9209	5	Tandem	8299.07	8255.35	-43.72	-0.530
9759	5	Tandem	8682.63	8692.48	9.85	0.113
1459	9	Single	11861.28	11824.33	-36.94	-0.312
1529	9	Single	11528.73	11463.48	-65.26	-0.569
2229	9	Single	11543.17	11492.34	-50.83	-0.442
4049	9	Single	10858.35	10818.63	-39.72	-0.367
4129	9	Single	10752.44	10737.13	-15.32	-0.143
4149	9	Single	10337.52	10309.40	-28.12	-0.273
4229	9	Single	10481.22	10564.59	83.38	0.789
4249	9	Single	10270.69	10305.61	34.92	0.339
5019	9	Single	10790.16	10809.62	19.46	0.180
5059	9	Single	11175.69	11145.80	-29.89	-0.268
5249	9	Single	10562.96	10474.43	-88.53	-0.845
5289	9	Single	10450.68	10478.43	27.75	0.265

Site	Vehicle Class	Axle Type	OWPM Load	Continuous Load	Difference	Percent Difference
5299	9	Single	11024.68	11099.17	74.48	0.671
6129	9	Single	11044.71	11083.61	38.90	0.351
6309	9	Single	10606.37	10514.86	-91.51	-0.870
6369	9	Single	11308.25	11235.00	-73.25	-0.652
6429	9	Single	11438.84	11474.27	35.42	0.309
6469*	9	Single	11200.32	11231.28	30.96	0.276
6479	9	Single	10571.02	10656.69	85.68	0.804
7029	9	Single	11701.97	11638.58	-63.38	-0.545
7109	9	Single	10821.30	10899.72	78.42	0.719
7159	9	Single	11223.41	11204.79	-18.62	-0.166
7269	9	Single	11947.68	11942.25	-5.43	-0.045
8029	9	Single	10400.23	10396.68	-3.55	-0.034
8049	9	Single	10631.59	10586.66	-44.93	-0.424
8129	9	Single	10178.82	10165.80	-13.02	-0.128
8209	9	Single	10547.63	10545.02	-2.61	-0.025
8219	9	Single	10484.50	10468.84	-15.66	-0.150
8229	9	Single	10799.78	10792.15	-7.62	-0.071
8440	9	Single	9533.17	9511.07	-22.10	-0.232
8729	9	Single	11841.91	11821.53	-20.37	-0.172
8829	9	Single	11138.17	11145.51	7.34	0.066
9189	9	Single	11021.44	10983.89	-37.55	-0.342
9209	9	Single	11235.12	11207.57	-27.55	-0.246
9759	9	Single	10266.24	10248.88	-17.36	-0.169
1459	9	Tandem	24117.80	21892.38	-2225.42	-10.165
1529	9	Tandem	26725.90	26569.37	-156.53	-0.589
2229	9	Tandem	23960.27	23818.77	-141.50	-0.594
4049	9	Tandem	24598.37	24312.65	-285.72	-1.175
4129	9	Tandem	21848.23	21747.73	-100.50	-0.462
4149	9	Tandem	21185.73	20933.83	-251.90	-1.203
4229	9	Tandem	22628.87	22594.63	-34.23	-0.152
4249	9	Tandem	21396.92	21397.70	0.78	0.004
5019	9	Tandem	19597.97	19652.75	54.78	0.279
5059	9	Tandem	20292.13	20206.95	-85.18	-0.422
5249	9	Tandem	19861.98	19492.68	-369.30	-1.895
5289	9	Tandem	18711.42	18746.50	35.08	0.187
5299	9	Tandem	20160.80	20284.38	123.58	0.609
6129	9	Tandem	20574.20	20492.30	-81.90	-0.400
6309	9	Tandem	19048.13	19005.37	-42.77	-0.225
6369	9	Tandem	25057.73	24807.17	-250.57	-1.010
6429	9	Tandem	21190.65	21133.67	-56.98	-0.270
6469*	9	Tandem	20828.85	20866.22	37.37	0.179
6479	9	Tandem	21692.13	21854.80	162.67	0.744

Site	Vehicle Class	Axle Type	OWPM Load	Continuous Load	Difference	Percent Difference
7029	9	Tandem	24648.52	24690.73	42.22	0.171
7109	9	Tandem	21366.88	21644.93	278.05	1.285
7159	9	Tandem	26761.08	26674.28	-86.80	-0.325
7269	9	Tandem	22216.97	22189.62	-27.35	-0.123
8029	9	Tandem	20425.45	20431.15	5.70	0.028
8049	9	Tandem	22696.78	22362.83	-333.95	-1.493
8129	9	Tandem	20592.48	20642.93	50.45	0.244
8209	9	Tandem	22429.05	22384.22	-44.83	-0.200
8219	9	Tandem	18897.90	18829.08	-68.82	-0.365
8229	9	Tandem	20541.37	20595.25	53.88	0.262
8440	9	Tandem	18276.82	18276.23	-0.58	-0.003
8729	9	Tandem	22586.45	22516.75	-69.70	-0.310
8829	9	Tandem	24693.00	24651.08	-41.92	-0.170
9189	9	Tandem	24199.10	24057.53	-141.57	-0.588
9209	9	Tandem	20310.63	20254.18	-56.45	-0.279
9759	9	Tandem	18890.00	18815.72	-74.28	-0.395
1459	13	Single	14890.49	14945.86	55.37	0.370
1529	13	Single	13149.68	13074.78	-74.90	-0.573
2229	13	Single	13923.50	13926.89	3.39	0.024
4049	13	Single	11665.06	11563.93	-101.13	-0.874
4129	13	Single	13450.12	13759.88	309.76	2.251
4149	13	Single	13330.65	13389.73	59.08	0.441
4229	13	Single	10886.43	10634.53	-251.89	-2.369
4249	13	Single	11020.76	11128.42	107.66	0.967
5019	13	Single	11692.92	11656.51	-36.41	-0.312
5059	13	Single	13325.43	13405.34	79.91	0.596
5249	13	Single	13415.56	13997.29	581.73	4.156
5289	13	Single	11668.46	11714.30	45.84	0.391
5299	13	Single	11047.45	10931.17	-116.28	-1.064
6129	13	Single	12505.08	12180.53	-324.56	-2.665
6309	13	Single	12566.32	12451.86	-114.46	-0.919
6369	13	Single	13125.57	13239.49	113.92	0.860
6429	13	Single	13034.40	13116.62	82.22	0.627
6469*	13	Single	13943.32	13977.14	33.83	0.242
6479	13	Single	12955.10	13138.87	183.77	1.399
7029	13	Single	15580.97	15271.95	-309.02	-2.023
7109	13	Single	10510.43	10539.01	28.58	0.271
7159	13	Single	14935.77	14828.57	-107.20	-0.723
7269	13	Single	13153.33	13173.81	20.48	0.155
8029	13	Single	13609.48	13551.43	-58.06	-0.428
8049	13	Single	13215.76	12644.36	-571.40	-4.519
8129	13	Single	13099.91	13313.24	213.33	1.602

Site	Vehicle Class	Axle Type	OWPM Load	Continuous Load	Difference	Percent Difference
8209	13	Single	13447.46	13528.02	80.56	0.595
8219	13	Single	12462.23	12554.43	92.19	0.734
8229	13	Single	11972.70	11911.04	-61.66	-0.518
8440	13	Single	11375.64	10888.83	-486.81	-4.471
8729	13	Single	12935.14	13152.21	217.07	1.650
8829	13	Single	14746.13	14532.95	-213.17	-1.467
9189	13	Single	12863.44	12804.11	-59.33	-0.463
9209	13	Single	13033.35	13024.65	-8.70	-0.067
9759	13	Single	12339.12	12565.31	226.19	1.800
1459	13	Tandem	24187.60	24213.80	26.20	0.108
1529	13	Tandem	23157.30	22884.67	-272.63	-1.191
2229	13	Tandem	20594.22	20767.97	173.75	0.837
4049	13	Tandem	21533.53	21472.38	-61.15	-0.285
4129	13	Tandem	19720.23	20092.35	372.12	1.852
4149	13	Tandem	22127.75	22394.42	266.67	1.191
4229	13	Tandem	19434.45	19423.77	-10.68	-0.055
4249	13	Tandem	18569.18	18589.52	20.33	0.109
5019	13	Tandem	18383.82	18433.93	50.12	0.272
5059	13	Tandem	20950.25	21233.68	283.43	1.335
5249	13	Tandem	21578.33	22144.90	566.57	2.558
5289	13	Tandem	17020.37	17459.35	438.98	2.514
5299	13	Tandem	18808.22	18896.57	88.35	0.468
6129	13	Tandem	20844.92	20639.42	-205.50	-0.996
6309	13	Tandem	21815.45	21400.67	-414.78	-1.938
6369	13	Tandem	24904.32	24861.25	-43.07	-0.173
6429	13	Tandem	20596.23	20572.45	-23.78	-0.116
6469*	13	Tandem	25300.53	25108.18	-192.35	-0.766
6479	13	Tandem	21083.53	21265.57	182.03	0.856
7029	13	Tandem	27721.62	27261.03	-460.58	-1.690
7109	13	Tandem	17929.43	17970.83	41.40	0.230
7159	13	Tandem	29649.75	29584.05	-65.70	-0.222
7269	13	Tandem	19479.70	19277.43	-202.27	-1.049
8030	13	Tandem	25507.38	25460.80	-46.58	-0.183
8049	13	Tandem	21589.90	22627.05	1037.15	4.584
8129	13	Tandem	23398.82	23504.68	105.87	0.450
8209	13	Tandem	27320.37	27480.87	160.50	0.584
8219	13	Tandem	20637.30	20896.33	259.03	1.240
8229	13	Tandem	22542.30	22564.65	22.35	0.099
8440	13	Tandem	20424.25	20866.65	442.40	2.120
8729	13	Tandem	23877.98	24351.93	473.95	1.946
8829	13	Tandem	28583.42	28636.62	53.20	0.186
9189	13	Tandem	26913.80	26696.95	-216.85	-0.812

Site	Vehicle Class	Axle Type	OWPM Load	Continuous Load	Difference	Percent Difference
9209	13	Tandem	24625.32	24556.02	-69.30	-0.282
9759	13	Tandem	21004.90	21103.10	98.20	0.465

*Indicates data was not used in the statistical analyses

Table B7. Rigid Pavement Design Life Based on Percent Slabs Cracked (1 of 3)

Site No.	Cont.	OWPM	OWPM CAADTT	OWPM Cont. VC5	OWPM Cont. VC9	HDF (Average)	HDF (Cluster)	HDF (Default)	MDF (Average)	MDF (Default)	MDF (Cluster)
1459	15.83	18.33	18.00	18.17	18.42	13.75	14.50	11.00	16.00	16.83	16.00
1529	21.92	22.92	21.00	22.92	23.25	18.50	24.17	14.08	21.83	22.58	22.17
2229	22.58	23.67	23.50	23.67	23.83	21.83	19.67	16.75	21.92	22.75	21.92
4049	17.92	19.00	18.58	19.00	19.50	16.75	14.92	12.75	18.50	18.83	18.00
4129	21.67	24.67	22.92	24.75	24.75	20.58	18.67	15.92	21.83	22.75	21.83
4149	21.75	24.17	21.67	24.17	24.50	20.00	26.75	15.58	21.83	22.67	21.75
4229	18.83	18.42	18.00	17.92	18.83	16.58	19.50	13.67	18.92	19.67	18.75
4249	15.75	16.00	15.75	16.00	16.08	12.33	15.83	9.58	15.83	16.50	15.83
5019	22.92	24.83	24.25	24.75	24.83	24.92	22.67	19.17	23.42	23.92	22.92
5059	15.58	15.92	15.67	15.92	16.50	13.17	18.50	9.75	15.50	15.92	15.25
5249	17.00	19.50	18.92	18.67	19.83	18.08	17.50	15.67	16.92	17.83	16.92
5289	19.75	20.75	19.92	20.75	20.75	14.67	19.75	10.83	19.92	20.83	19.83
5299	19.67	21.92	20.83	21.92	21.75	23.83	21.50	17.83	19.50	19.92	19.33
6019	23.58	M	M	M	M	23.83	24.92	21.83	23.50	23.42	23.92
6129	16.50	18.75	17.75	18.75	18.92	18.92	16.92	14.50	15.92	16.75	16.50
6309	20.50	21.58	20.92	21.75	21.58	17.83	19.50	15.75	20.92	21.50	20.58
6369	15.42	15.83	15.92	15.83	16.75	19.83	13.67	14.75	14.75	15.25	15.00
6429	17.67	20.08	19.67	20.08	20.58	19.67	17.58	14.75	16.92	17.75	17.67
6469	21.42	M	M	M	M	19.67	26.83	14.75	20.83	21.75	20.92
6479	24.50	27.75	26.83	27.75	26.83	17.75	23.83	13.50	24.17	24.92	24.58
7029	16.75	17.92	17.83	17.92	17.67	25.67	16.92	18.75	16.50	16.92	16.67
7109	19.33	22.58	20.58	22.67	20.92	19.00	17.00	14.67	18.92	19.67	19.67
7159	23.67	25.50	24.83	25.50	25.58	30.00	24.58	26.58	22.58	23.50	23.25
7269	21.08	22.58	21.83	22.58	22.75	30.00	22.75	24.67	20.75	21.42	21.00

Site No.	Cont.	Week	Week CAADTT	Week VC5	Week VC9	HDF (Average)	HDF (Cluster)	HDF (Default)	MDF (Average)	MDF (Default)	MDF (Cluster)
8029	16.92	17.83	17.42	17.83	17.92	14.50	19.50	10.75	17.00	17.58	16.92
8049	20.50	20.58	19.67	20.75	21.67	25.67	22.83	19.33	20.58	21.42	20.83
8129	21.00	23.33	21.92	23.33	23.17	21.08	19.00	16.58	20.75	21.08	20.92
8209	19.00	19.92	19.67	19.92	19.92	20.58	18.17	14.92	19.83	20.75	18.83
8219	20.17	21.58	20.75	21.58	21.83	22.83	20.67	17.50	19.75	20.50	20.08
8229	18.75	21.50	20.92	21.50	20.67	21.00	18.83	15.75	18.75	19.67	18.58
8440	17.67	16.50	16.42	16.83	16.58	15.83	16.50	14.67	17.75	17.92	18.42
8729	19.58	20.83	19.92	20.83	21.50	29.67	20.58	21.92	18.67	19.58	19.25
8829	24.50	26.75	26.00	26.75	26.67	28.92	26.00	21.75	23.92	24.83	24.67
9189	16.92	18.00	17.75	18.00	18.58	21.67	19.00	15.75	17.17	17.92	16.83
9209	16.83	17.83	17.00	17.83	18.50	15.75	13.83	11.58	15.92	16.83	16.67
9759	24.58	24.83	24.58	24.83	24.92	17.75	21.92	14.00	24.58	25.08	24.67

*Note N/A excludes sites in clusters which have two or less members. M indicates week or continuous data was missing.

Table B7. Rigid Pavement Design Life Based on Percent Slabs Cracked (2 of 3)

Site No.	Cont.	AGPV (Average)	AGPV Cluster	AGPV (Default)	TTC Average	TTC Cluster	TTC (Comp M-E PDG Values to Clusters)	Single (Average)	Single Cluster	Single (Default)
1459	15.83	14.75	15.92	16.75	15.92	20.50	22.67	19.75	19.92	19.67
1529	21.92	22.67	21.75	23.58	17.50	24.92	28.33	21.75	21.67	21.67
2229	22.58	22.75	22.17	22.92	22.25	22.50	21.92	22.50	22.33	22.33
4049	17.92	18.83	18.50	19.50	17.67	17.75	17.50	17.75	17.75	17.83
4129	21.67	22.58	21.67	22.92	16.92	22.92	25.67	21.75	21.92	21.58
4149	21.75	22.75	21.75	22.75	18.67	24.83	27.75	21.67	21.50	21.42
4229	18.83	18.92	18.83	19.50	18.50	18.08	17.67	18.75	18.08	18.75
4249	15.75	16.33	16.42	16.92	12.50	16.75	17.92	12.58	13.67	11.75
5019	22.92	23.50	22.75	23.58	24.50	24.00	24.50	22.92	22.92	22.92
5059	15.58	15.58	15.58	15.67	16.75	16.58	15.92	15.58	15.58	15.50
5249	17.00	16.00	16.92	14.92	14.92	14.58	13.67	20.42	20.42	20.33
5289	19.75	19.83	19.83	20.00	18.67	18.50	18.00	19.75	19.67	19.42
5299	19.67	19.83	19.67	19.83	22.58	18.75	18.75	19.67	19.67	19.67
6019	23.58	23.42	23.58	22.42	17.42	19.00	19.50	21.67	24.42	17.75
6129	16.50	16.67	16.58	16.58	17.92	17.83	17.67	16.50	16.50	16.50
6309	20.50	19.75	20.50	19.33	21.42	22.42	22.75	18.42	16.67	15.75
6369	15.42	15.50	15.50	15.50	17.92	14.67	14.50	15.42	15.42	15.42
6429	17.67	18.50	17.75	18.58	18.50	17.92	18.50	17.67	17.67	17.67
6469	21.42	20.92	21.50	20.75	24.75	21.00	20.83	21.33	21.33	21.33
6479	24.50	24.58	24.58	24.75	25.58	25.58	24.92	24.08	24.00	24.00

Site No.	Cont.	AGPV (Average)	AGPV Cluster	AGPV (Default)	TTC Average	TTC Cluster	TTC (Comp M-E PDG Values to Clusters)	Single (Average)	Single Cluster	Single (Default)
7029	16.75	16.75	16.75	16.67	19.58	16.67	15.92	16.75	16.75	16.75
7109	19.33	18.75	18.75	19.42	14.58	14.58	14.00	19.58	19.58	19.50
7159	23.67	23.58	23.50	21.92	26.92	22.83	22.67	23.67	23.67	23.67
7269	21.08	21.00	21.00	21.00	26.75	21.92	21.92	21.08	21.08	21.08
8029	16.92	17.08	16.50	16.67	17.83	17.50	17.17	16.83	16.75	16.75
8049	20.50	20.50	20.50	20.25	22.67	18.92	18.92	20.50	20.50	20.50
8129	21.00	21.08	21.00	21.00	21.50	21.08	20.75	20.83	20.75	20.58
8209	19.00	18.50	18.92	16.92	22.75	22.17	21.58	19.00	19.00	19.00
8219	20.17	19.92	19.92	19.83	21.67	18.50	18.00	20.08	20.08	20.00
8229	18.75	18.58	18.50	18.08	18.92	18.75	18.58	18.75	18.75	18.75
8440	17.67	17.50	17.67	17.58	13.58	14.58	14.92	16.67	18.58	9.67
8729	19.58	19.58	19.67	19.00	22.92	19.50	19.08	19.58	19.58	19.58
8829	24.50	23.92	24.50	23.75	27.83	23.42	22.83	24.50	24.50	24.50
9189	16.92	16.83	16.92	16.67	20.92	17.75	17.58	16.92	16.92	16.92
9209	16.83	16.58	16.75	16.00	17.00	16.75	16.58	16.83	16.83	16.83
9759	24.58	24.42	24.08	24.50	17.92	22.42	24.42	21.58	20.42	16.42

*Note N/A excludes sites in clusters which have two or less members. M indicates week or continuous data was missing.

Table B7. Rigid Pavement Design Life Based on Percent Slabs Cracked (3 of 3)

Site No.	Cont.	Tandem (Clusters)	Tandem Avg	Tandem (Default)	Tridem (Clusters)	Tridem (Average)	Tridem (Default)	Quad (Cluster)	Quad (Default)	Quad Avg
1459	15.83	16.83	17.08	14.75	15.83	15.83	15.75	15.83	15.83	15.83
1529	21.92	22.92	27.92	23.00	21.92	21.92	21.83	21.92	21.92	21.92
2229	22.58	21.67	23.00	18.42	22.50	22.50	22.42	N/A	22.50	22.50
4049	17.92	17.50	17.92	14.50	17.92	17.92	17.92	17.92	17.92	17.92
4129	21.67	19.83	19.75	15.75	21.67	21.58	21.50	21.67	21.67	21.67
4149	21.75	18.75	18.67	14.75	21.75	21.75	21.75	21.75	21.75	21.75
4229	18.83	18.92	19.00	15.42	18.83	18.83	18.67	18.83	18.83	18.83
4249	15.75	12.67	11.92	9.00	N/A	15.75	15.50	15.75	15.75	15.75
5019	22.92	22.92	16.58	12.58	22.92	22.92	22.83	22.92	22.92	22.92
5059	15.58	17.67	12.08	8.83	15.58	15.58	15.58	15.58	15.58	15.58
5249	17.00	18.92	18.33	14.00	17.00	17.00	17.00	17.00	17.00	17.00
5289	19.75	19.92	14.58	11.00	19.75	19.75	19.75	N/A	19.83	19.75
5299	19.67	18.75	13.83	9.75	19.67	19.67	19.67	19.67	19.67	19.67
6019	23.58	25.50	26.42	21.42	23.67	23.75	22.50	23.58	23.50	23.58
6129	16.50	17.83	12.42	8.92	16.50	16.50	16.50	16.50	16.50	16.50
6309	20.50	18.42	19.00	14.50	20.42	20.42	20.42	20.50	20.42	20.50
6369	15.42	12.92	17.83	12.75	15.42	15.42	15.50	15.42	15.50	15.42
6429	17.67	16.92	16.83	12.92	17.67	17.67	17.67	17.67	17.67	17.67
6469	21.42	20.67	16.50	11.92	N/A	21.42	21.42	21.42	21.42	21.42
6479	24.50	23.25	22.92	17.92	24.50	24.50	24.50	24.50	24.50	24.50
7029	16.75	29.75	30.00	27.83	16.75	16.75	16.75	16.75	16.75	16.75
7109	19.33	23.83	22.92	17.67	19.33	19.33	19.25	N/A	19.33	19.33
7159	23.67	30.00	30.00	29.75	23.67	23.67	21.83	23.67	23.67	23.67
7269	21.08	16.92	19.75	12.92	21.08	21.08	21.33	21.08	21.08	21.08
8029	16.92	14.00	13.75	10.67	16.92	16.92	16.92	16.92	16.92	16.92

Site No.	Cont.	Tandem (Clusters)	Tandem Avg	Tandem (Default)	Tridem (Clusters)	Tridem (Average)	Tridem (Default)	Quad (Cluster)	Quad (Default)	Quad Avg
8049	20.50	11.92	16.83	11.83	20.50	20.50	20.50	20.50	20.50	20.50
8129	21.00	20.83	15.42	11.92	21.00	21.00	21.00	21.00	21.00	21.00
8209	19.00	14.50	18.92	13.67	19.00	19.00	19.00	19.00	19.00	19.00
8219	20.17	16.08	10.83	7.75	20.17	20.17	20.25	20.17	20.17	20.17
8229	18.75	20.17	19.58	13.83	18.75	18.75	18.75	18.75	18.75	18.75
8440	17.67	17.42	15.42	12.00	17.58	17.58	17.42	17.67	17.67	17.67
8729	19.58	17.83	19.92	13.50	19.58	19.58	19.67	19.58	19.58	19.58
8829	24.50	26.92	30.00	25.75	24.50	24.50	24.50	24.50	24.50	24.50
9189	16.92	19.42	26.50	18.17	16.92	16.92	16.92	16.92	16.92	16.92
9209	16.83	18.75	14.33	9.75	16.83	16.83	16.83	16.83	16.83	16.83
9759	24.58	21.75	16.92	12.58	24.58	24.58	24.25	24.58	24.58	24.58

*Note N/A excludes sites in clusters which have two or less members or the utilized flexible pavement design could not produce usable data for comparison. M indicates week or continuous data was missing.

Table B8. Flexible Pavement Design Life Based on Fatigue Cracking (1 of 2)

Site No.	Cont.	OWPM	OWPM CADDT	OWPM Cont. VC5	OWPM Cont. VC9	MDF Avg	MDF Cluster	HDF Cluster	HDF Avg	AGPV Avg	AGPV Cluster
1459	10.75	10.92	10.92	10.92	11.00	10.83	10.83	10.75	10.75	10.83	10.83
1529	9.83	10.42	9.67	10.42	10.58	9.83	9.92	9.83	9.83	9.67	9.83
2229	11.92	12.67	12.67	12.67	12.67	11.83	11.83	11.92	11.92	11.83	11.92
4049	13.67	14.00	13.67	14.08	13.92	13.75	13.67	13.67	13.67	13.67	13.58
4129	10.00	11.00	10.67	11.08	11.17	10.25	10.17	10.00	10.00	10.08	9.92
4149	12.67	13.58	11.83	13.58	13.58	12.58	12.58	12.67	12.67	12.92	12.83
4229	12.67	12.67	12.58	12.58	12.75	12.75	12.67	12.67	12.67	12.83	12.67
4249	12.58	10.83	10.75	10.83	10.83	10.67	10.92	12.58	12.58	12.67	12.58
5019	16.08	17.50	16.92	17.33	17.50	16.67	16.33	16.08	16.08	16.67	16.67
5059	18.83	16.75	18.75	16.75	16.92	18.75	18.67	18.83	18.83	18.67	18.67
5249	17.17	19.67	19.42	18.50	19.83	17.00	16.92	17.17	17.17	16.83	17.00
5289	11.50	11.67	11.50	11.67	11.67	11.58	11.50	11.50	11.50	11.50	11.33
5299	21.58	24.25	23.50	24.17	23.92	21.42	21.58	21.58	21.58	20.67	21.67
6019	17.58	M	M	M	M	17.67	17.75	17.58	17.58	17.67	17.50
6129	19.92	21.83	20.83	21.83	21.83	19.92	20.33	19.92	19.92	20.58	20.42
6309	9.25	9.67	9.58	9.75	9.67	9.50	9.25	9.25	9.25	9.42	9.08
6369	23.67	23.58	23.67	23.58	24.08	22.83	23.50	23.67	23.67	23.00	23.58
6429	16.50	17.58	16.83	17.50	17.58	15.83	16.58	16.50	16.50	16.58	16.50
6469	4.58	M	M	M	M	4.58	4.58	4.58	4.58	4.42	4.58
6479	16.92	19.25	18.75	19.17	18.75	17.00	17.00	16.92	16.92	16.92	17.00
7029	18.92	19.92	19.83	19.92	19.83	18.92	18.92	18.92	18.92	19.75	18.92
7109	12.83	14.75	13.67	14.83	14.00	12.75	13.00	12.83	12.83	12.83	12.75
7159	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7269	19.83	20.67	20.33	20.67	20.75	19.58	19.83	19.83	19.83	19.75	19.67
8029	14.58	14.83	14.67	14.83	14.83	14.67	14.58	14.58	14.58	14.92	14.67

Site No.	Cont.	OWPM	OWPM CADDT	OWPM Cont. VC5	OWPM Cont. VC9	MDF Avg	MDF Cluster	HDF Cluster	HDF Avg	AGPV Avg	AGPV Cluster
8049	18.25	15.75	15.00	18.83	15.83	17.92	18.17	18.25	18.25	18.50	18.42
8129	11.33	12.17	11.58	12.17	12.17	10.92	11.08	11.33	11.33	11.42	11.00
8209	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8219	18.58	19.75	19.08	19.75	19.83	17.83	18.58	18.58	18.58	18.67	18.58
8229	19.83	20.92	20.75	20.92	20.83	20.00	19.75	19.83	19.83	19.92	19.83
8440	13.50	12.75	12.67	12.83	12.83	13.42	13.58	13.50	13.50	13.50	13.42
8729	21.17	22.58	21.67	22.58	22.67	20.67	20.83	21.17	21.17	20.92	20.92
8829	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9189	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9209	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9759	8.83	9.50	9.33	9.42	9.50	8.83	8.83	8.83	8.83	8.83	8.83

*Note N/A excludes sites in clusters which have two or less members. ND indicates that the flexible pavement design used in the analysis could not produce usable distress data for comparison. M indicates week or continuous data was missing

Table B8. Flexible Pavement Design Life Based on Fatigue Cracking (2 of 2)

Site No.	Cont.	TTC Avg	TTC Cluster	SA Avg	SA Cluster	Tan Avg	Tan Cluster	Tri Avg	Tri Cluster	Quad Avg	Quad Cluster
1459	10.75	10.75	13.08	12.58	12.83	10.92	10.92	10.75	10.75	10.92	10.42
1529	9.83	8.50	10.83	10.33	10.17	10.83	9.92	9.75	9.75	10.92	10.58
2229	11.92	12.67	12.58	12.58	12.42	11.92	11.75	11.83	11.83	11.67	N/A
4049	13.67	14.67	14.58	12.67	12.67	13.67	13.67	13.58	13.67	13.17	13.50
4129	10.00	8.83	10.92	9.92	10.58	9.67	9.67	9.92	10.00	10.67	10.75
4149	12.67	12.67	14.75	11.83	11.75	11.75	11.75	12.58	12.58	13.75	12.17
4229	12.67	12.75	12.50	12.75	12.75	12.75	12.67	12.67	12.67	11.58	12.42
4249	12.58	10.92	13.75	10.67	11.00	10.58	10.75	12.08	N/A	10.58	11.67
5019	16.08	16.83	16.67	15.67	15.67	13.83	15.92	15.92	15.92	15.00	15.58
5059	18.83	17.83	17.58	19.00	19.08	17.08	19.75	18.75	18.83	18.67	19.00
5249	17.17	16.00	15.67	20.00	20.00	17.67	17.75	17.33	17.33	17.83	17.33
5289	11.50	10.75	10.67	10.58	10.42	10.25	11.75	11.42	11.42	10.58	N/A
5299	21.58	23.42	21.92	21.42	21.42	19.67	21.50	21.58	21.58	20.83	20.92
6019	17.58	11.67	13.50	17.08	17.75	18.42	18.33	17.75	17.67	18.00	18.42
6129	19.92	21.75	20.92	19.83	19.83	18.58	20.75	19.92	20.00	19.75	20.58
6309	9.25	8.83	9.92	9.42	9.25	8.67	8.67	9.17	9.25	9.33	9.50
6369	23.67	25.08	22.83	22.75	22.67	24.67	21.67	23.67	23.58	23.58	23.67
6429	16.50	17.75	17.58	17.67	17.42	16.58	16.42	16.42	16.58	16.67	16.75
6469	4.58	4.75	4.58	4.50	4.50	3.83	4.58	4.58	N/A	4.42	4.50
6479	16.92	18.67	18.17	16.75	16.67	16.75	16.75	17.00	17.00	16.50	17.58
7029	18.92	18.75	17.83	20.00	20.00	20.00	20.00	18.92	18.92	19.58	19.67
7109	12.83	10.58	10.42	13.67	13.50	14.75	14.83	12.83	12.83	12.67	N/A
7159	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7269	19.83	19.83	18.75	20.83	20.75	19.58	18.25	19.83	19.83	19.83	19.83
8029	14.58	15.17	14.67	13.75	13.67	13.50	13.50	14.58	14.58	15.50	13.83
8049	18.25	17.92	17.67	18.83	18.83	16.92	14.83	18.25	18.17	17.83	18.58

Site No.	Cont.	TTC Avg	TTC Cluster	SA Avg	SA Cluster	TanAvg	Tan Cluster	Tri Avg	Tri Cluster	Quad Avg	Quad Cluster
8129	11.33	11.33	10.92	10.67	10.58	9.67	11.17	11.33	11.33	10.58	10.92
8209	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8219	18.58	17.83	17.67	16.75	16.75	14.67	18.67	18.50	18.67	17.83	18.58
8229	19.83	19.92	19.67	20.50	19.92	20.17	20.58	19.83	19.83	20.33	20.58
8440	13.50	7.17	7.83	12.67	13.83	11.50	12.67	13.42	13.33	13.33	13.42
8729	21.17	22.67	20.92	22.67	22.67	21.58	20.75	21.17	21.08	20.83	20.92
8829	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9189	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9209	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9759	8.83	5.67	6.58	8.42	8.00	7.08	8.50	8.83	8.83	8.83	8.92

*Note N/A excludes sites in clusters which have two or less members. ND indicates that the flexible pavement design used in the analysis could not produce usable distress data for comparison. M indicates week or continuous data was missing

Table B9. Flexible Pavement Design Life Based on Rutting (1 of 2)

Site No.	Cont.	OWPM	OWPM CADDT	OWPM Cont. VC5	OWPM Cont. VC9	MDF Avg	MDF Cluster	HDF Cluster	HDF Avg	HDF Default	AGPV Avg	AGPV Cluster
1459	15.75	16.83	16.83	16.83	16.83	16.67	16.50	15.75	15.75	15.75	15.83	16.50
1529	17.67	18.67	17.67	18.67	18.67	17.58	17.67	17.67	17.67	17.67	17.00	17.67
2229	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4049	18.75	20.00	19.92	20.00	20.00	19.58	18.75	18.75	18.75	18.75	17.75	17.83
4129	17.75	19.75	18.67	19.67	19.75	17.75	17.75	17.75	17.75	17.75	17.75	17.67
4149	13.00	13.83	12.67	13.83	13.83	12.83	12.83	13.00	13.00	13.00	13.75	13.75
4229	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4249	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5019	18.83	20.00	20.00	20.00	20.00	19.67	18.92	18.83	18.83	18.83	18.83	19.67
5059	15.92	14.75	16.00	14.75	14.75	15.83	15.83	15.92	15.92	15.92	15.75	15.83
5249	11.67	13.75	13.67	13.67	13.83	11.50	11.58	11.67	11.67	11.67	11.75	11.33
5289	14.67	14.67	13.92	14.67	14.67	14.67	14.67	14.67	14.67	14.67	14.75	14.58
5299	10.58	13.83	13.67	13.83	13.83	10.67	10.58	10.58	10.58	10.58	10.83	10.67
6019	17.50	M	M	M	M	17.42	17.50	17.50	17.50	17.50	17.75	17.00
6129	13.83	14.92	14.75	14.92	15.08	13.75	13.83	13.83	13.83	13.83	13.75	13.75
6309	15.92	17.67	17.50	17.67	17.67	16.00	15.83	15.92	15.92	15.92	16.75	15.75
6369	14.75	15.75	15.75	15.75	15.83	14.67	14.75	14.75	14.75	14.75	13.67	14.83
6429	14.67	15.75	15.50	15.75	15.75	13.83	14.67	14.67	14.67	14.67	14.67	14.58
6469	9.75	M	M	M	M	9.67	9.67	9.75	9.75	9.75	8.67	10.42
6479	13.83	15.50	14.83	15.50	14.92	13.83	13.83	13.83	13.83	13.83	14.67	13.83
7029	6.75	6.83	6.83	6.83	6.83	6.75	6.75	6.75	6.75	6.75	6.75	6.75
7109	17.75	20.00	19.75	20.00	20.00	17.75	17.83	17.75	17.75	17.75	17.67	17.67
7159	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7269	17.58	17.83	17.75	17.83	18.00	16.67	17.58	17.58	17.58	17.58	16.92	16.83
8029	12.83	13.67	13.00	13.67	13.67	13.33	12.83	12.83	12.83	12.83	13.83	13.00

Site No.	Cont.	OWPM	OWPM CADDT	OWPM Cont. VC5	OWPM Cont. VC9	MDF Avg	MDF Cluster	HDF Cluster	HDF Avg	HDF Default	AGPV Avg	AGPV Cluster
8049	12.83	11.75	11.58	13.83	11.75	12.75	12.83	12.83	12.83	12.83	12.83	13.33
8129	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8209	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8219	14.75	16.50	15.75	16.50	16.58	13.83	14.75	14.75	14.75	13.83	14.75	14.83
8229	10.83	11.75	11.75	11.75	11.75	11.00	10.83	10.83	10.83	11.00	10.92	10.83
8440	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8729	10.83	11.75	11.58	11.75	11.75	10.67	10.75	10.83	10.83	10.67	10.83	10.83
8829	9.33	10.33	9.83	10.33	10.25	8.83	9.67	9.33	9.33	8.92	9.92	9.67
9189	7.92	8.67	8.67	8.67	8.67	8.58	7.83	7.92	7.92	8.58	8.67	8.50
9209	8.92	9.75	9.67	9.83	9.83	8.75	8.75	8.92	8.92	8.75	9.67	8.83
9759	26.83	29.67	29.58	29.75	29.75	26.75	26.83	26.83	26.83	26.75	26.67	26.83

*Note N/A excludes sites in clusters which have two or less members. ND indicates that the flexible pavement design used in the analysis could not produce usable distress data for comparison. M indicates week or continuous data was missing.

Table B9. Flexible Pavement Design Life Based on Rutting (2 of 2)

Site No.	Cont.	TTC Avg	TTC Cluster	SA Avg	SA Cluster	Tan Avg	Tan Cluster	Tri Avg	Tri Cluster	Quad Avg	Quad Cluster
1459	15.75	16.75	18.83	17.75	17.83	15.92	15.92	15.83	15.83	17.67	14.42
1529	17.67	14.75	17.75	17.58	17.42	17.83	17.58	17.50	17.50	20.00	20.00
2229	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4049	18.75	20.00	20.00	17.75	17.75	19.33	19.33	18.67	18.75	15.92	16.92
4129	17.75	16.92	19.67	17.75	18.00	17.67	17.58	17.67	17.75	18.92	19.92
4149	13.00	14.25	15.83	12.75	12.67	12.75	12.75	12.92	12.83	15.58	11.75
4229	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4249	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5019	18.83	19.75	18.75	19.75	19.75	17.67	18.83	18.75	18.75	14.75	15.58
5059	15.92	13.83	13.67	16.00	16.00	14.83	16.75	15.92	16.00	15.50	17.75
5249	11.67	10.50	9.75	13.67	13.67	11.75	11.75	11.67	11.67	13.75	11.75
5289	14.67	13.83	13.25	13.83	13.83	13.75	14.75	14.50	14.33	11.58	N/A
5299	10.58	11.83	11.83	10.67	10.67	9.75	10.58	10.58	10.58	9.67	9.92
6019	17.50	12.42	13.50	16.83	17.50	17.83	17.67	17.50	17.42	17.75	18.83
6129	13.83	14.83	14.67	13.83	13.75	13.08	13.92	13.75	13.83	11.92	14.67
6309	15.92	16.58	17.67	15.83	15.75	15.58	15.50	15.83	15.83	16.58	17.67
6369	14.75	15.00	14.75	14.75	14.75	14.92	14.17	14.75	14.75	14.75	14.83
6429	14.67	16.83	15.83	14.75	14.75	14.67	14.67	14.67	14.67	14.58	14.83
6469	9.75	10.50	9.75	9.67	9.67	8.83	9.67	9.67	N/A	7.83	8.50
6479	13.83	16.50	15.67	13.75	13.75	13.75	13.75	13.83	13.83	12.83	15.42
7029	6.75	5.92	5.83	6.92	6.83	8.75	8.58	6.75	6.75	6.92	7.58
7109	17.75	13.75	13.67	17.75	17.75	20.00	20.00	17.75	17.75	15.58	N/A
7159	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7269	17.58	14.67	13.83	17.75	17.75	15.75	15.67	17.67	17.67	15.83	16.67
8029	12.83	13.75	12.75	12.58	12.42	11.75	11.75	12.75	12.75	14.75	10.92
8049	12.83	11.67	11.75	13.83	13.75	11.92	11.50	12.83	12.83	11.75	13.75
8129	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Site No.	Cont.	TTC Avg	TTC Cluster	SA Avg	SA Cluster	Tan Avg	Tan Cluster	Tri Avg	Tri Cluster	Quad Avg	Quad Cluster
8209	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8219	14.75	12.92	13.67	14.67	14.67	12.83	14.75	14.75	14.75	12.75	14.75
8229	10.83	10.75	10.00	10.83	10.83	10.92	11.00	10.83	10.83	11.67	11.83
8440	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8729	10.83	10.75	10.75	11.50	11.17	10.92	10.75	10.83	10.83	9.67	9.83
8829	9.33	9.75	9.75	9.67	9.67	9.92	9.58	9.50	9.42	11.00	9.08
9189	7.92	8.67	8.67	8.08	7.92	8.83	8.67	7.92	7.92	10.67	8.83
9209	8.92	7.67	6.83	9.67	9.67	8.83	9.42	8.92	8.92	10.83	8.83
9759	26.83	15.42	16.58	25.92	25.67	23.83	26.08	26.83	26.83	26.75	28.00

*Note N/A excludes sites in clusters which have two or less members. ND indicates that the flexible pavement design used in the analysis could not produce usable distress data for comparison. M indicates week or continuous data was missing.

AADTT Clustering

Table B10. Low AADTT Group

Low Traffic (1)	
Site	AADTT
2209	88
6019	112
6309	123
4229	151
2029	201
7329	237
8440	277
1529	295
9759	321
4249	326
1459	358
4129	386
8129	412
7069	431
2229	436
4049	523
4149	669
8029	809
5019	833
6429	846
6479	899
5289	975
7109	976

Table B11. Medium AADTT Group

Medium Traffic (2)	
Site	AADTT
5249	1222
5059	1425
6469	1452
6129	1548
6369	1695
8049	1809
8229	1881
8219	1895
5299	2188
8829	2236
9189	2781
8209	2802

Table B12. High AADTT Group

High Traffic (3)	
Site	AADTT
9799	3050
7269	3101
9209	3106
8729	3171
7029	3569
7159	5435

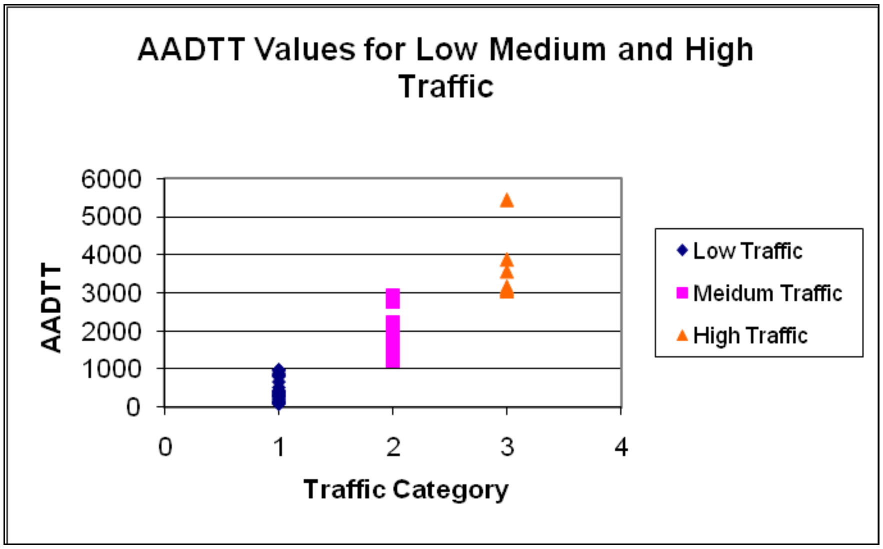

Figure B1. AADTT Cluster Groupings

TTC Clustering

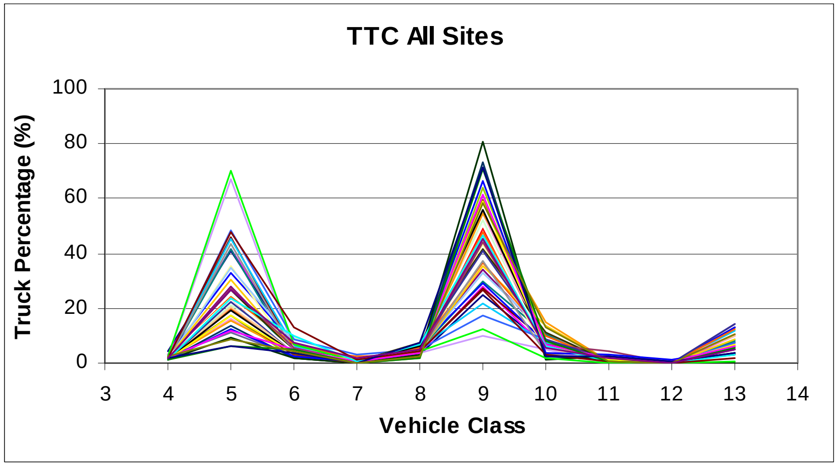

Figure B2. TTCs for all Analyzed Sites

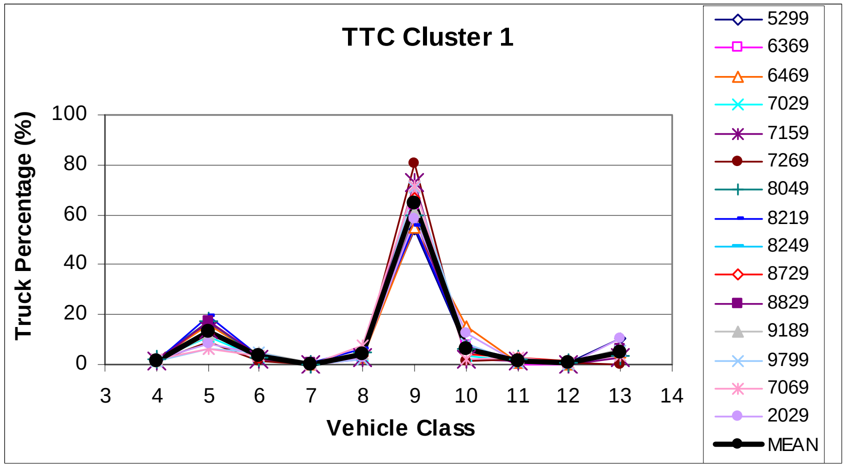

Figure B3. TTCs for Cluster 1 (Class 9 Dominant)

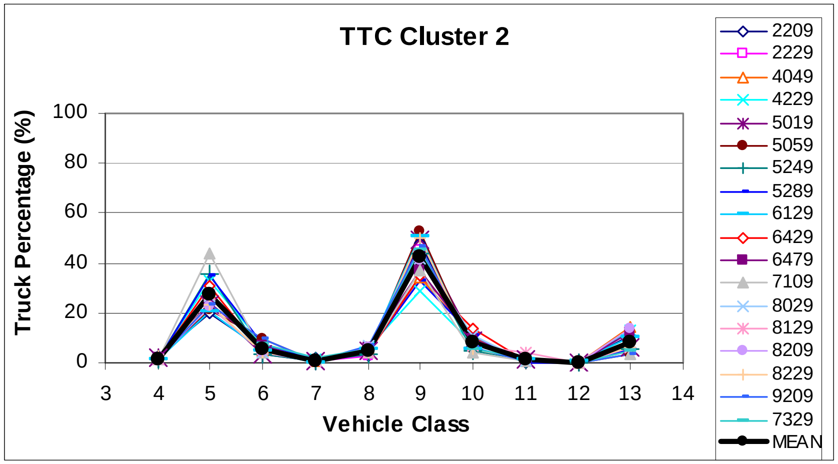

Figure B4. TTCs for Cluster 2 (Even Dominance)

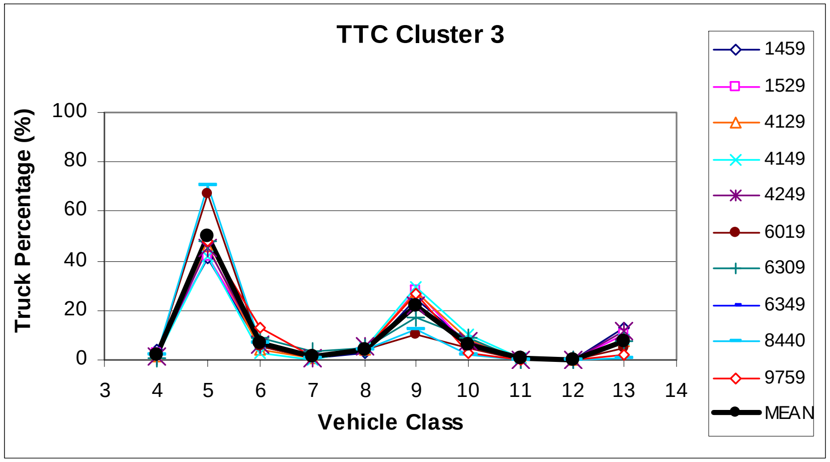

Figure B5. TTCs for Cluster 3 (Class 5 Dominant)

VC 4-7 MDFs Clustering

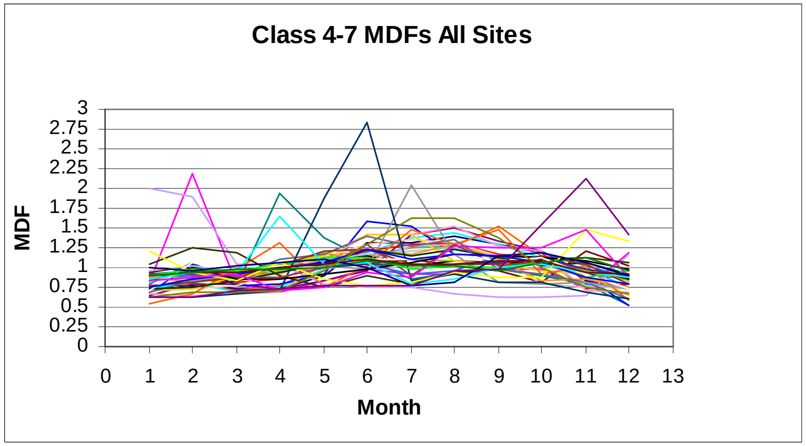

Figure B6. VC 4-7 MDFs for all Analyzed Sites

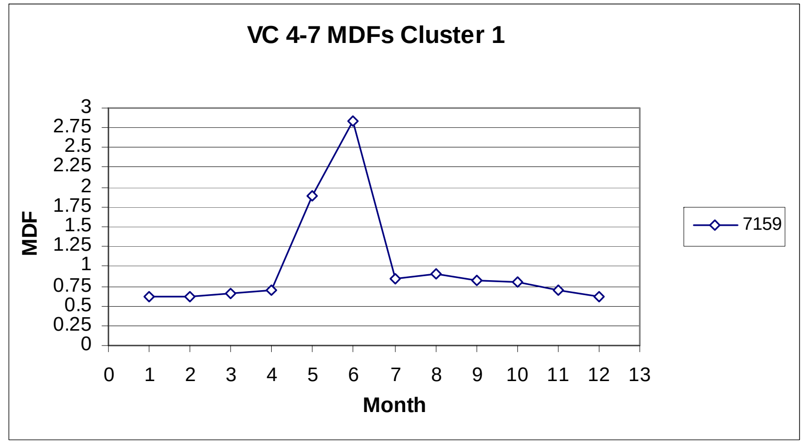

Figure B7. Light Truck MDFs for Cluster 1 (Month 6 Dominant)

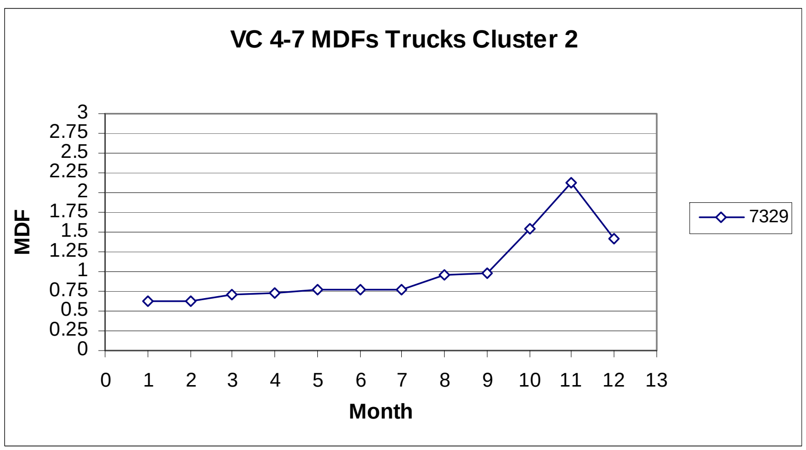

Figure B8. VC 4-7 MDFs for Cluster 2 (Month 11 Dominant)

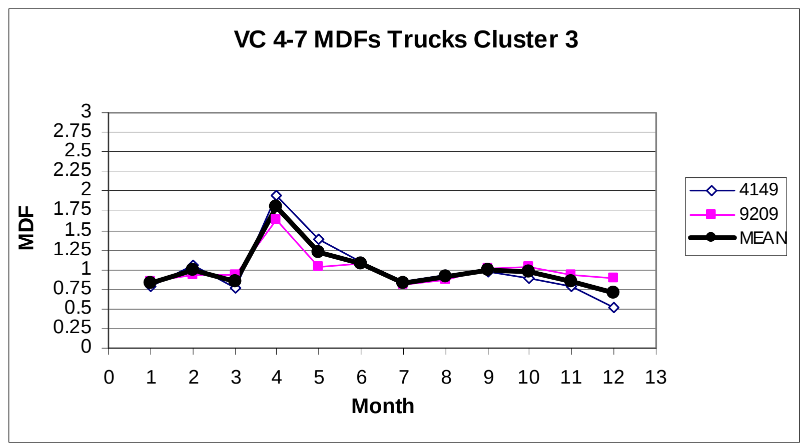

Figure B9. VC 4-7 MDFs for Cluster 3 (Month 4 Dominant)

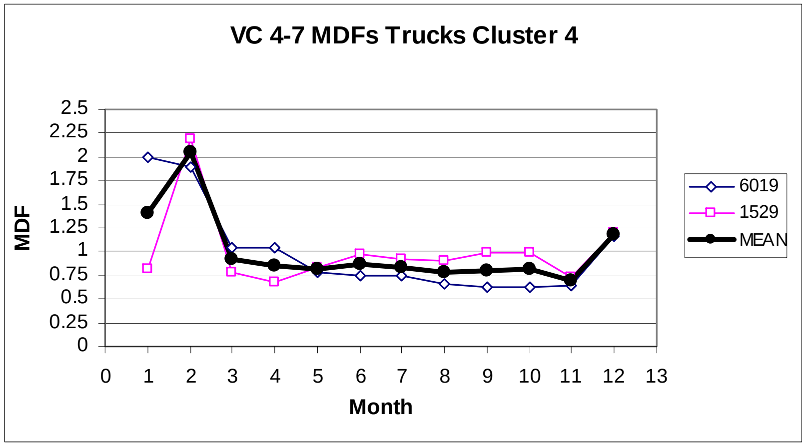

Figure B10. VC 4-7 MDFs for Cluster 4 (Month 2 Dominant)

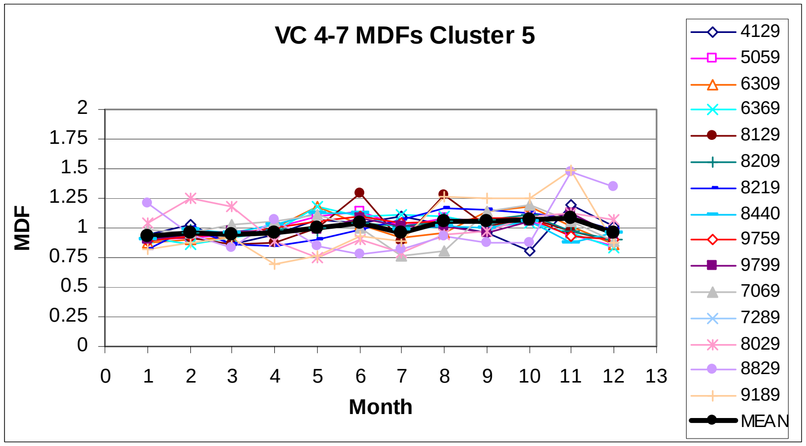

Figure B11. VC 4-7 MDFs for Cluster 5 (No Dominance)

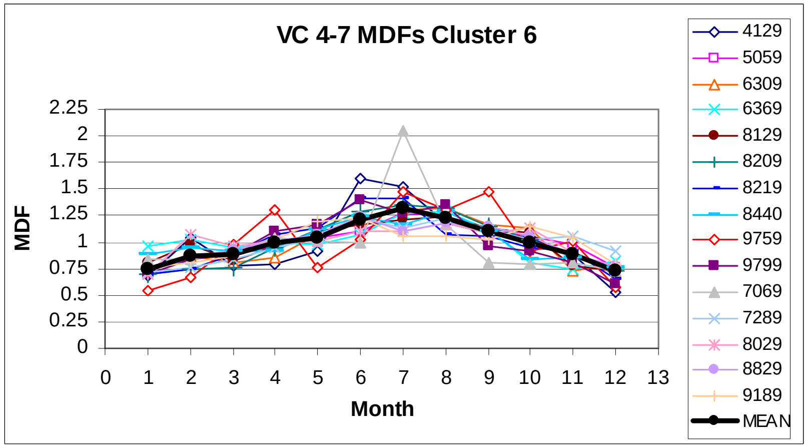

Figure B12. VC 4-7 MDFs for Cluster 6 (Summer Dominant)

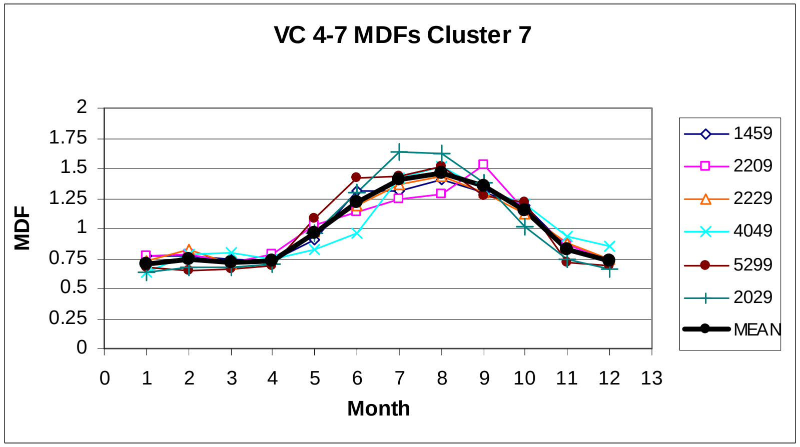

Figure B13. VC 4-7 MDFs for Cluster 7 (Summer/Fall Dominant)

VC 8-10 MDFs Clustering

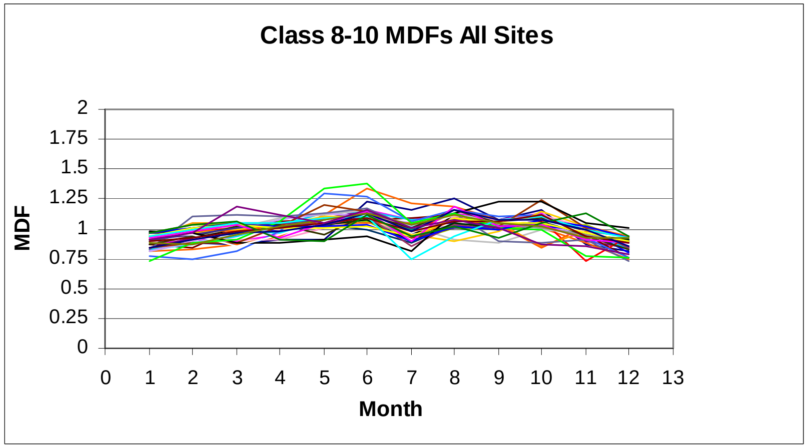

Figure B14. VC 8-10 MDFs for all Analyzed Sites

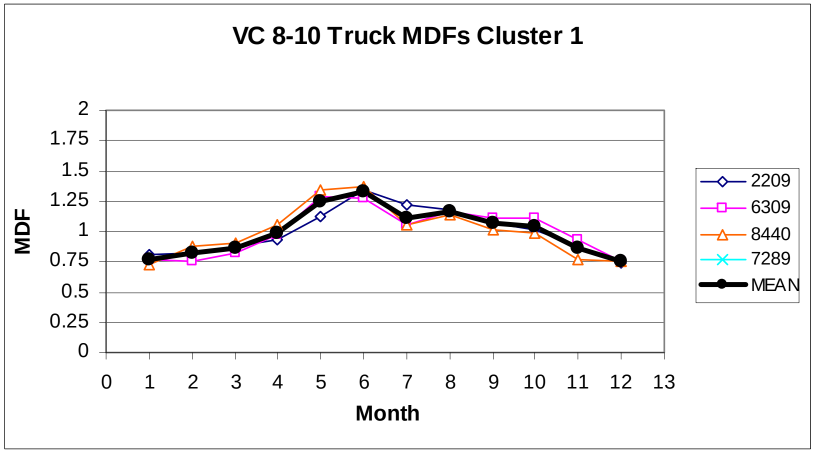

Figure B15. VC 8-10 MDFs for Cluster 1 (Summer Dominant)

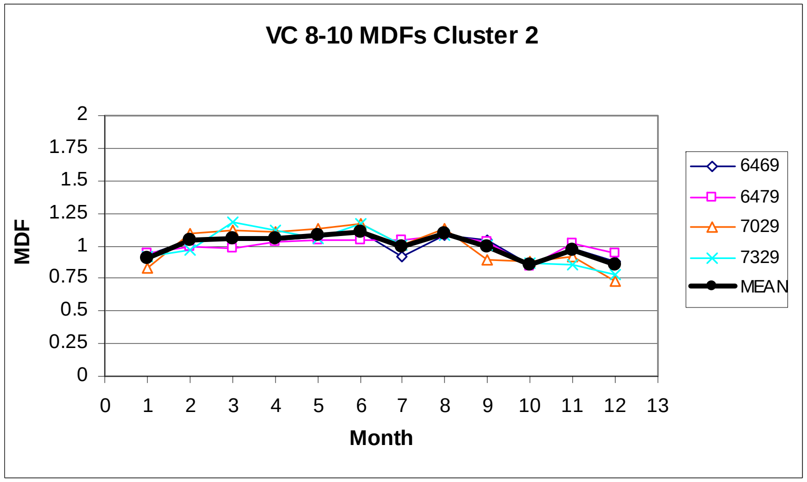

Figure B16. VC 8-10 MDFs for Cluster 2

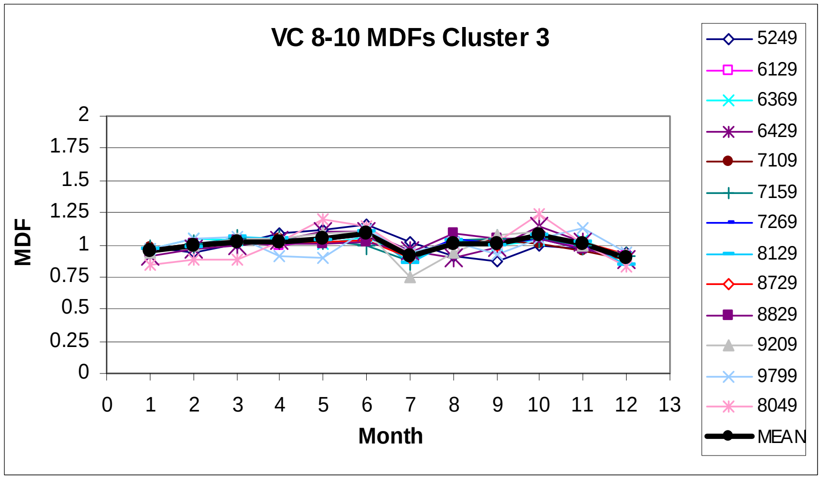

Figure B17. VC 8-10 MDFs for Cluster 3

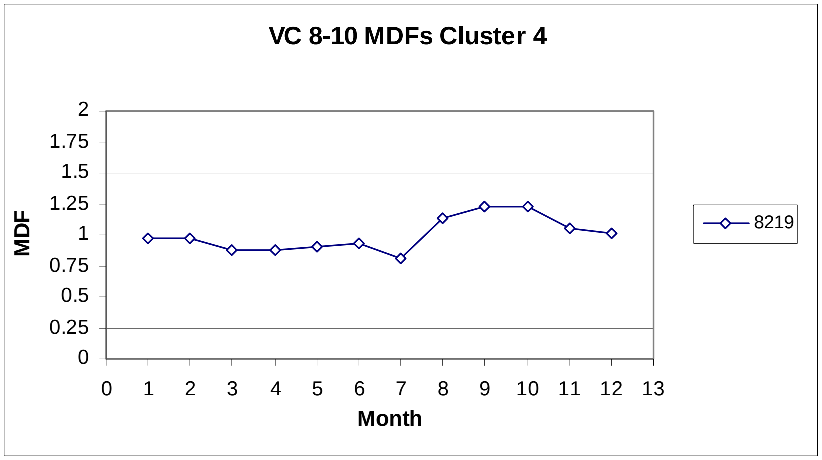

Figure B18. VC 8-10 MDFs for Cluster 4 (Fall Dominant)

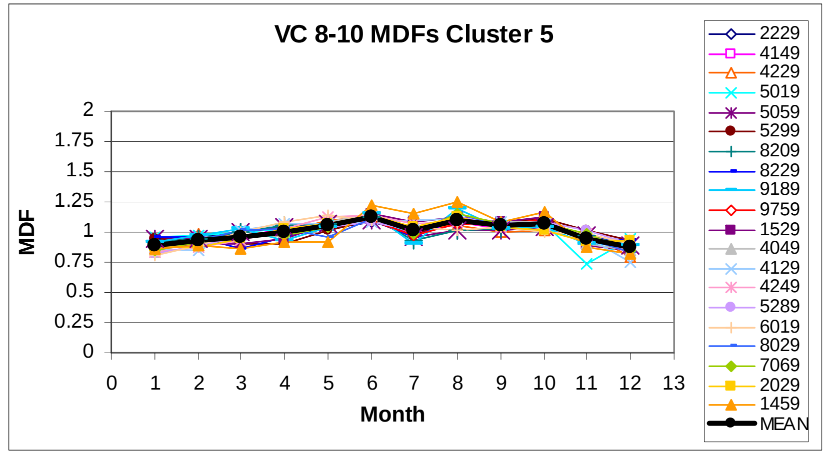

Figure B19. VC 8-10 MDFs for Cluster 5

VC 11-13 MDFs Clustering

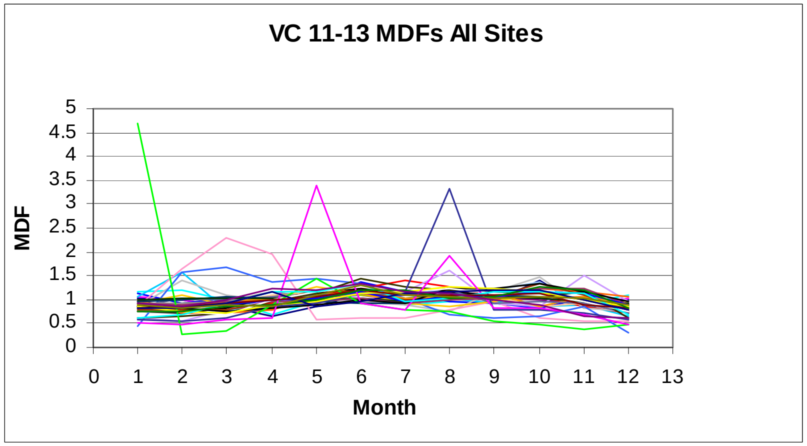

Figure B20. VC 11-13 MDFs for all Analyzed Sites

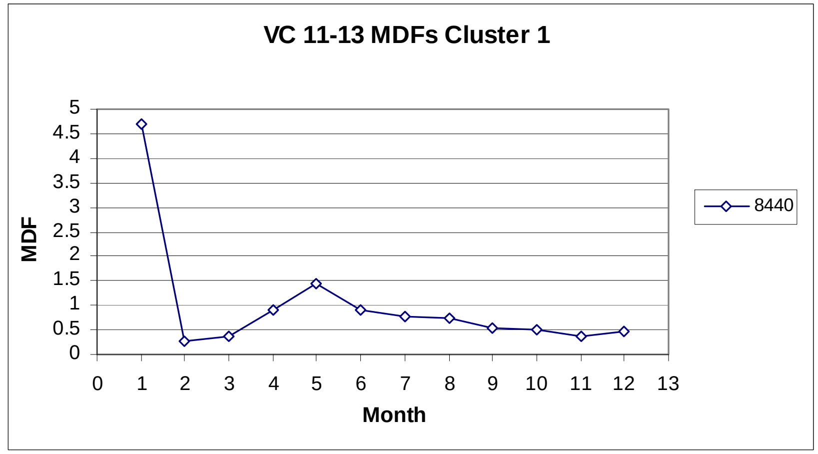

Figure B21. VC 11-13 MDFs for Cluster 1 (Month 1 Dominant)

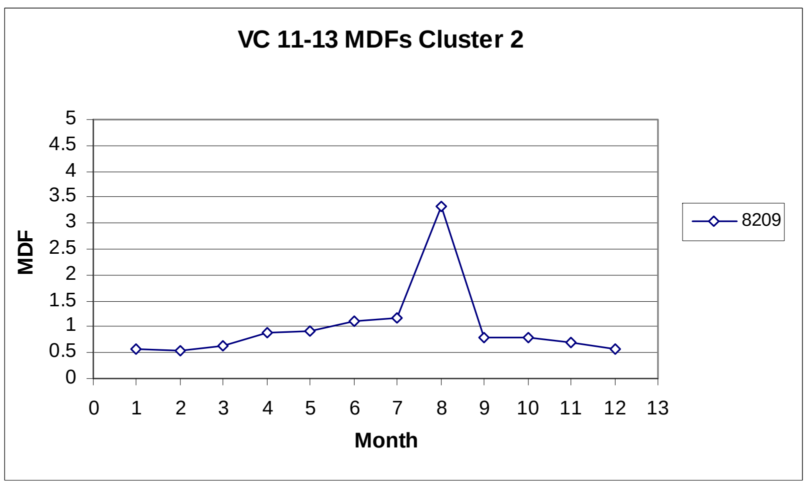

Figure B22. VC 11-13 MDFs for Cluster 2 (Month 8 Dominant)

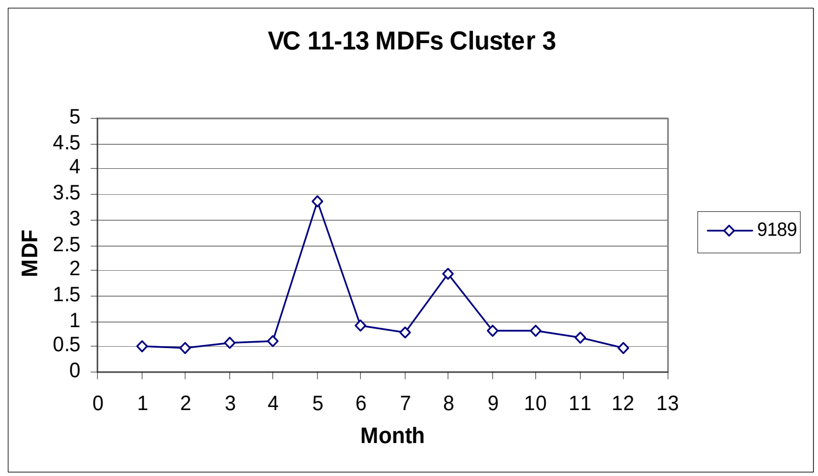

Figure B23. VC 11-13 MDFs for Cluster 3 (Months 5/8 Dominant)

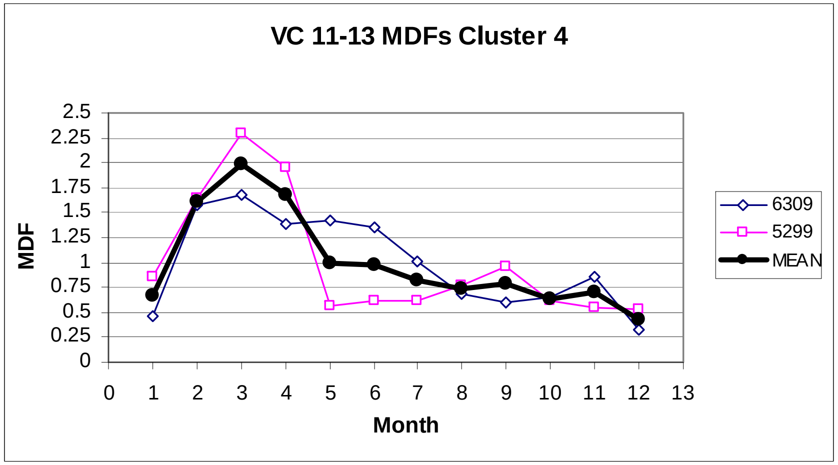

Figure B24. VC 11-13 MDFs for Cluster 4 (Spring Dominant)

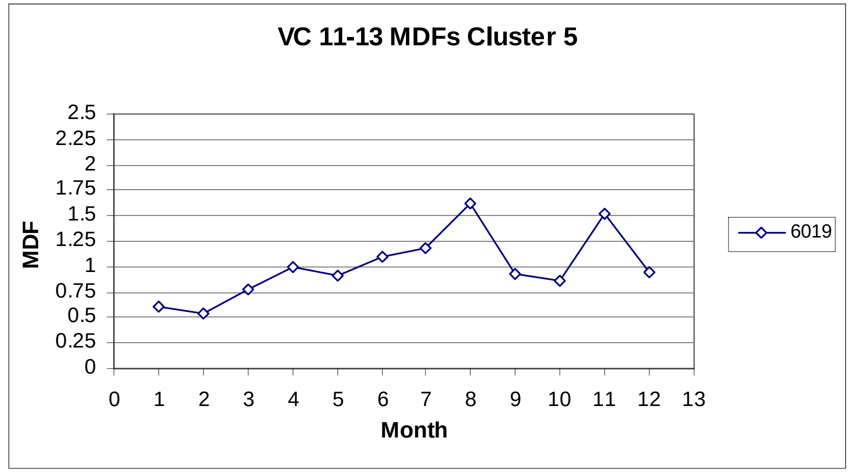

Figure B25.VC 11-13 MDFs for Cluster 5 (Month 8/11Dominant)

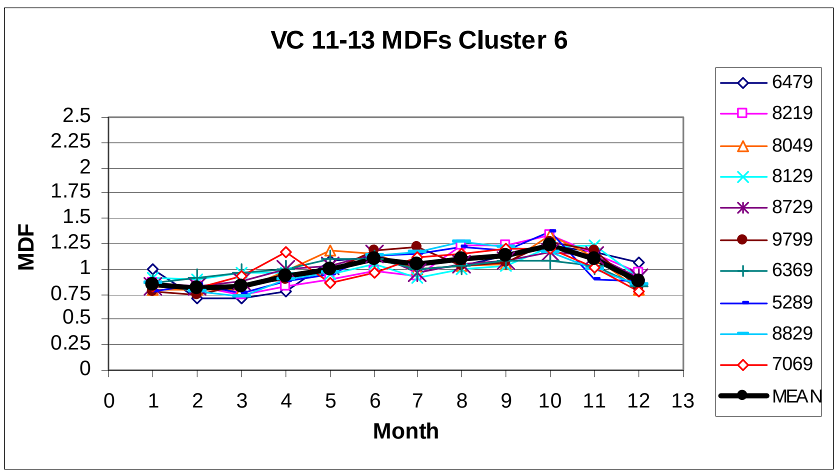

Figure B26 VC 11-13 MDFs for Cluster 6 (No Dominance)

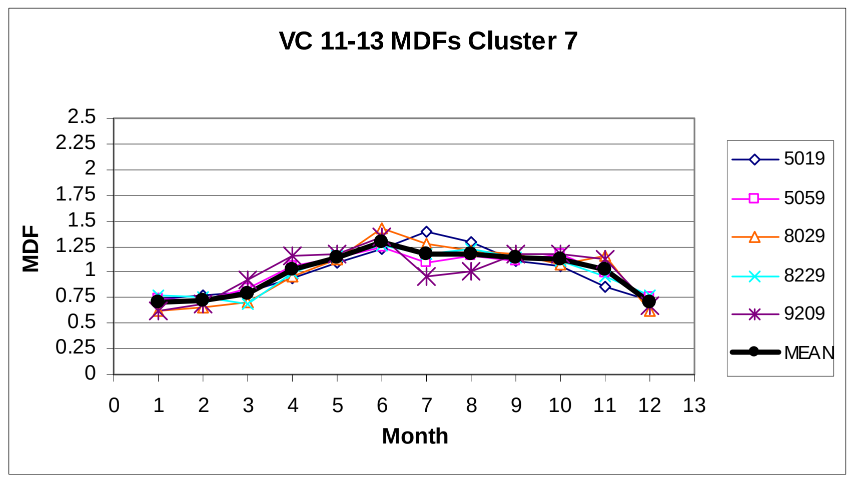

Figure B27. VC 11-13 MDFs for Cluster 7 (Summer Dominance)

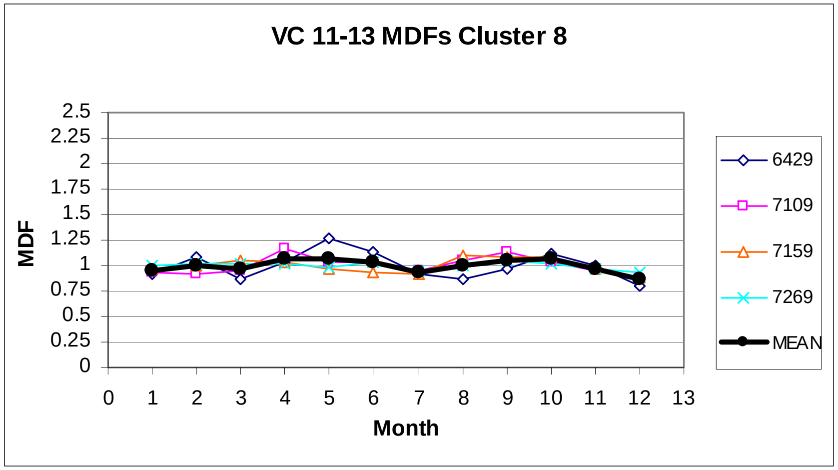

Figure B28. VC 11-13 MDFs for Cluster 8 (No Dominance)

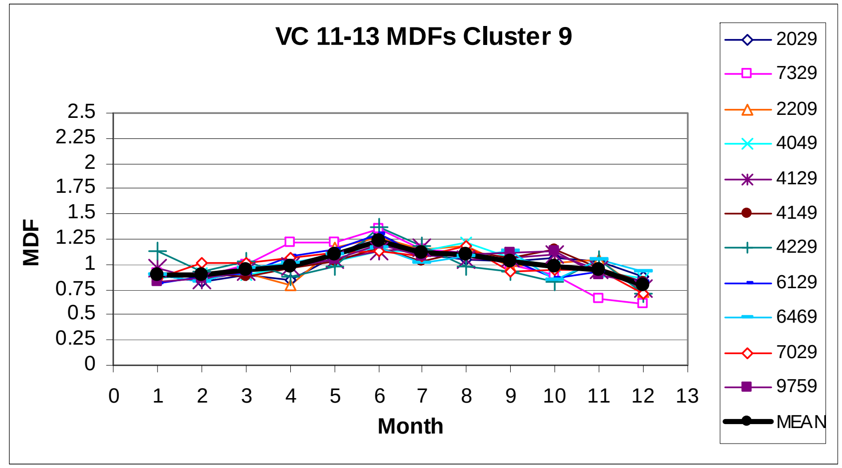

Figure B29.VC 11-13 MDFs for Cluster 9 (Summer Dominance)

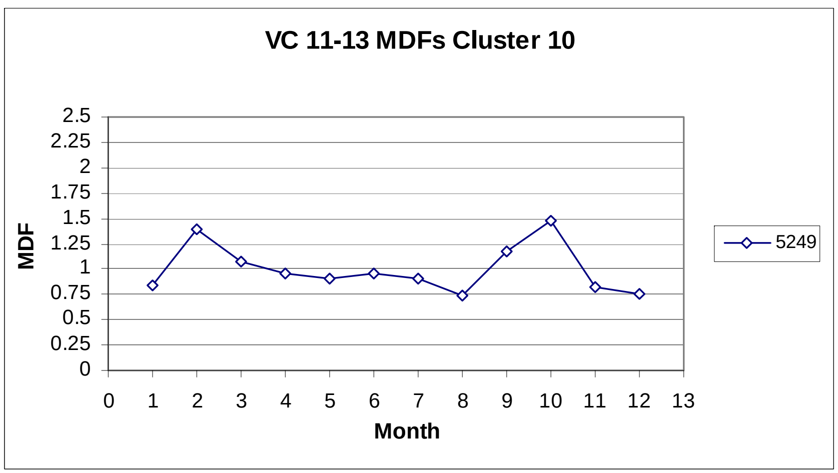

Figure B30. VC 11-13 MDFs for Cluster 10 (Peak Months 2/10)

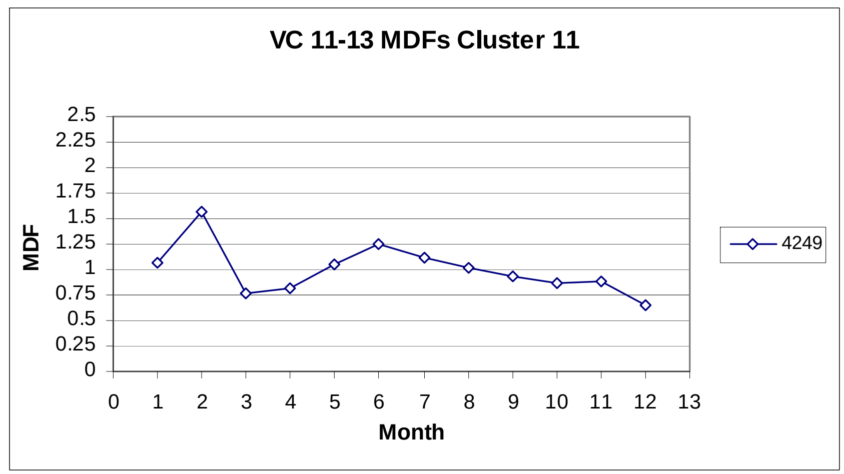

Figure B31. VC 11-13 MDFs for Cluster 11 (Peak Month 2)

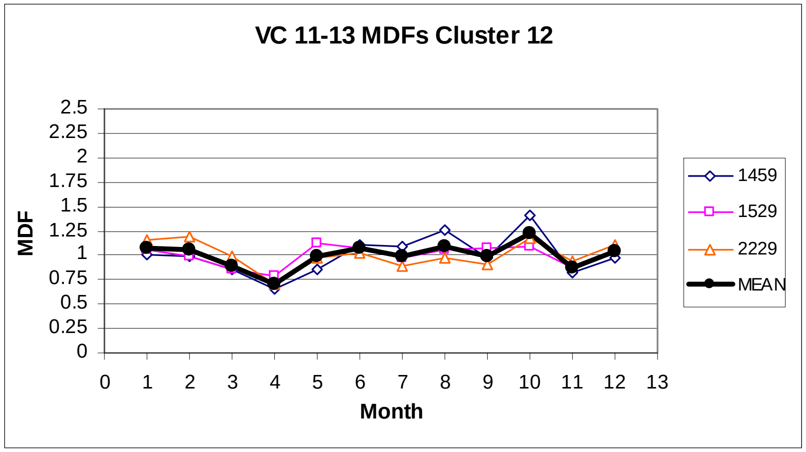

Figure B32. VC 11-13 MDFs for Cluster 12 (Indistinct)

Hourly Distribution Factor Clustering

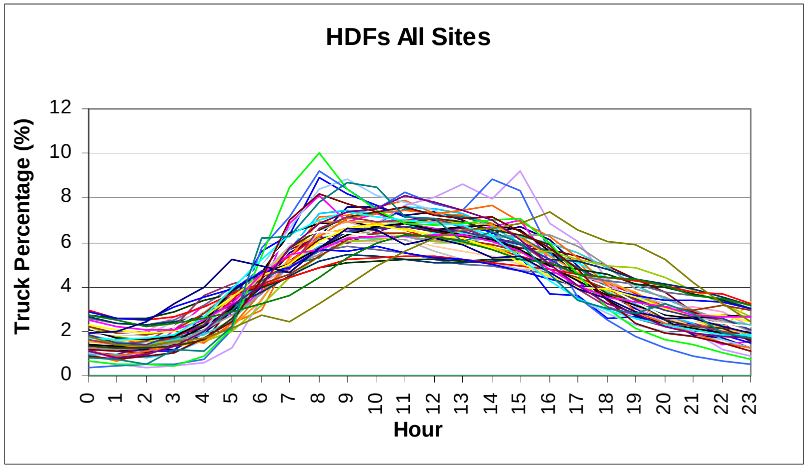

Figure B33. HDFs for all Analyzed Sites

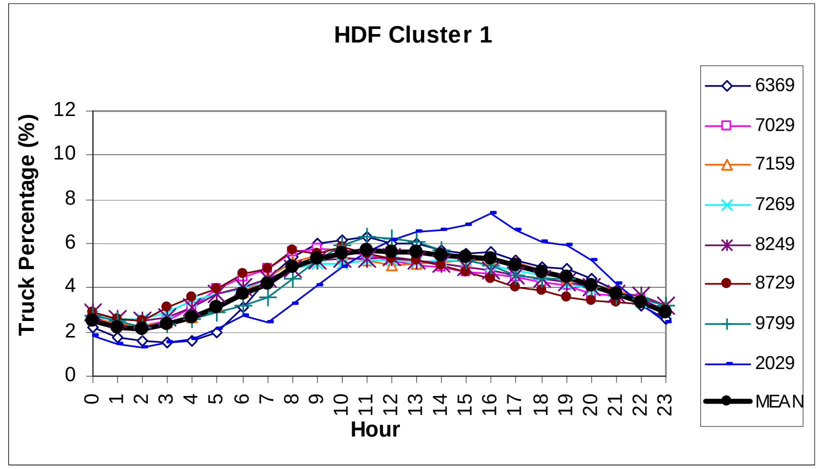

Figure B34. HDFs for Cluster 1 (Even Distribution)

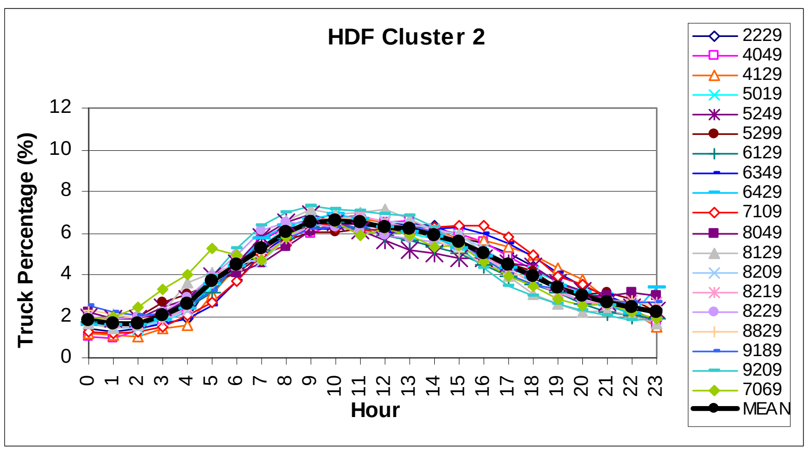

Figure B35. HDFs for Cluster 2 (Morning Dominant)

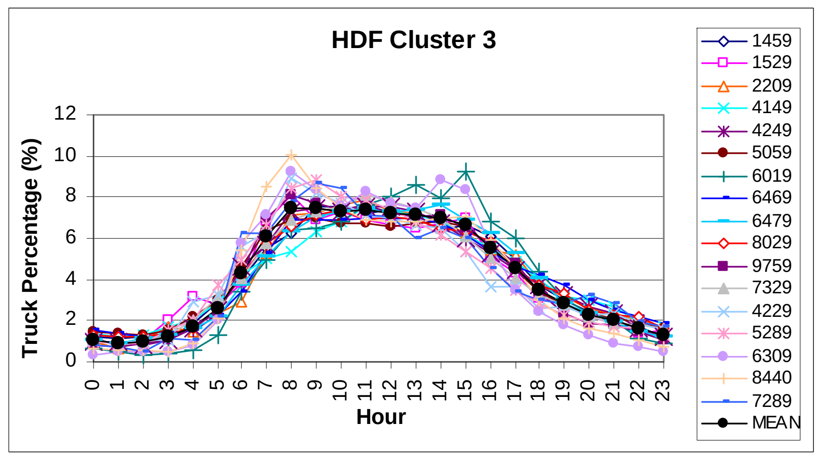

Figure B36. HDFs for Cluster 3 (Midday Peak Distribution)

Appendix C

Cluster Analysis Results-Single Axle Load Spectra

All Single Axle Load Spectra (LS) Clustering

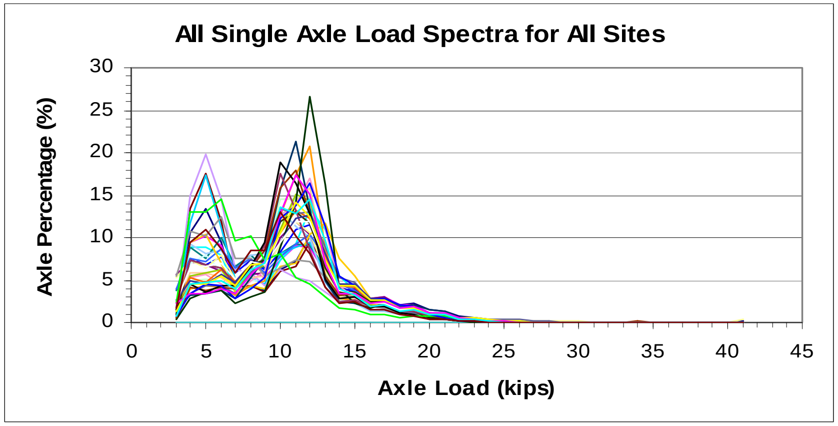

Figure C1. All Single Axle LS for all Analyzed Sites

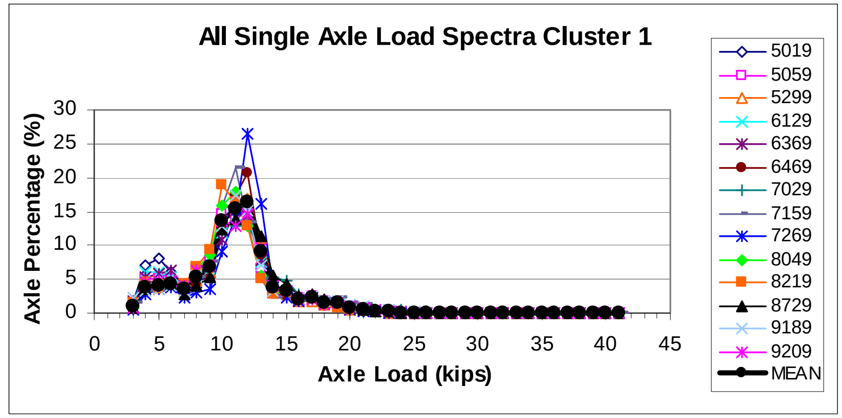

Figure C2. All Single Axle LS for Cluster 1

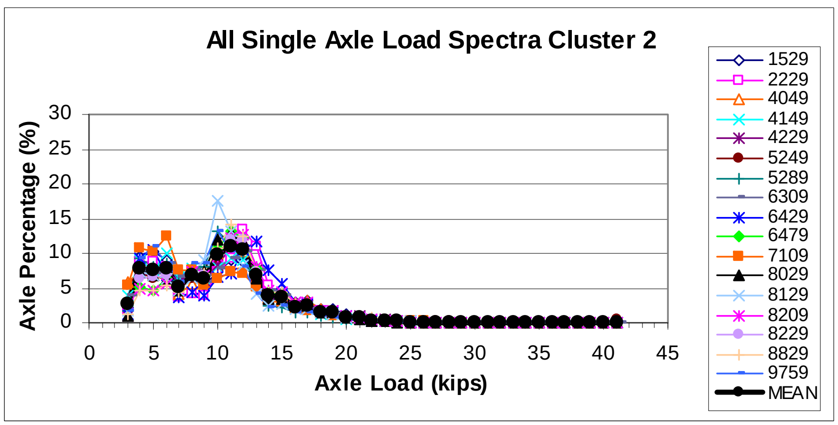

Figure C3. All Single Axle LS for Cluster 2

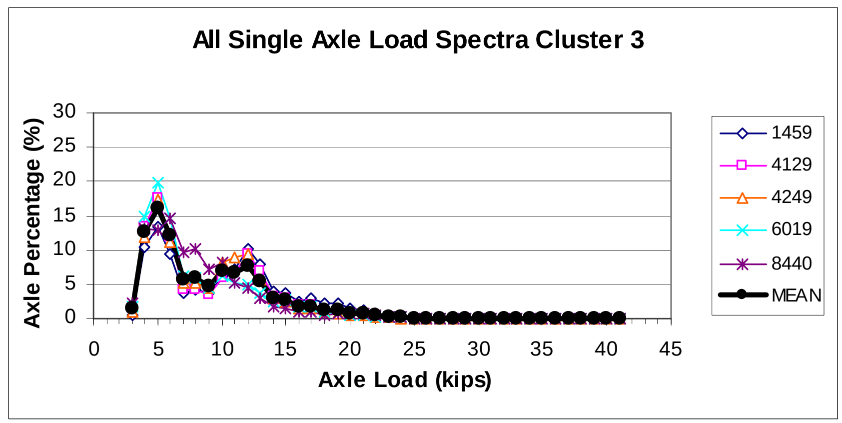

Figure C4. All Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC4 Clustering

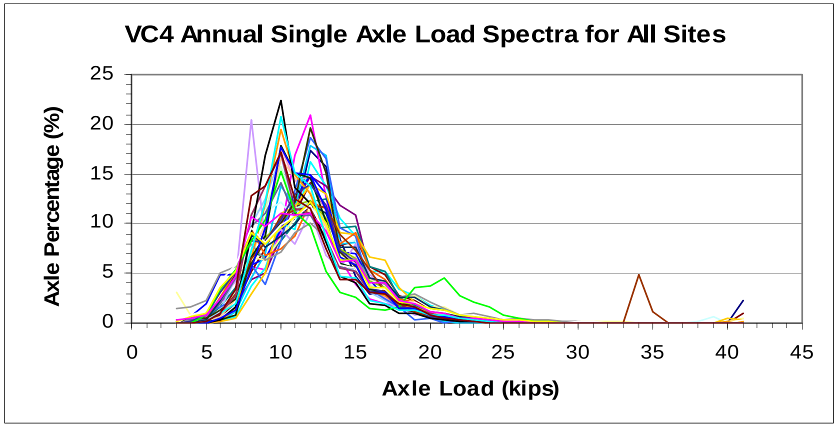

Figure C5. VC4 Single Axle LS for all Analyzed Sites

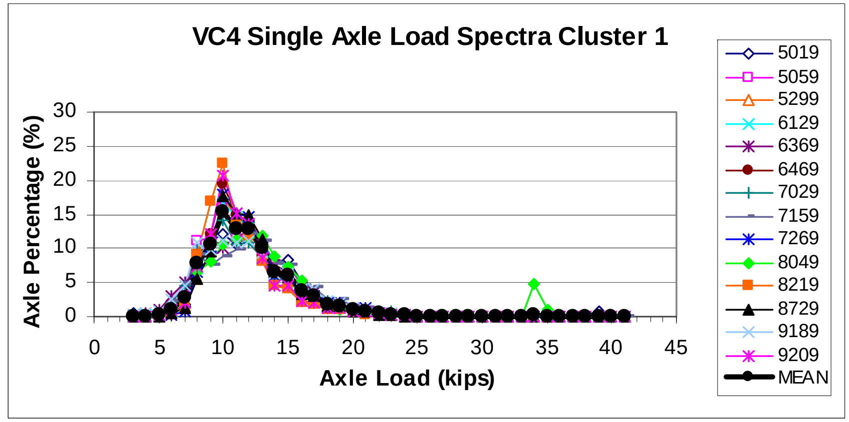

Figure C6. VC4 Single Axle LS for Cluster 1

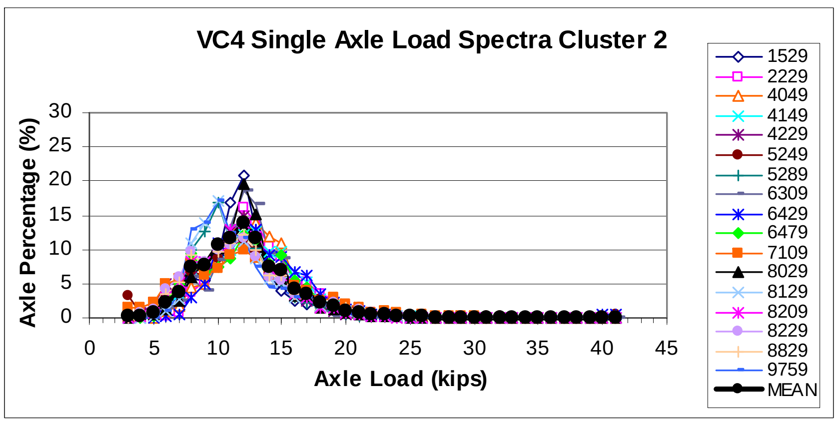

Figure C7. VC4 Single Axle LS for Cluster 2

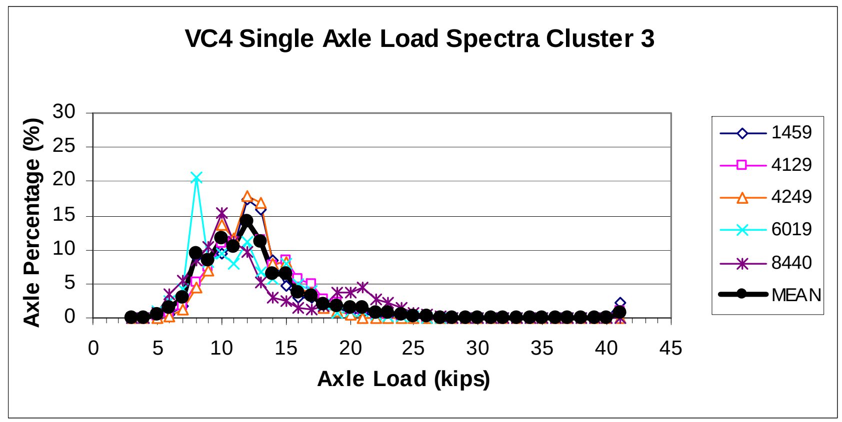

Figure C8. VC4 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC5 Clustering

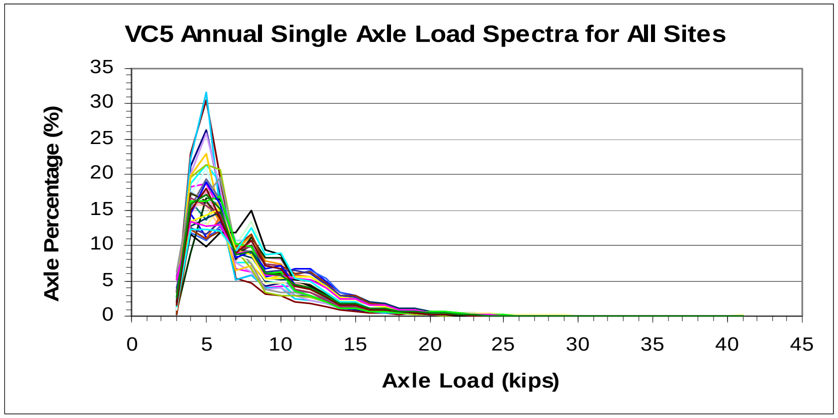

Figure C9. VC5 Single Axle LS for all Analyzed Sites

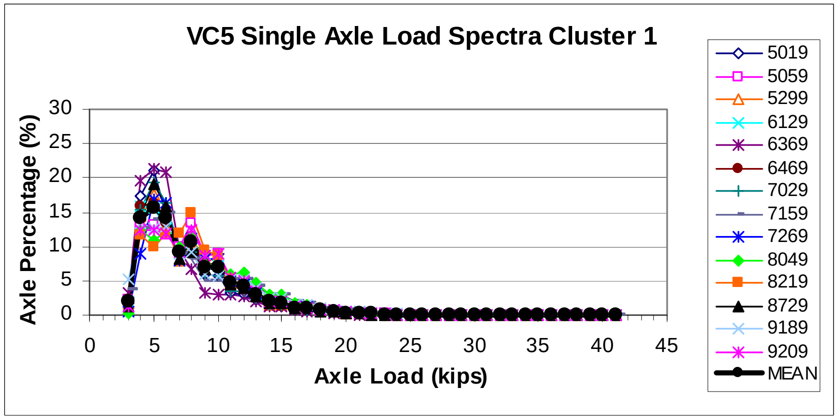

Figure C10. VC5 Single Axle LS for Cluster 1

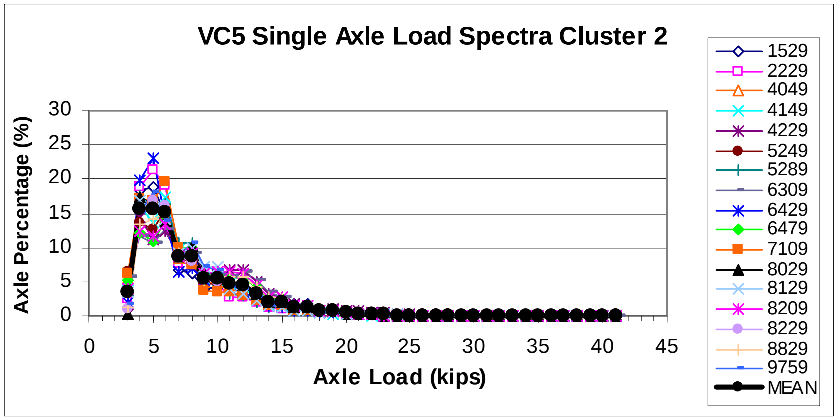

Figure C11. VC5 Single Axle LS for Cluster 2

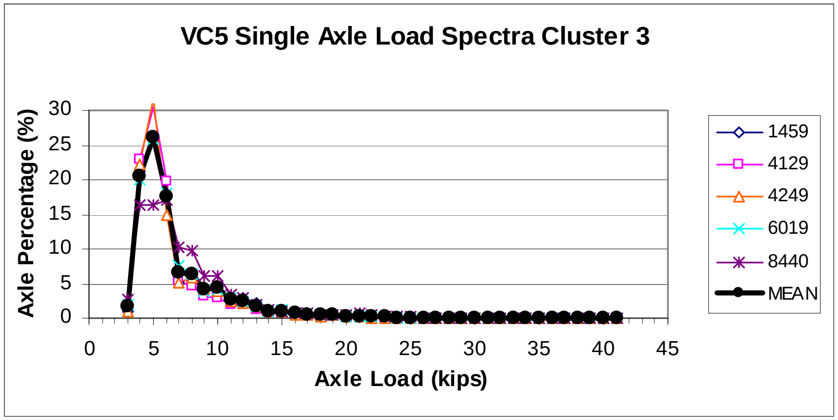

Figure C12. VC5 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC6 Clustering

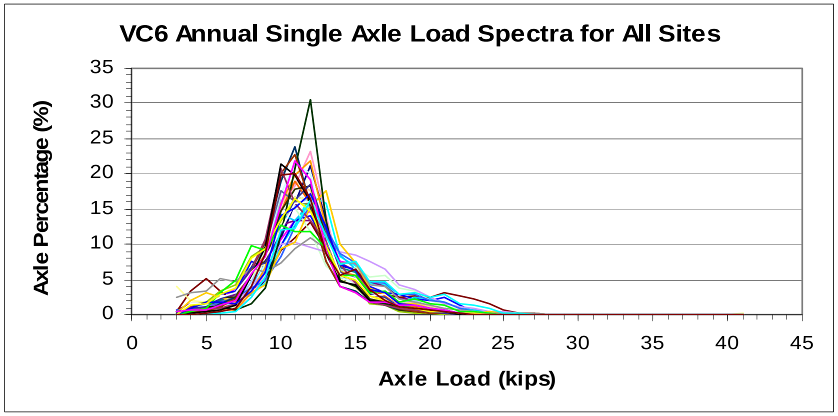

Figure C13. VC6 Single Axle LS for all Analyzed Sites

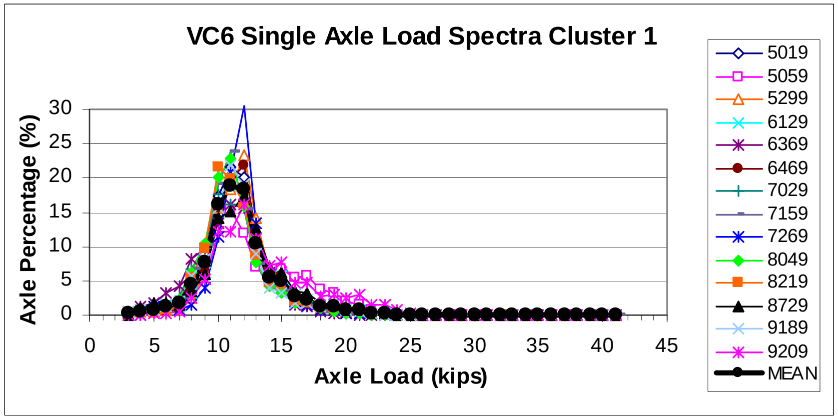

Figure C14. VC6 Single Axle LS for Cluster 1

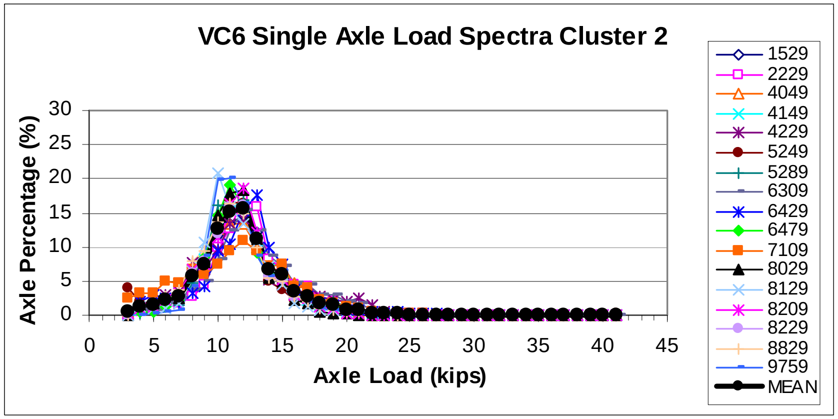

Figure C15. VC6 Single Axle LS for Cluster 2

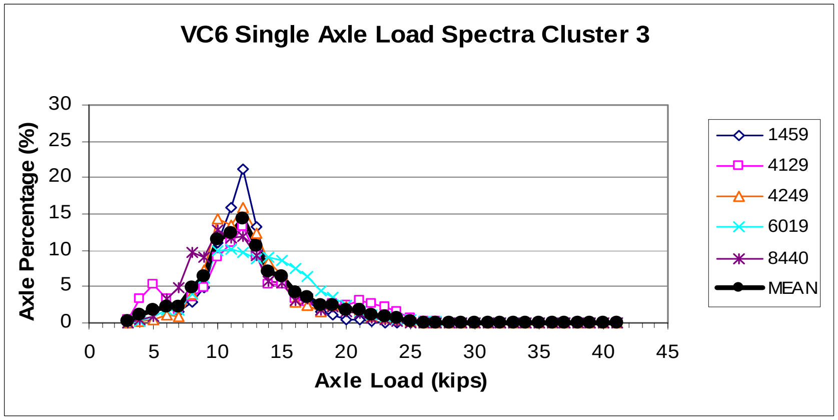

Figure C16. VC6 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC7 Clustering

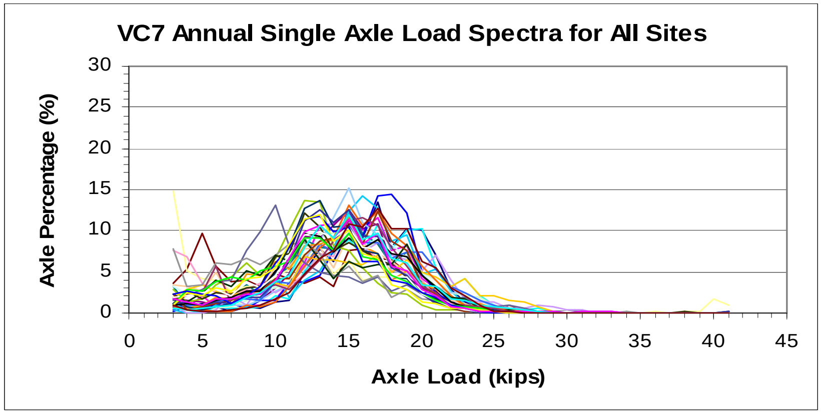

Figure C17. VC7 Single Axle LS for all Analyzed Sites

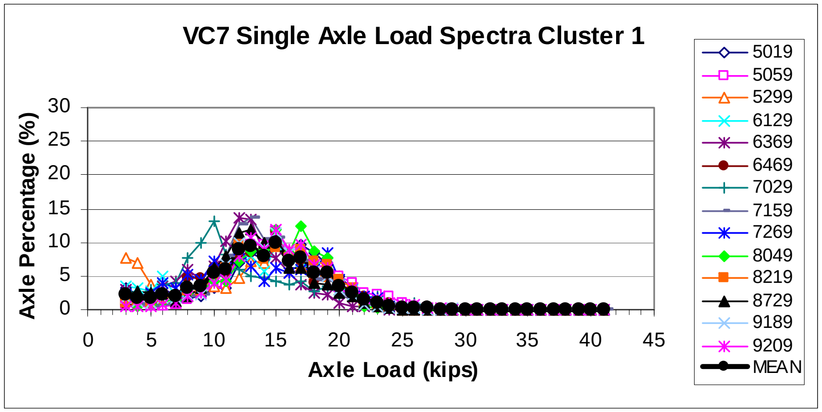

Figure C18. VC7 Single Axle LS for Cluster 1

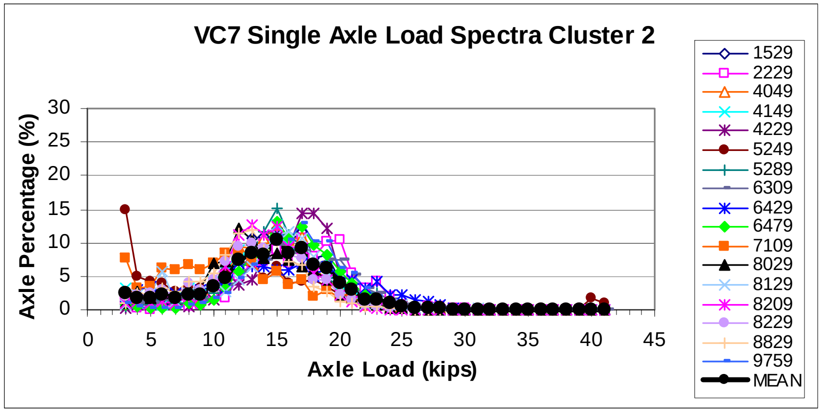

Figure C19. VC7 Single Axle LS for Cluster 2

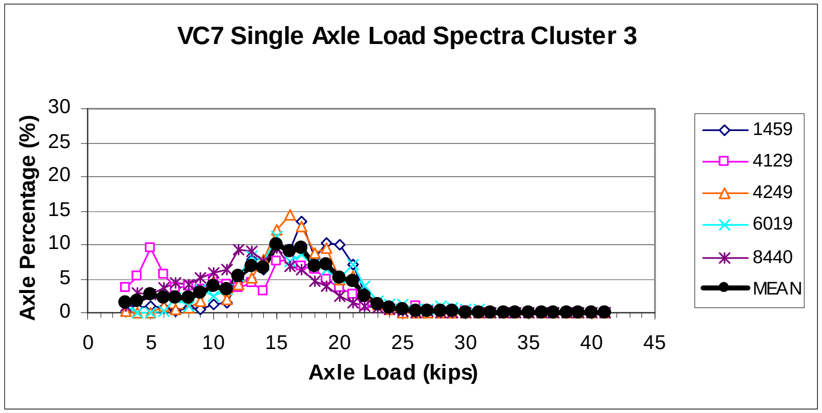

Figure C20. VC7 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC8 Clustering

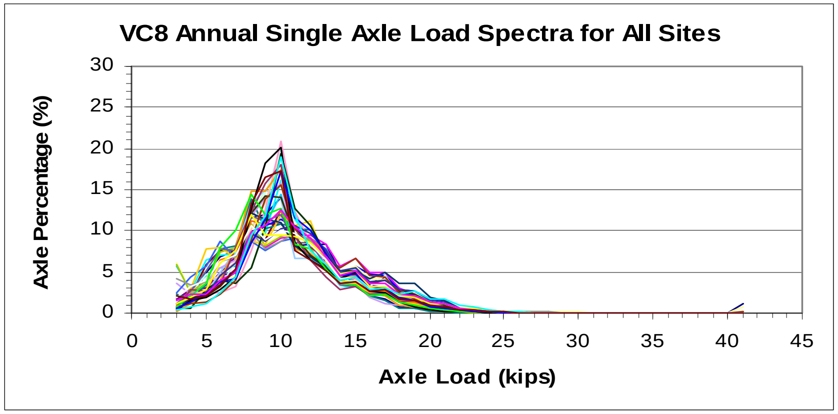

Figure C21. VC8 Single Axle LS for all Analyzed Sites

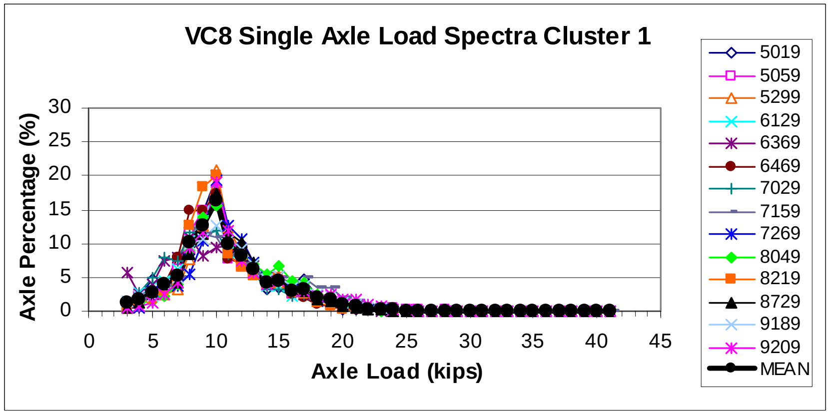

Figure C22. VC8 Single Axle LS for Cluster 1

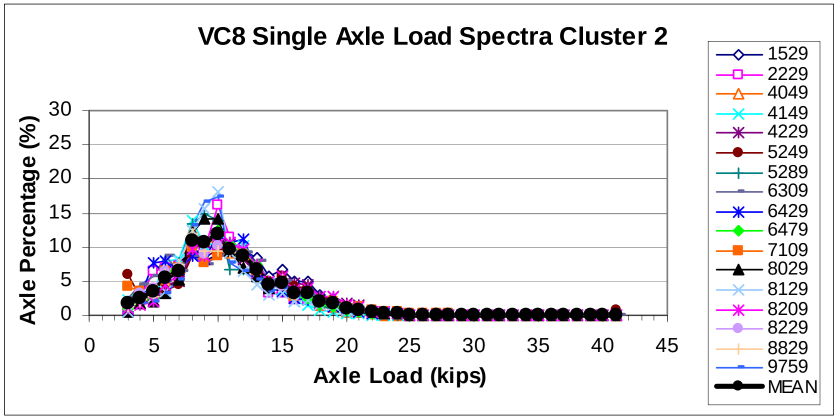

Figure C23. VC8 Single Axle LS for Cluster 2

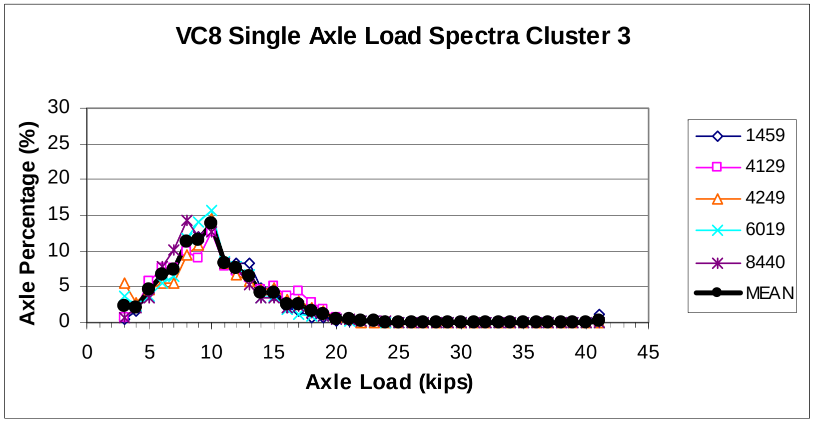

Figure C24. VC8 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC9 Clustering

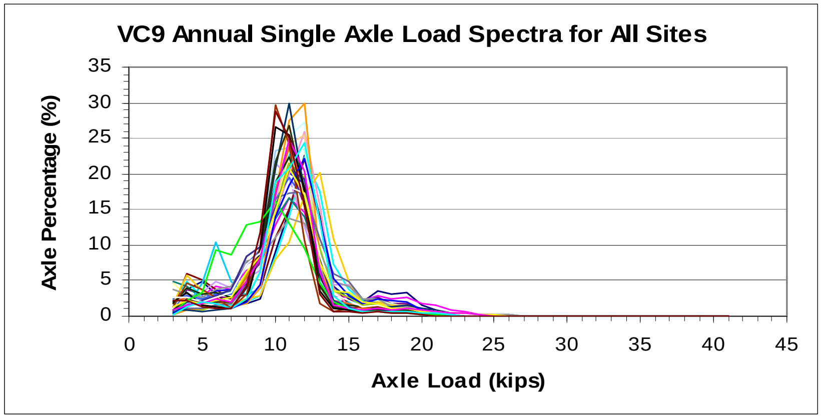

Figure C25. VC9 Single Axle LS for all Analyzed Sites

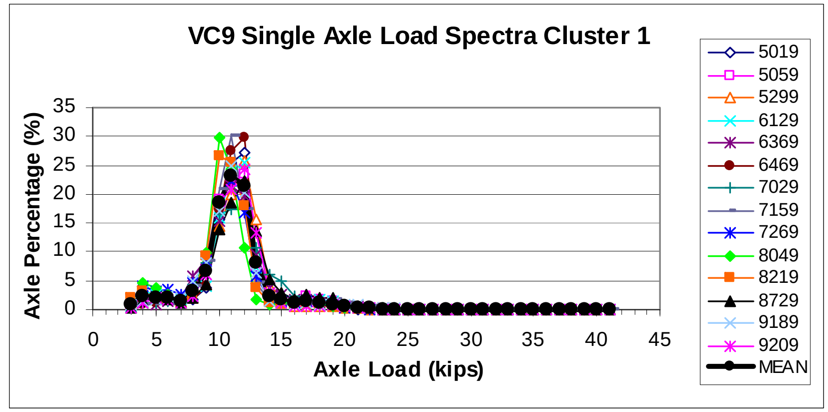

Figure C26. VC9 Single Axle LS for Cluster 1

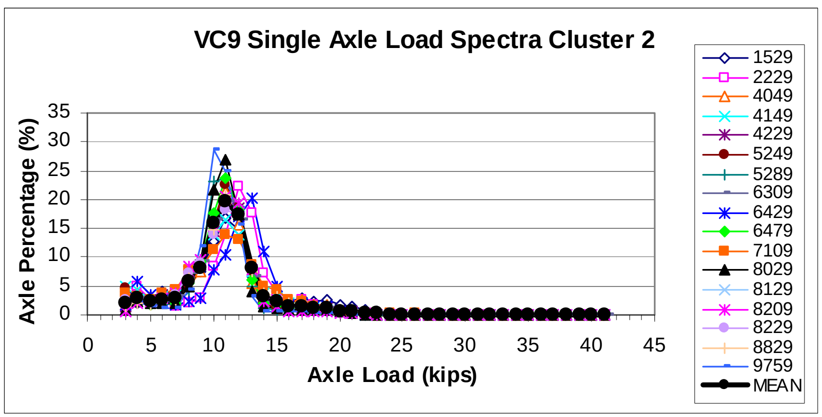

Figure C27. VC10 Single Axle LS for Cluster 2

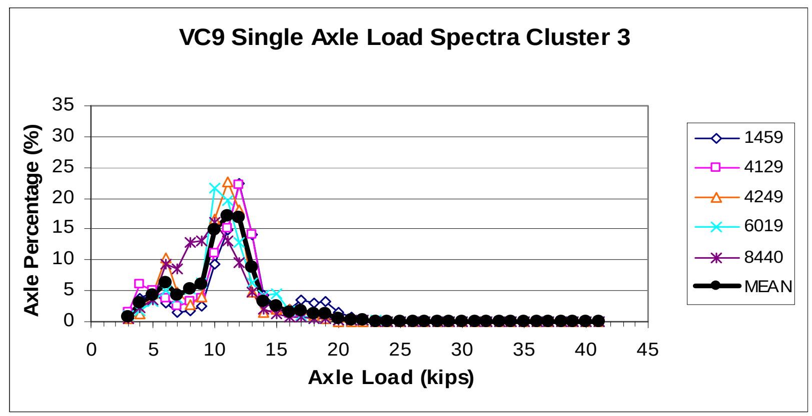

Figure C28. VC11 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC10 Clustering

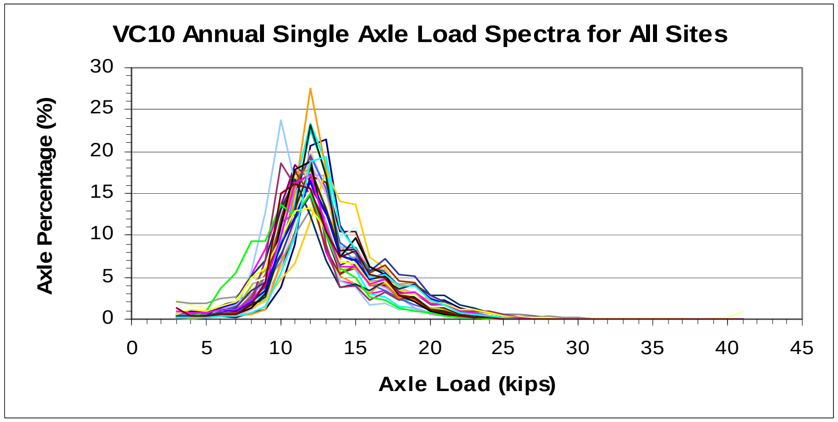

Figure C29. VC10 Single Axle LS for all Analyzed Sites

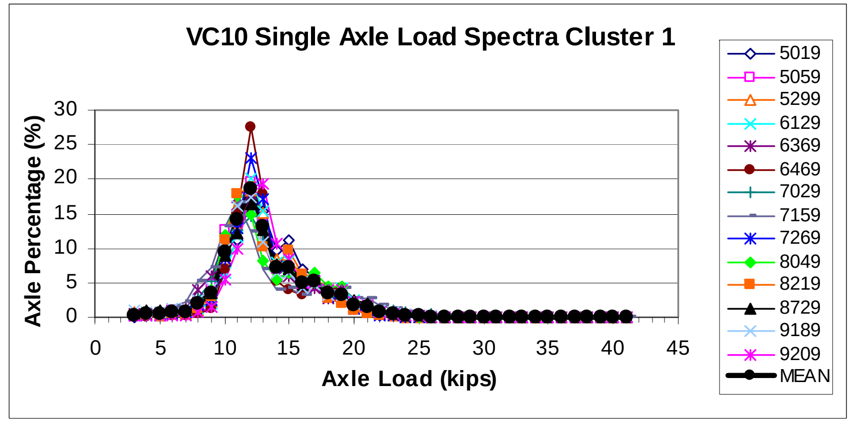

Figure C30. VC10 Single Axle LS for Cluster 1

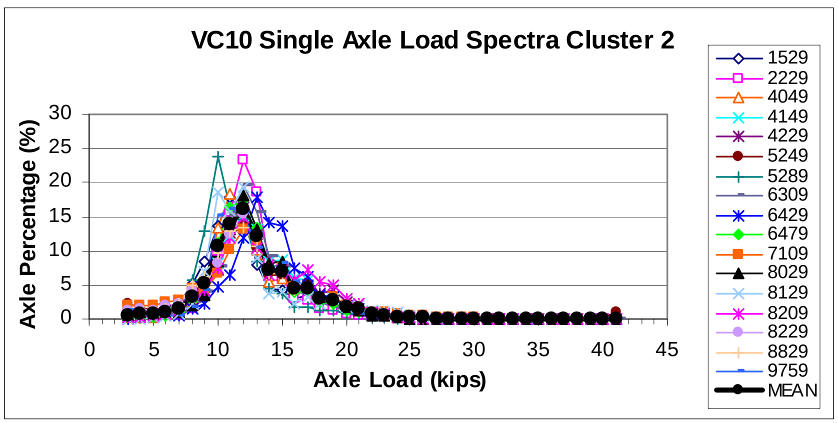

Figure C31. VC10 Single Axle LS for Cluster 2

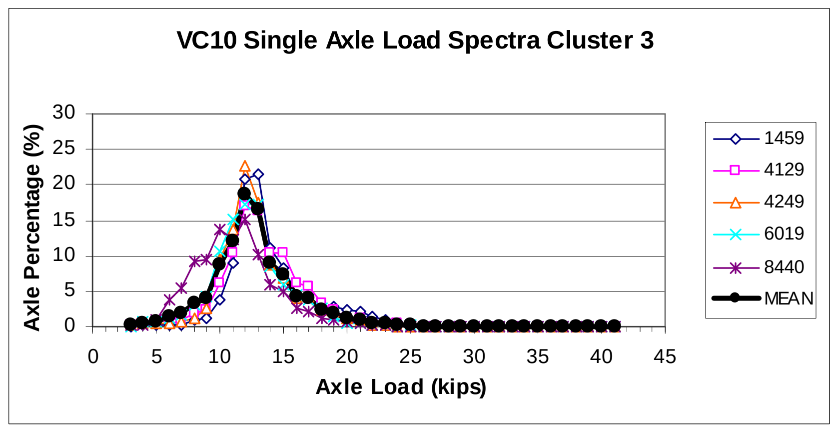

Figure C32. VC10 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC11 Clustering

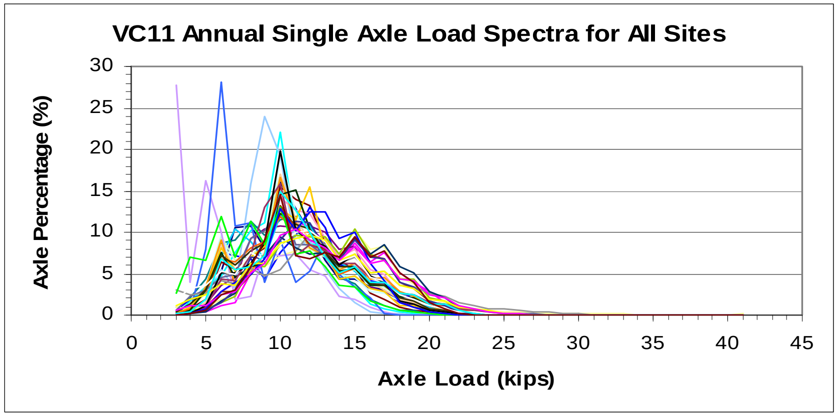

Figure C33. VC11 Single Axle LS for all Analyzed Sites

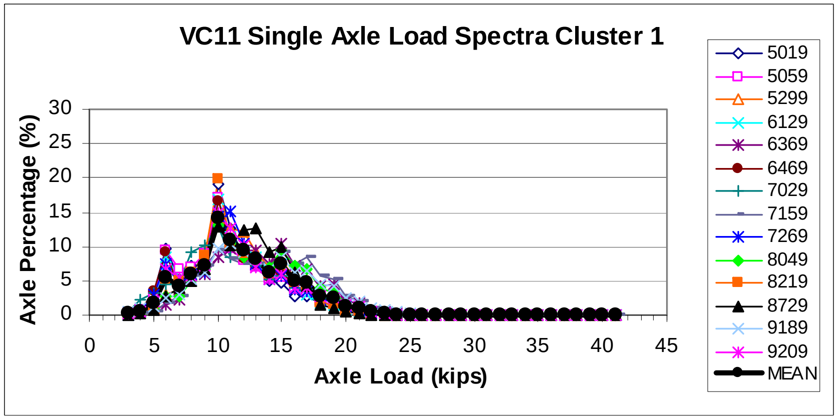

Figure C34. VC11 Single Axle LS for Cluster 1

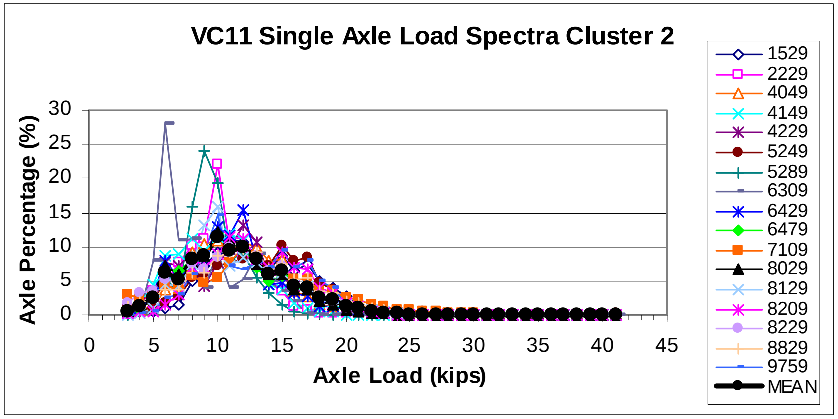

Figure C35. VC11 Single Axle LS for Cluster 2

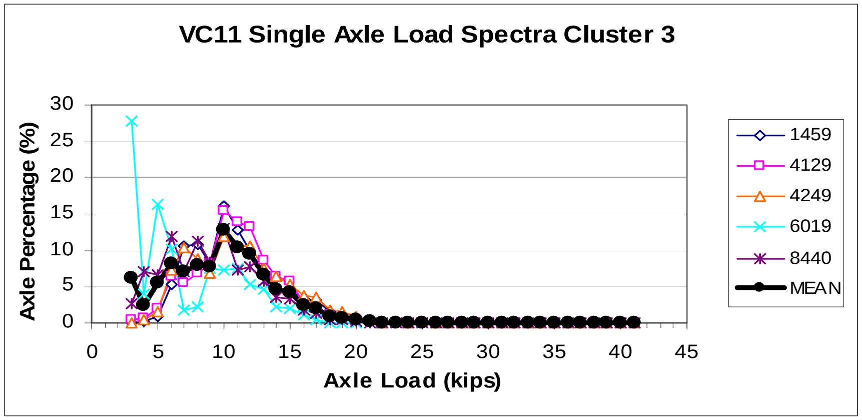

Figure C36. VC11 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC12 Clustering

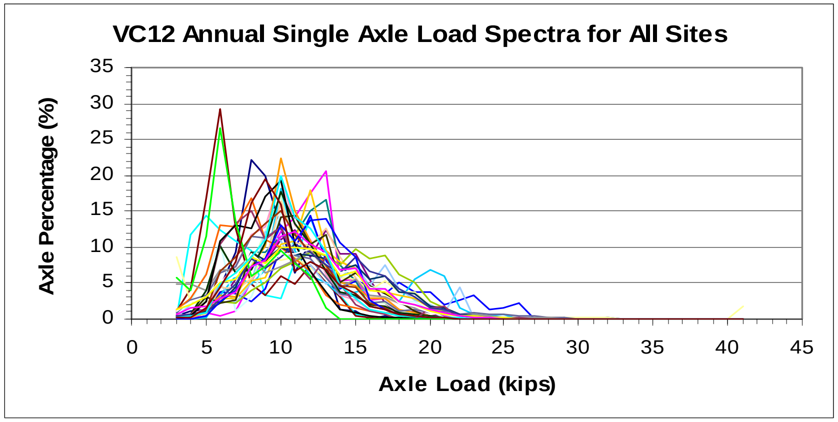

Figure C37. VC12 Single Axle LS for all Analyzed Sites

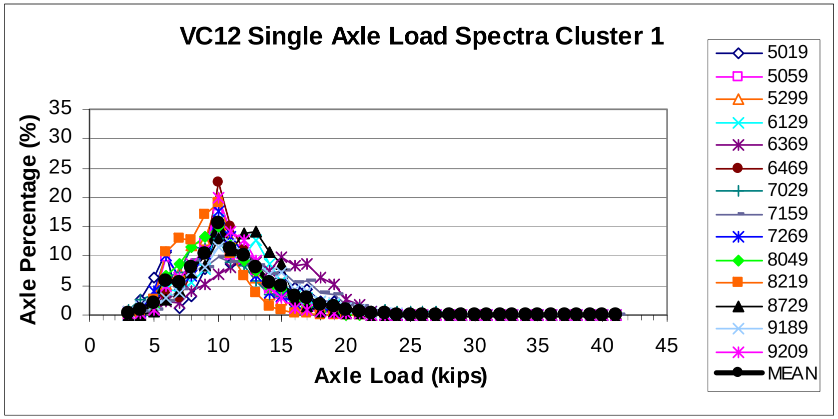

Figure C38. VC12 Single Axle LS for Cluster 1

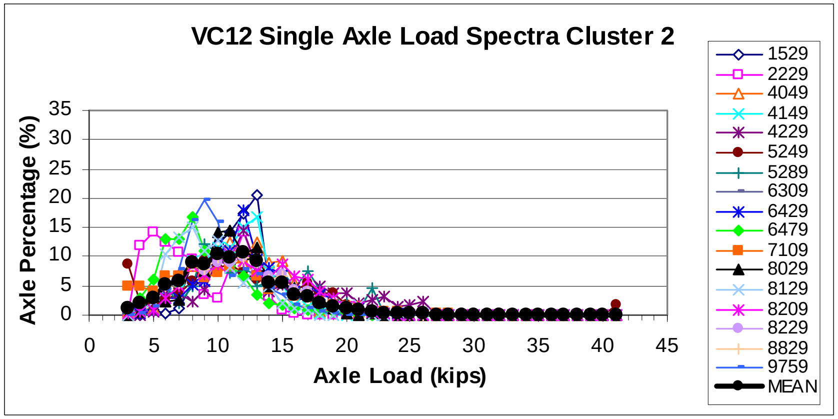

Figure C39. VC12 Single Axle LS for Cluster 2

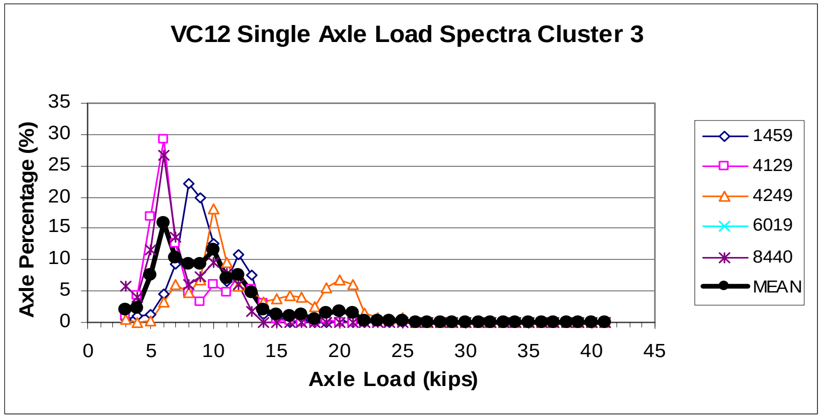

Figure C40. VC12 Single Axle LS for Cluster 3

Single Axle Load Spectra (LS) for VC13 Clustering

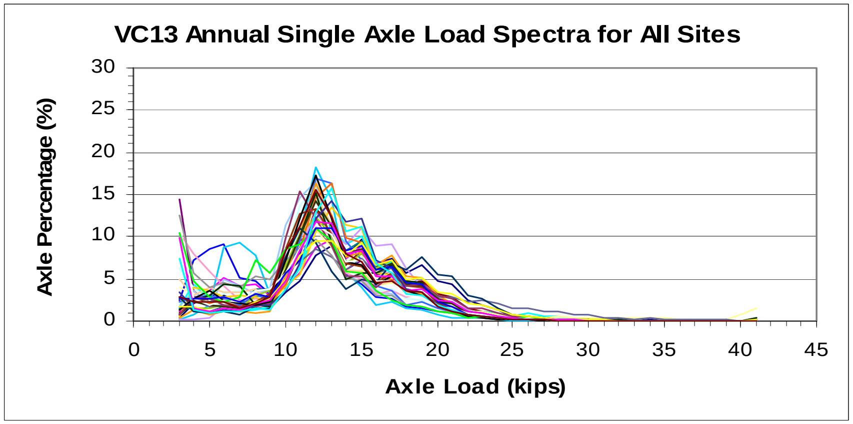

Figure C41. VC13 Single Axle LS for all Analyzed Sites

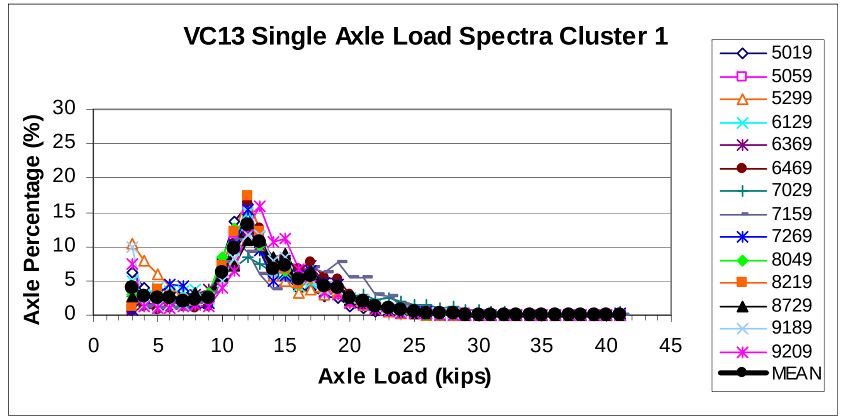

Figure C42. VC13 Single Axle LS for Cluster 1

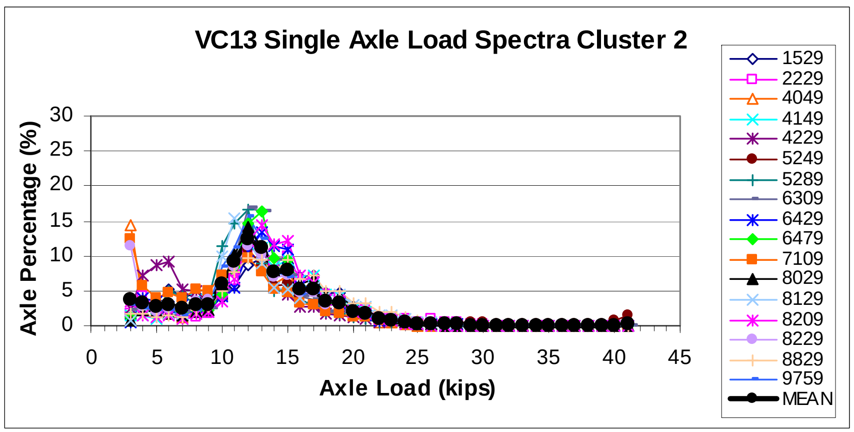

Figure C43. VC13 Single Axle LS for Cluster 2

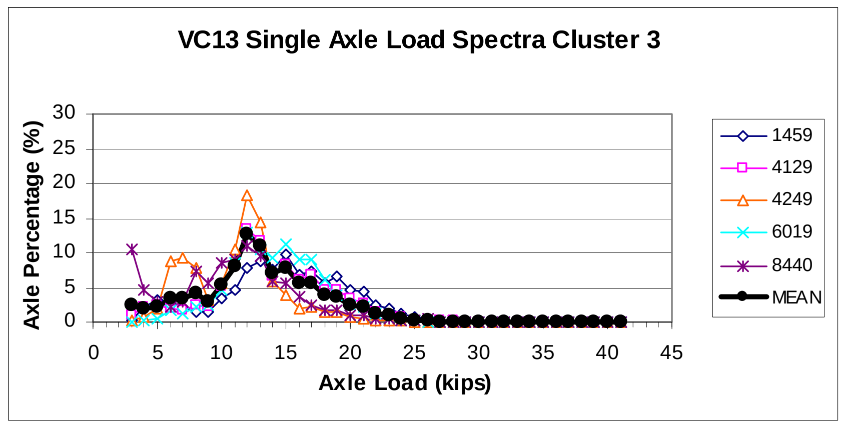

Figure C44. VC13 Single Axle LS for Cluster 3

Appendix D

Cluster Analysis Results-Tandem Axle Load Spectra

All Tandem Axle LS Clustering

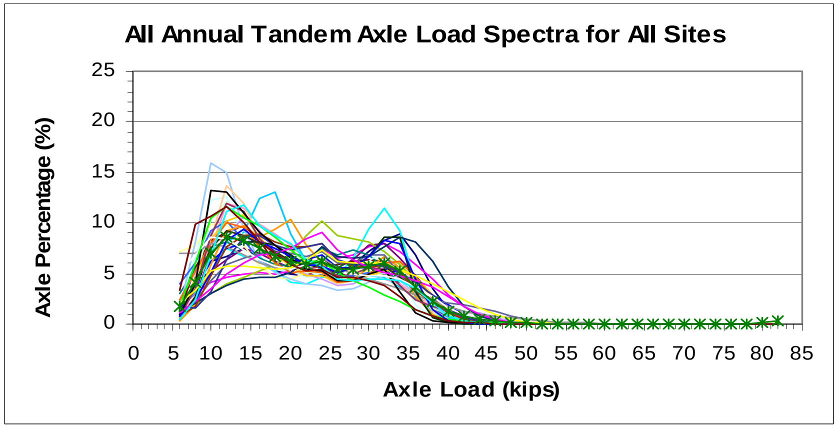

Figure D1. All Tandem Axle LS for all Analyzed Sites

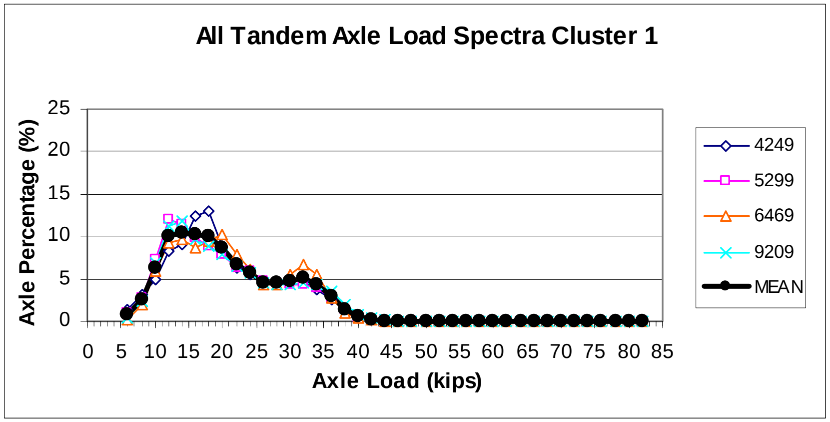

Figure D2. All Tandem Axle LS for Cluster 1

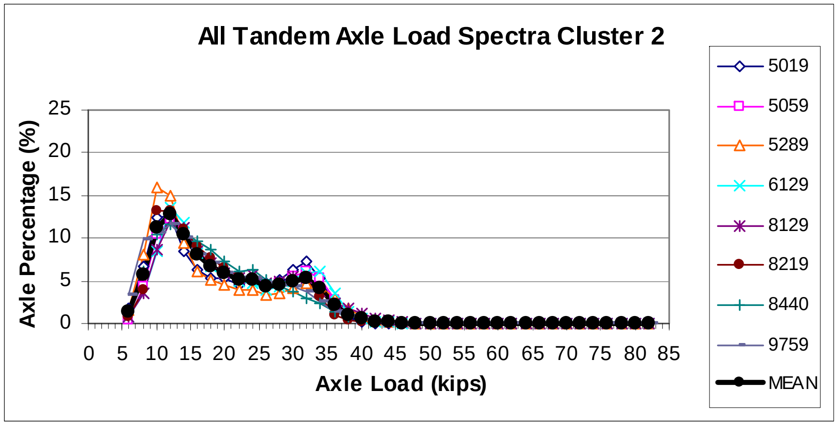

Figure D3. All Tandem Axle LS for Cluster 2

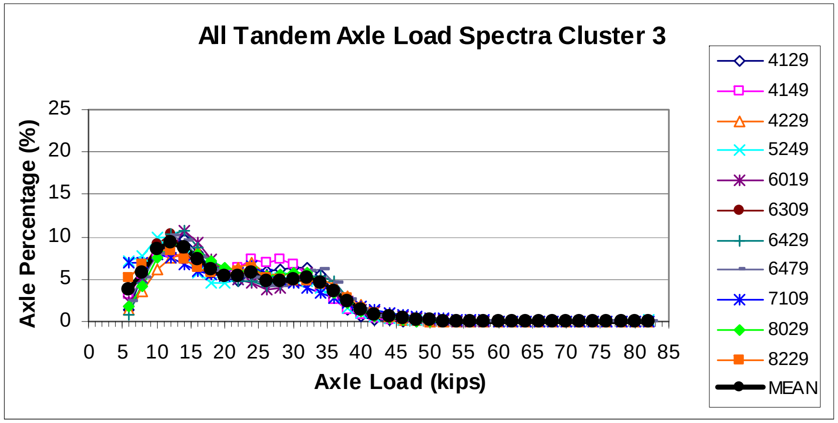

Figure D4. All Tandem Axle LS for Cluster 3

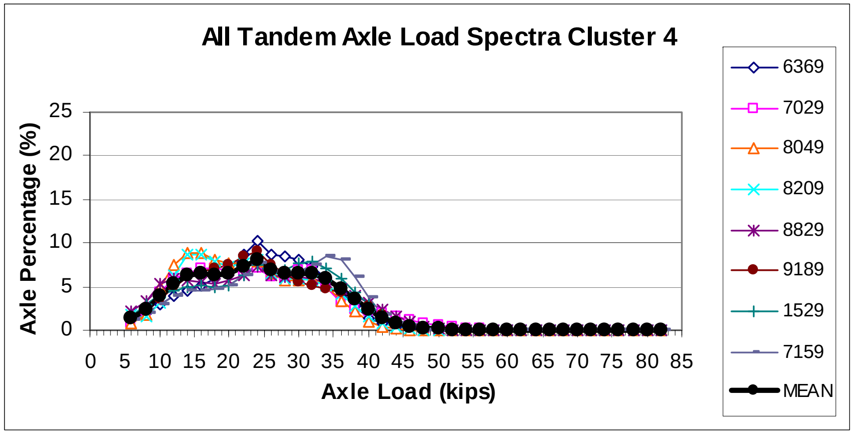

Figure D5. All Tandem Axle LS for Cluster 4

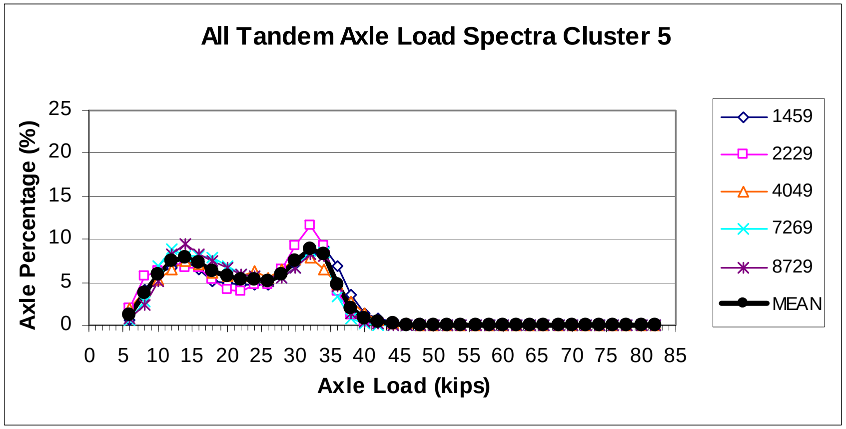

Figure D6. All Tandem Axle LS for Cluster 5

VC4 Tandem Axle LS Clustering

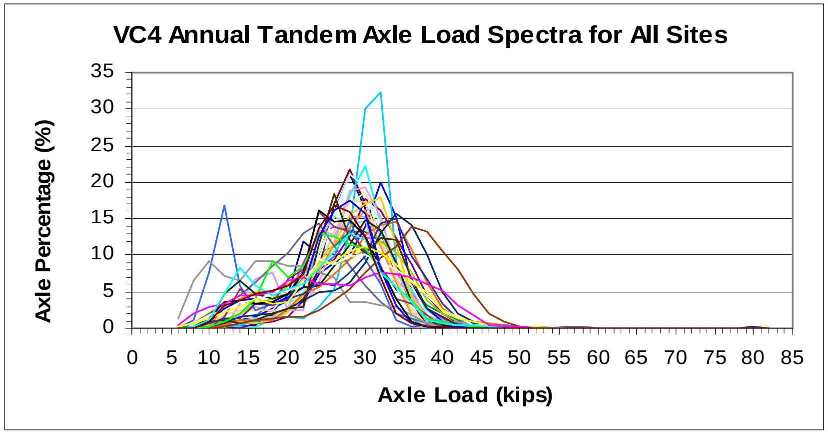

Figure D7. VC4 Tandem Axle LS for all Analyzed Sites

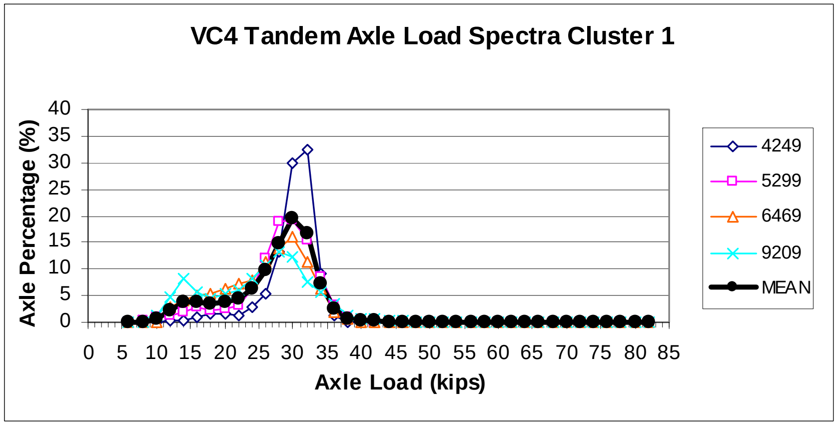

Figure D8. VC4 Tandem Axle LS for Cluster 1

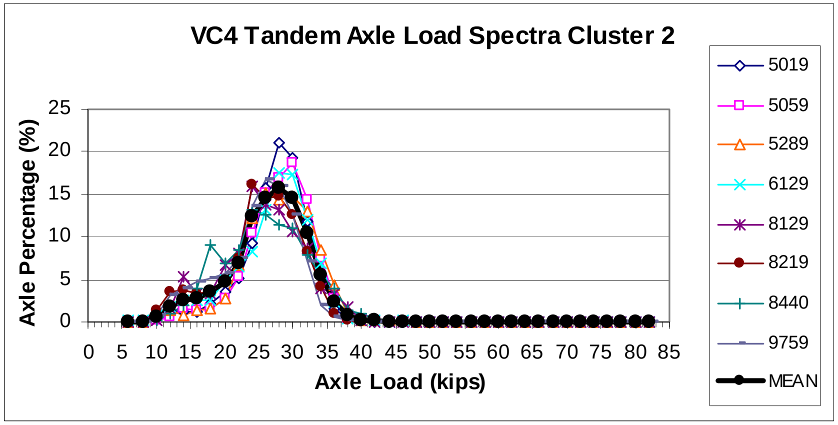

Figure D9. VC4 Tandem Axle LS for Cluster 2

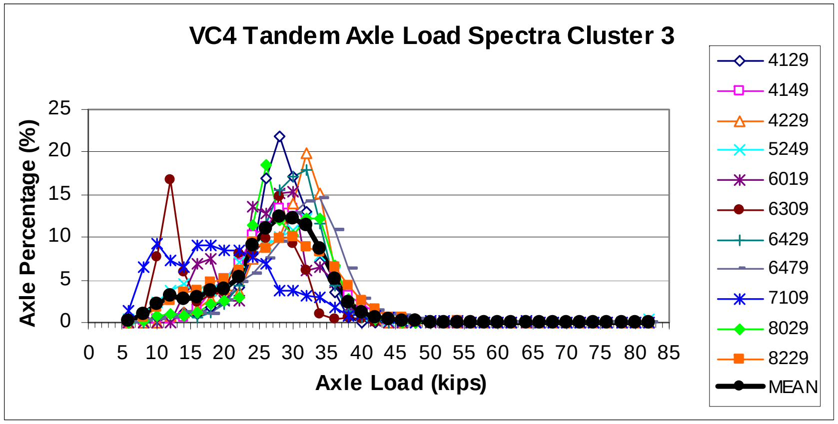

Figure D10. VC4 Tandem Axle LS for Cluster 3

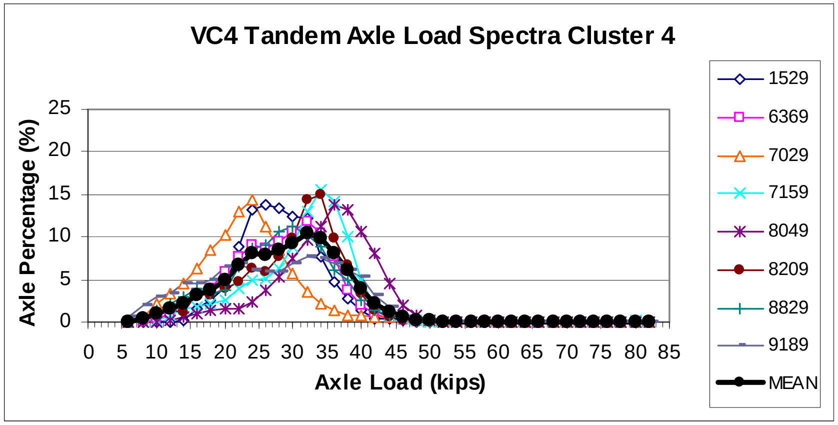

Figure D11. VC4 Tandem Axle LS for Cluster 4

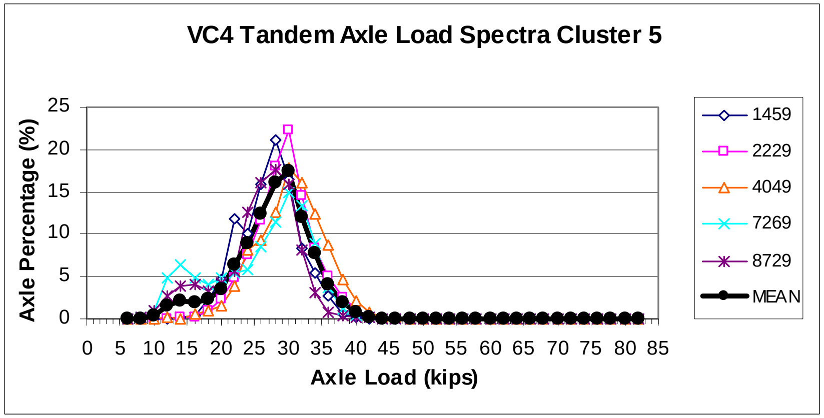

Figure D12. VC4 Tandem Axle LS for Cluster 5

VC5 Tandem Axle LS Clustering

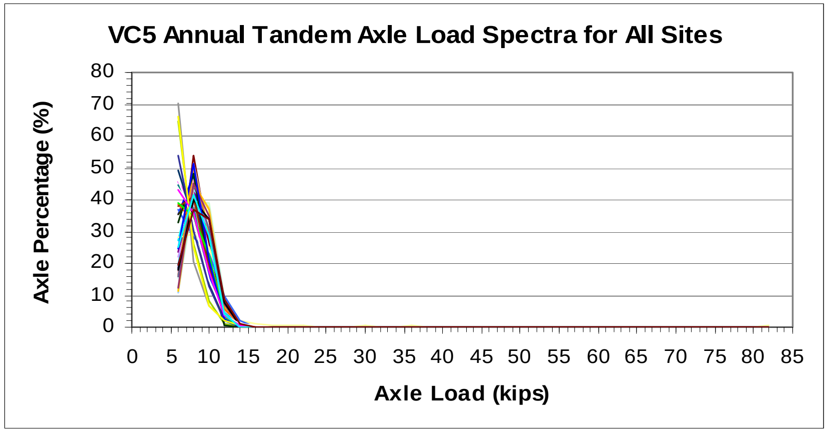

Figure D13. VC5 Tandem Axle LS for all Analyzed Sites

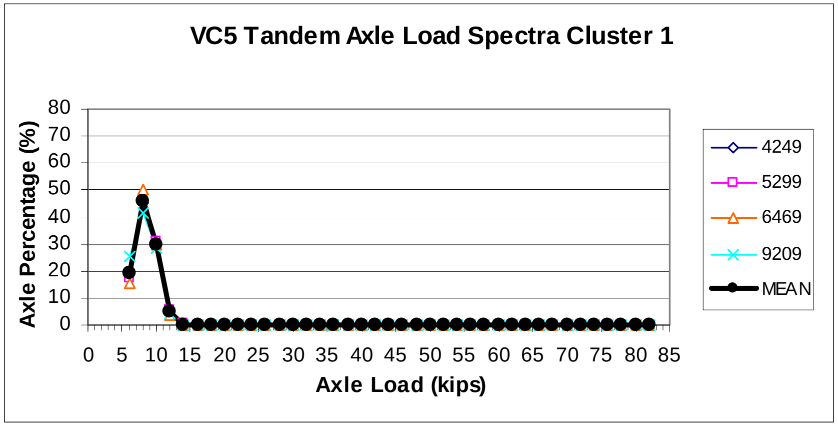

Figure D14. VC5 Tandem Axle LS for Cluster 1

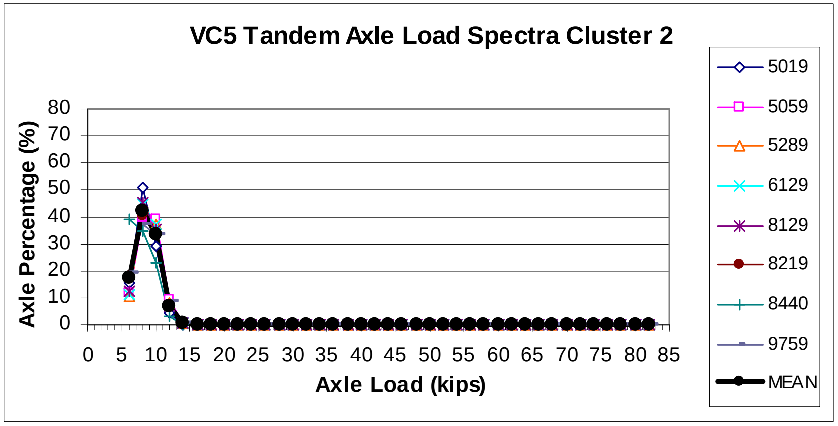

Figure D15. VC5 Tandem Axle LS for Cluster 2

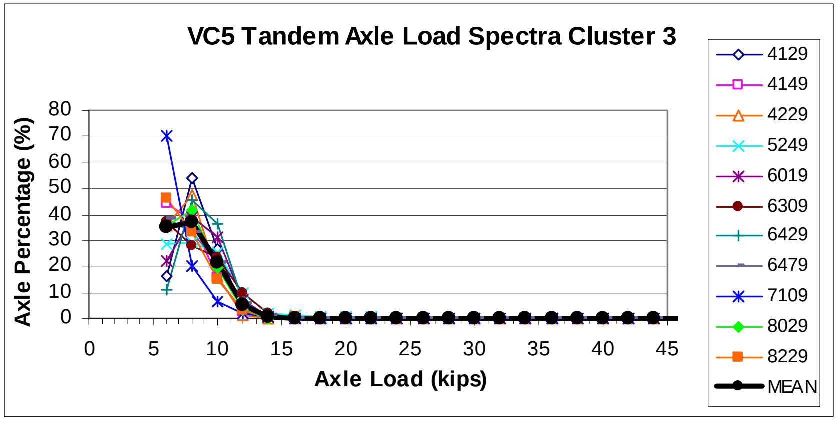

Figure D16. VC5 Tandem Axle LS for Cluster 3

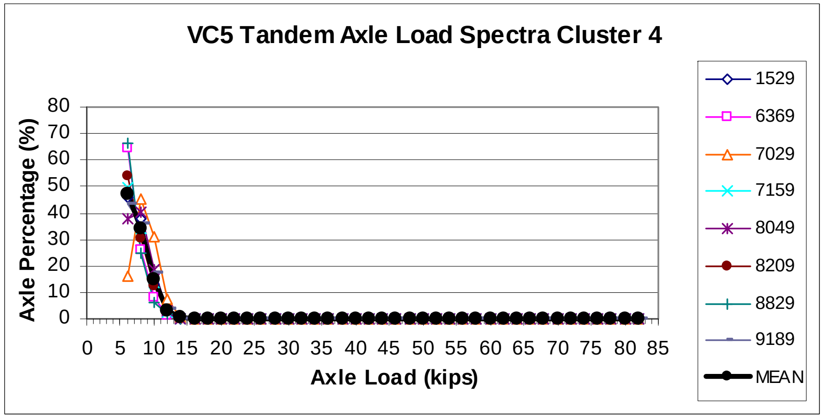

Figure D17. VC5 Tandem Axle LS for Cluster 4

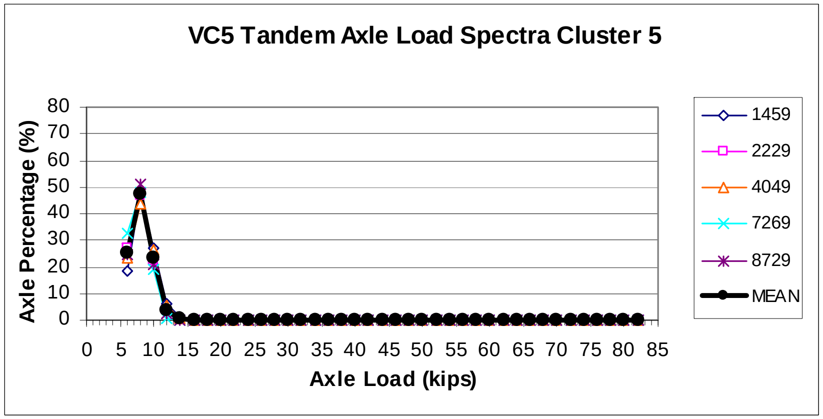

Figure D18. VC5 Tandem Axle LS for Cluster 5

VC6 Tandem Axle LS Clustering

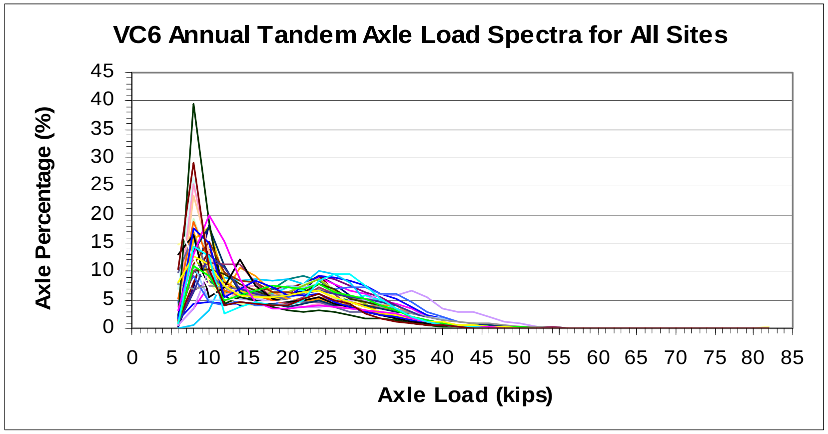

Figure D19. VC6 Tandem Axle LS for all Analyzed Sites

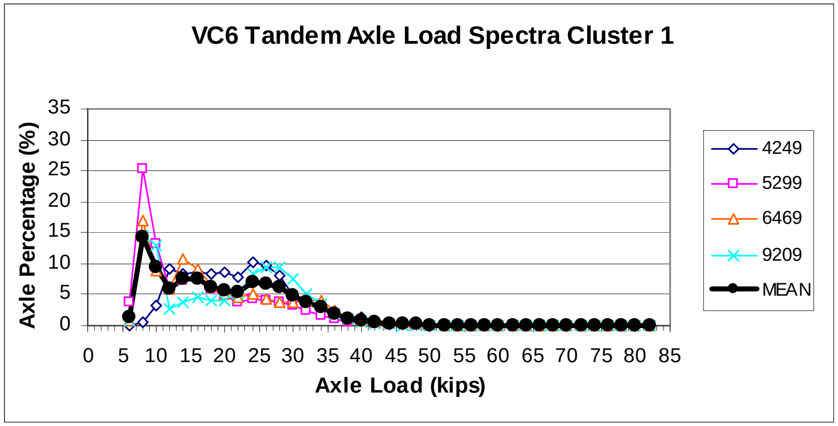

Figure D20. VC6 Tandem Axle LS for Cluster 1

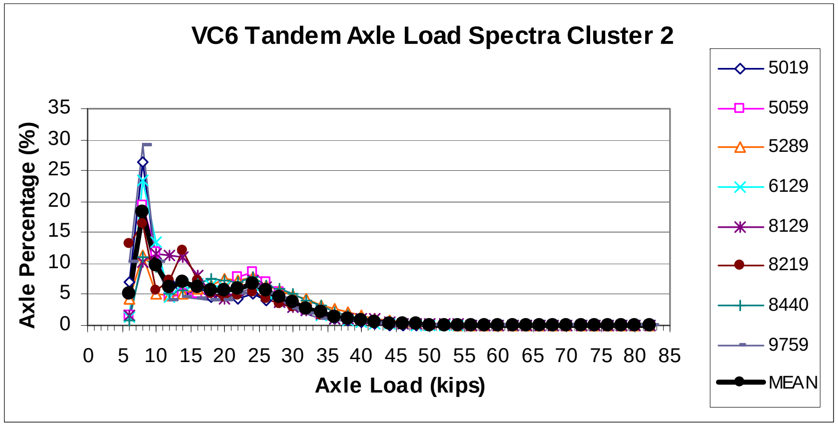

Figure D21. VC6 Tandem Axle LS for Cluster 2

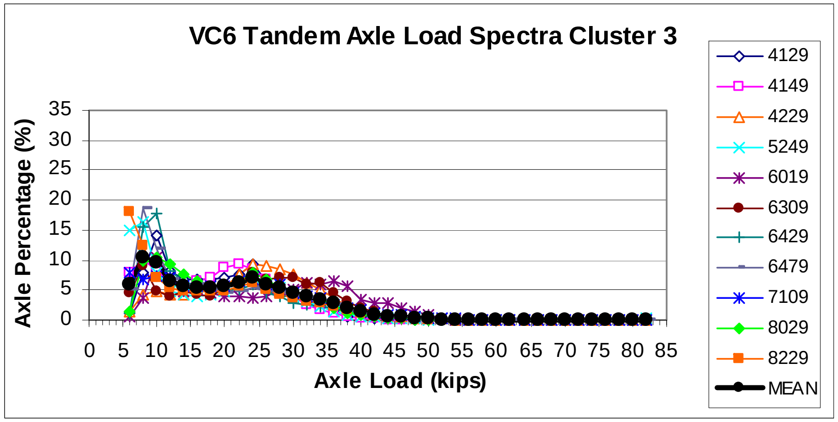

Figure D22. VC6 Tandem Axle LS for Cluster 3

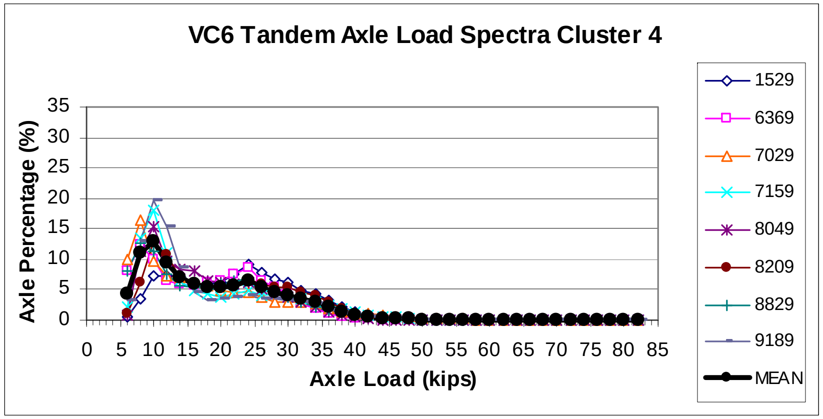

Figure D23. VC6 Tandem Axle LS for Cluster 4

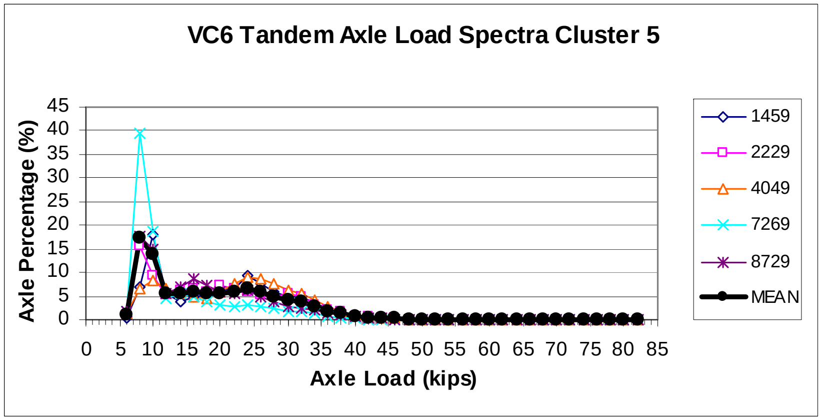

Figure D24. VC6 Tandem Axle LS for Cluster 5

VC7 Tandem Axle LS Clustering

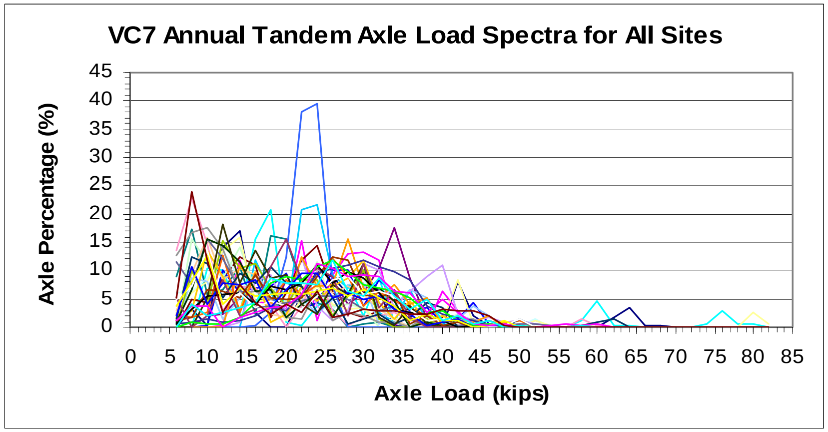

Figure D25. VC7 Tandem Axle LS for all Analyzed Sites

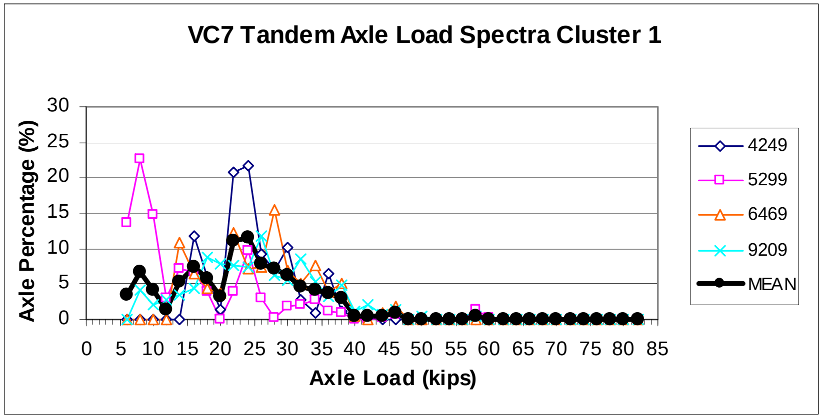

Figure D26. VC7 Tandem Axle LS for Cluster 1

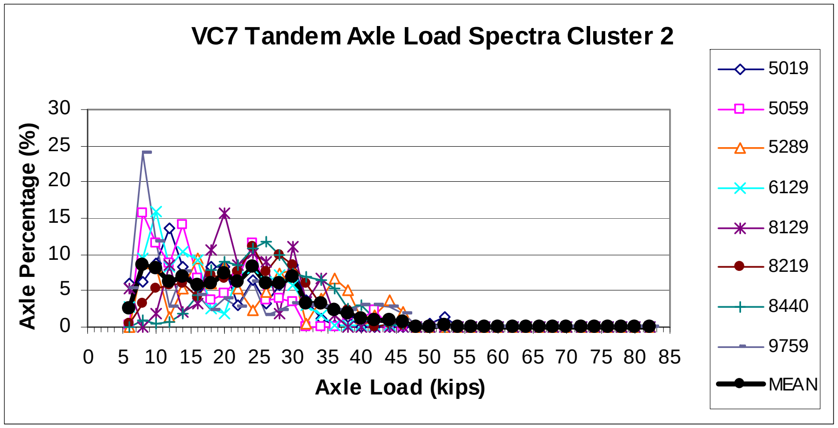

Figure D27. VC7 Tandem Axle LS for Cluster 2

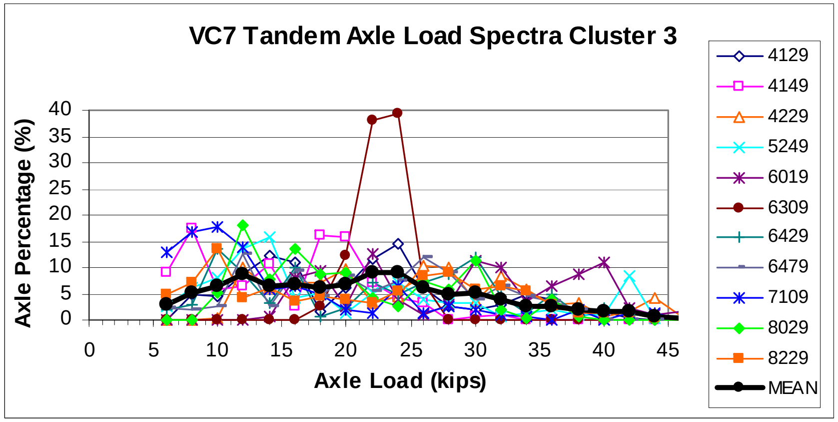

Figure D28. VC7 Tandem Axle LS for Cluster 3

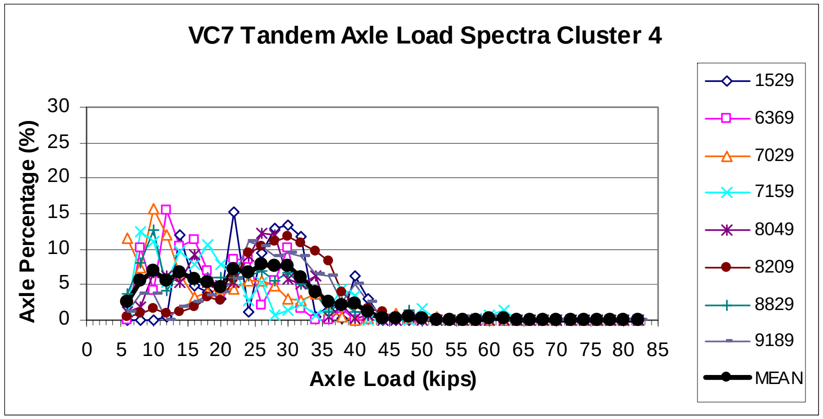

Figure D29. VC7 Tandem Axle LS for Cluster 4

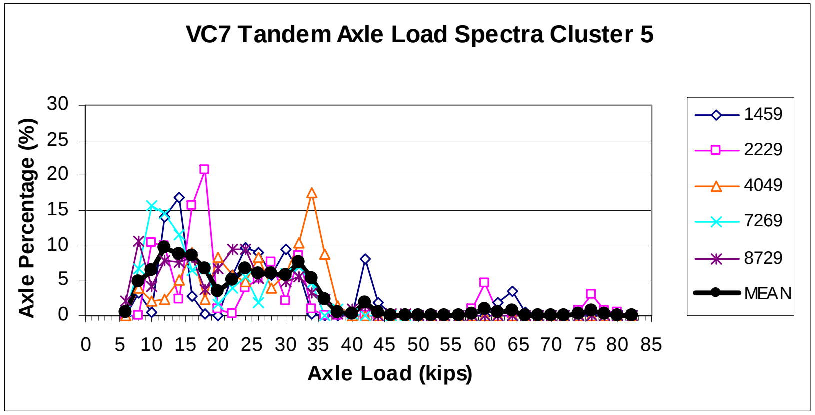

Figure D30. VC7 Tandem Axle LS for Cluster 5

VC8 Tandem Axle LS Clustering

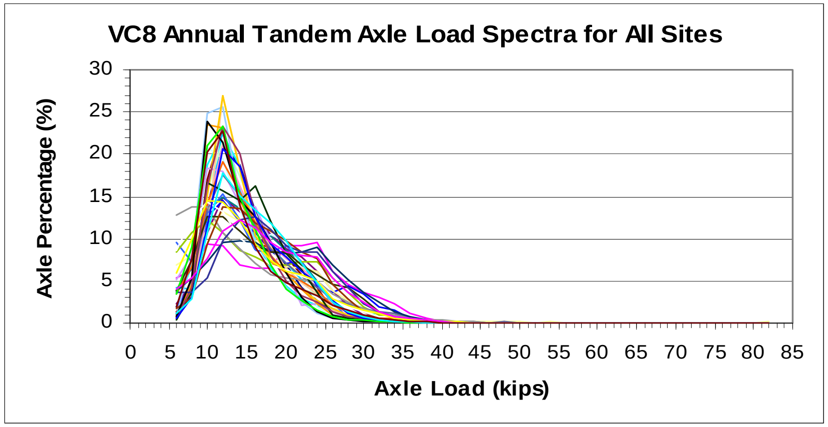

Figure D31. VC8 Tandem Axle LS for all Analyzed Sites

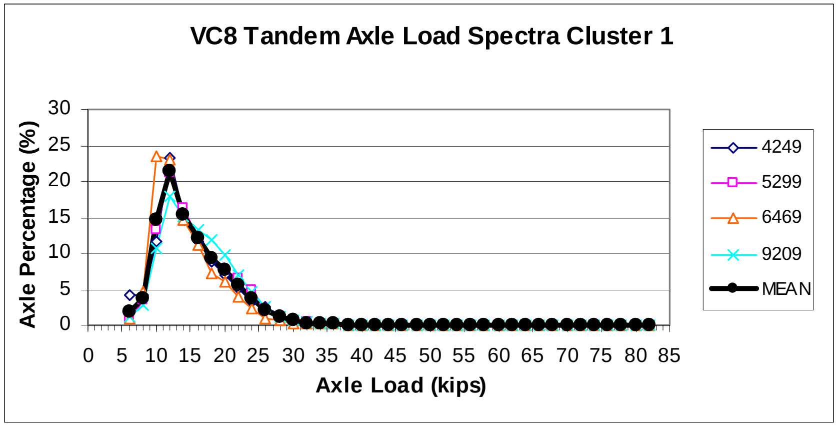

Figure D32. VC8 Tandem Axle LS for Cluster 1

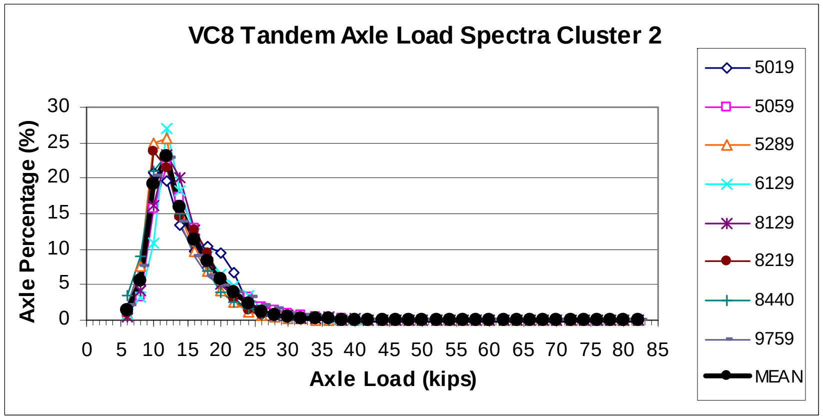

Figure D33. VC8 Tandem Axle LS for Cluster 2

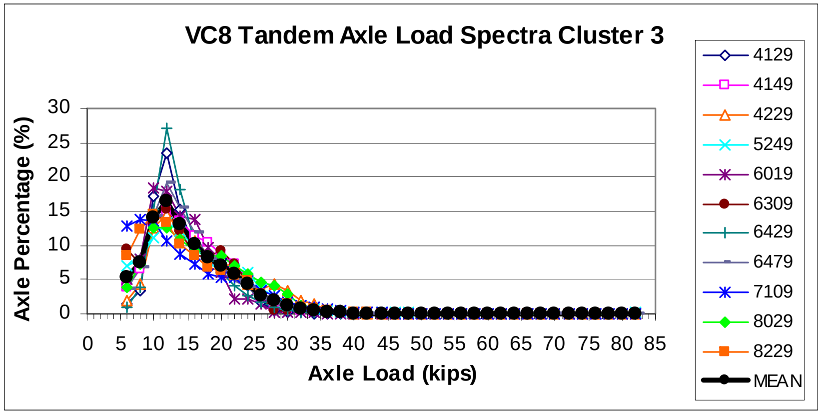

Figure D34. VC8 Tandem Axle LS for Cluster 3

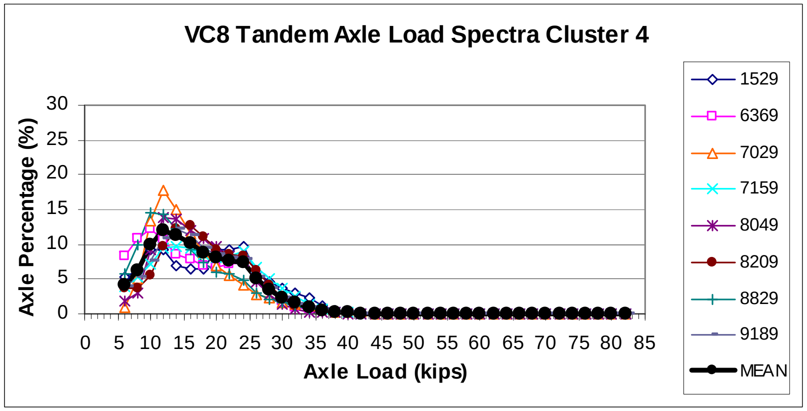

Figure D35. VC8 Tandem Axle LS for Cluster 4

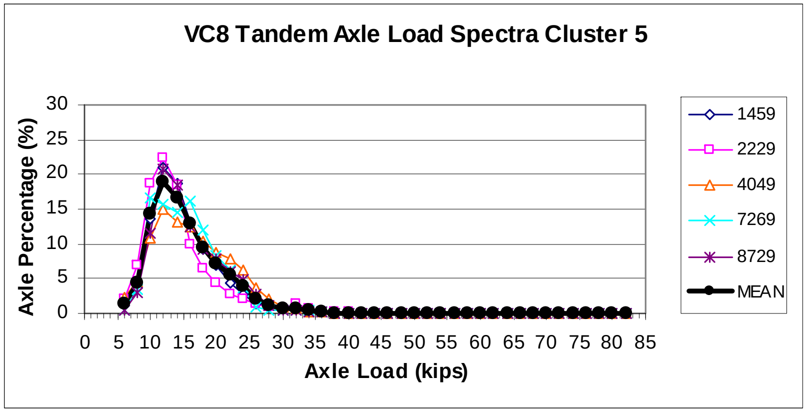

Figure D36. VC8 Tandem Axle LS for Cluster 5

VC9 Tandem Axle LS Clustering

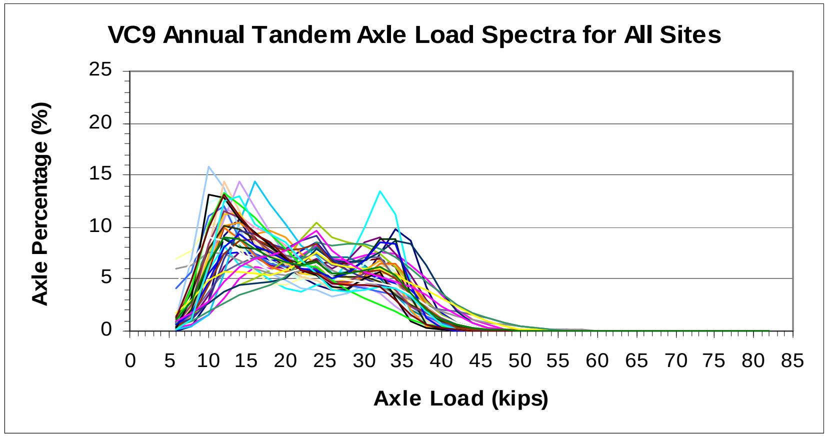

Figure D37. VC9 Tandem Axle LS for all Analyzed Sites

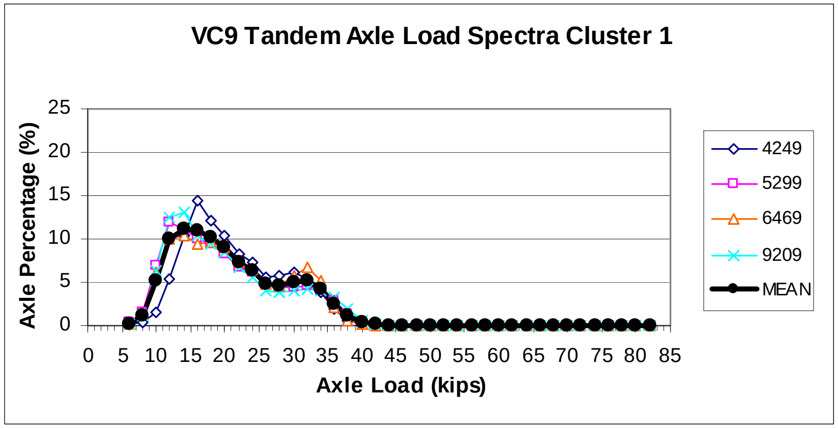

Figure D38. VC9 Tandem Axle LS for Cluster 1

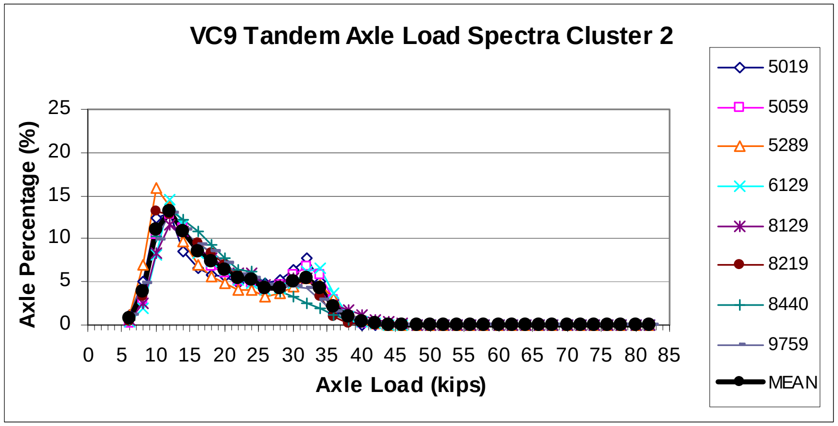

Figure D39. VC9 Tandem Axle LS for Cluster 2

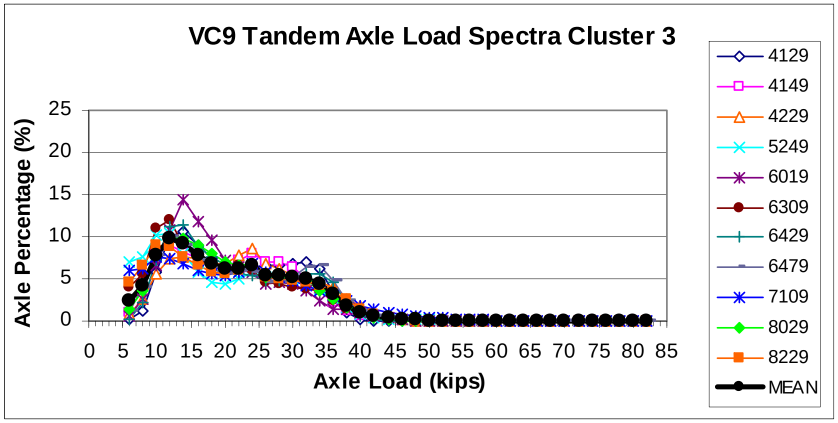

Figure D40. VC9 Tandem Axle LS for Cluster 3

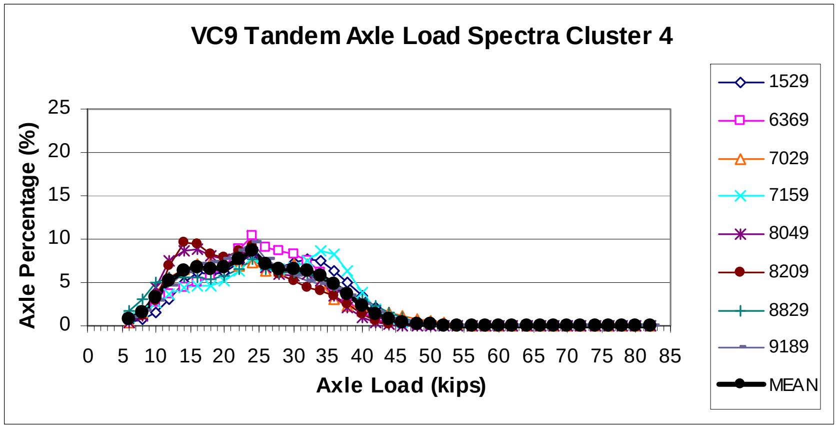

Figure D41. VC9 Tandem Axle LS for Cluster 4

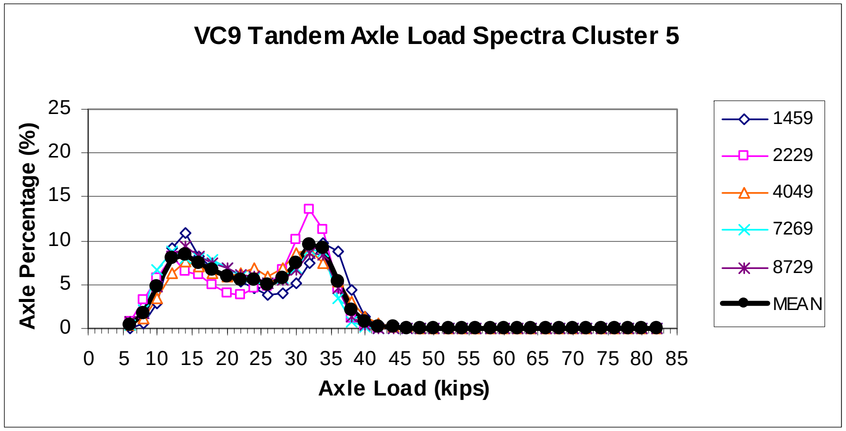

Figure D42. VC9 Tandem Axle LS for Cluster 5

VC10 Tandem Axle LS Clustering

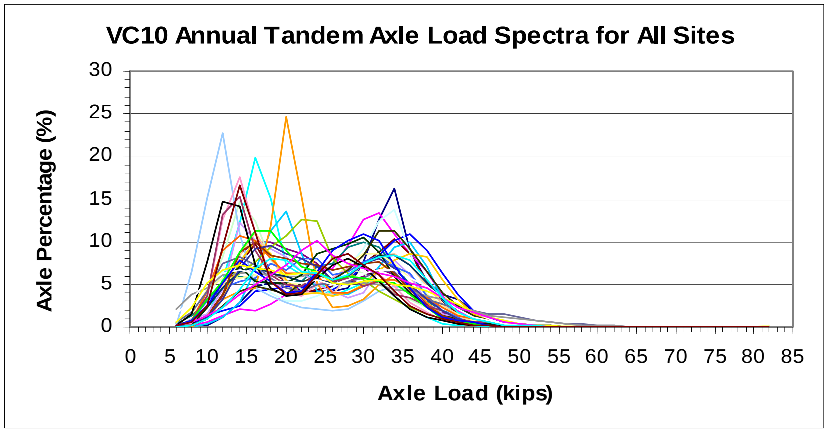

Figure D43. VC10 Tandem Axle LS for all Analyzed Sites

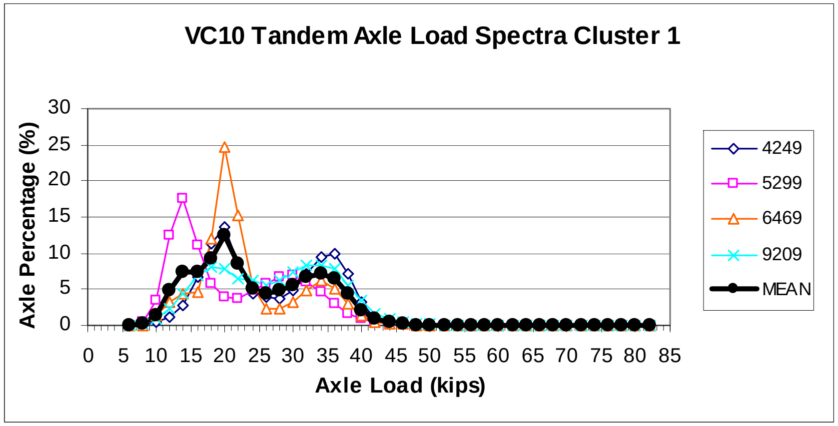

Figure D44. VC10 Tandem Axle LS for Cluster 1

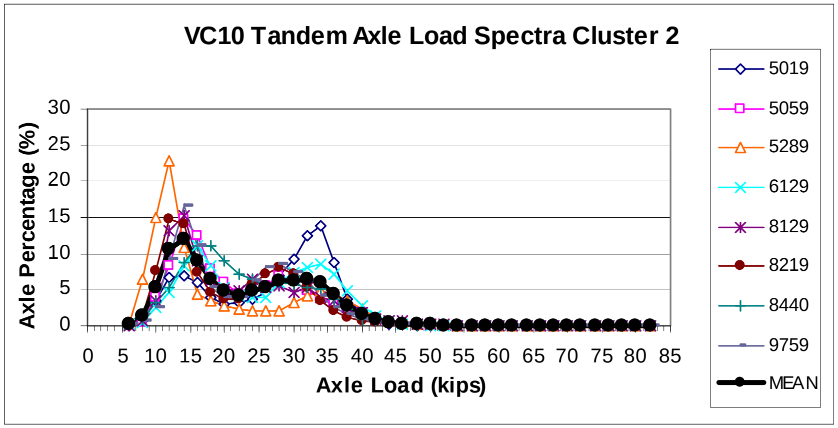

Figure D45. VC10 Tandem Axle LS for Cluster 2

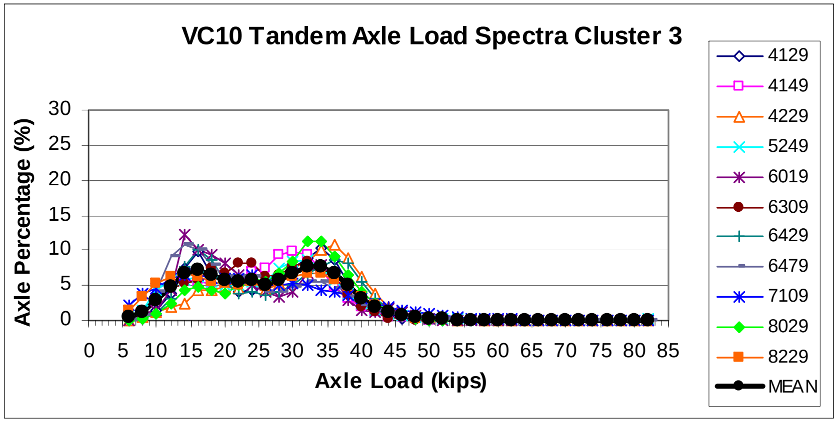

Figure D46. VC10 Tandem Axle LS for Cluster 3

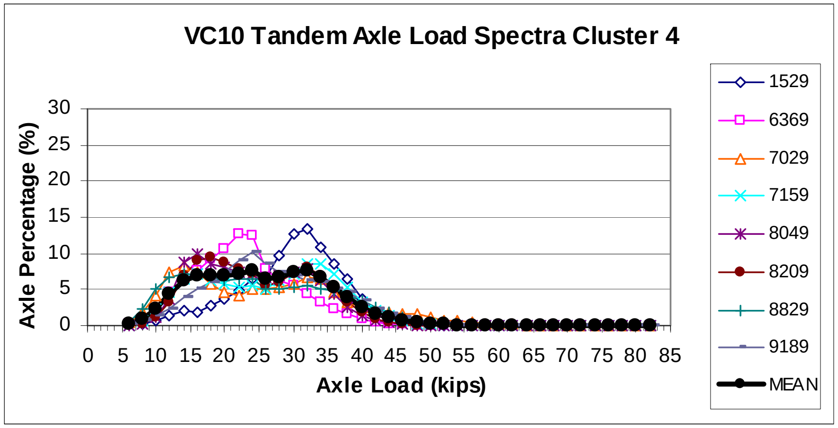

Figure D47. VC10 Tandem Axle LS for Cluster 4

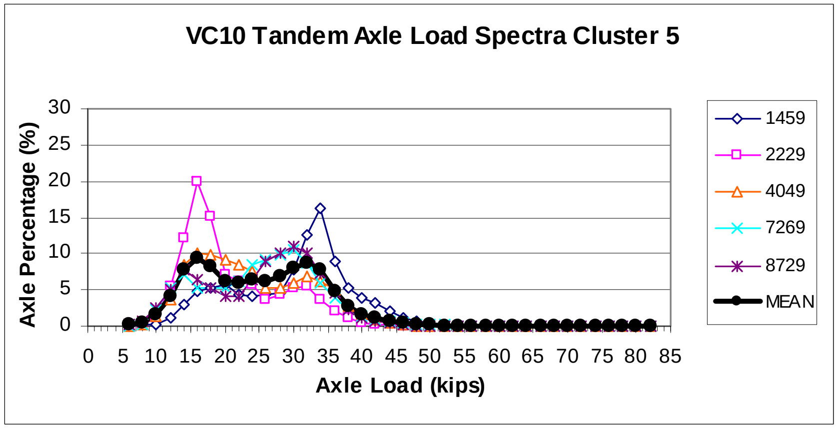

Figure D48. VC10 Tandem Axle LS for Cluster 5

VC12 Tandem Axle LS Clustering

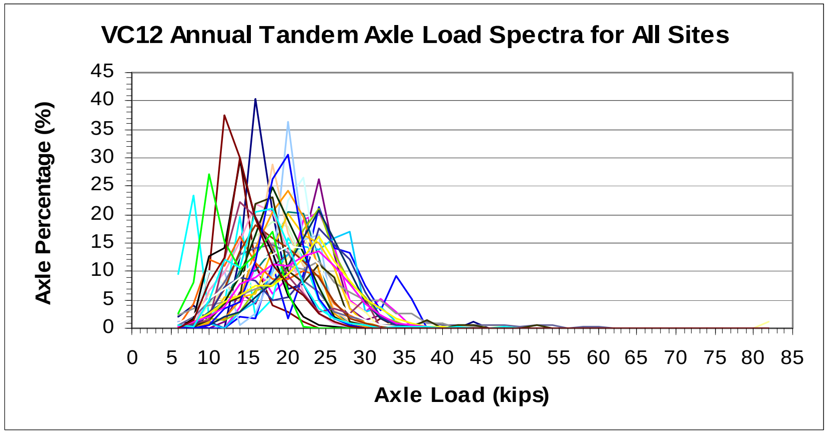

Figure D49. VC12 Tandem Axle LS for all Analyzed Sites

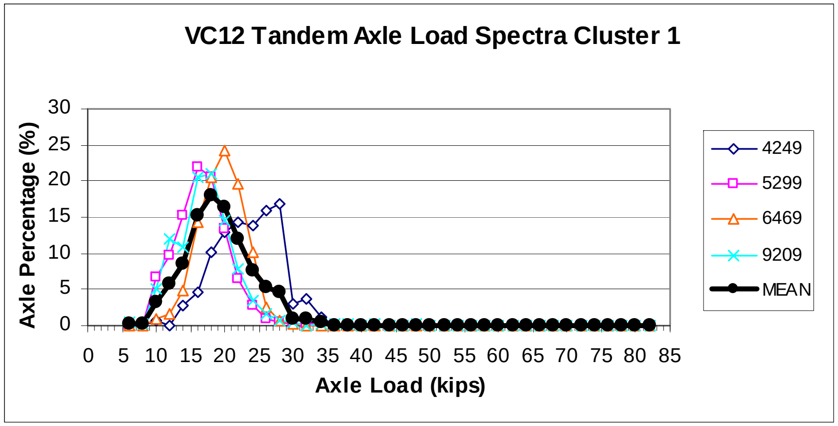

Figure D50. VC12 Tandem Axle LS for Cluster 1

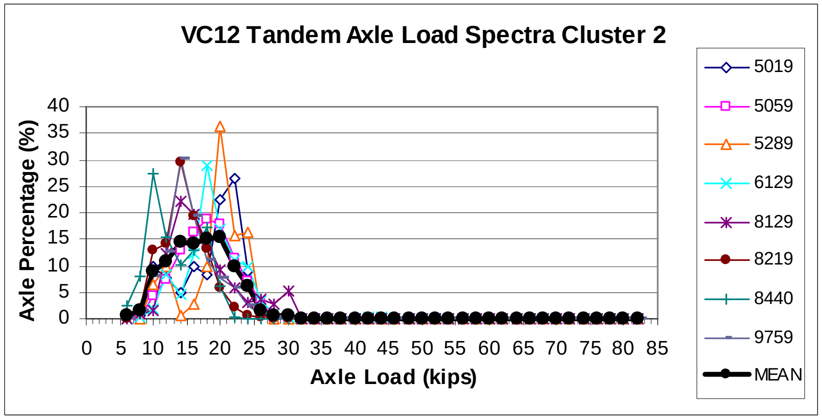

Figure D51. VC12 Tandem Axle LS for Cluster 2

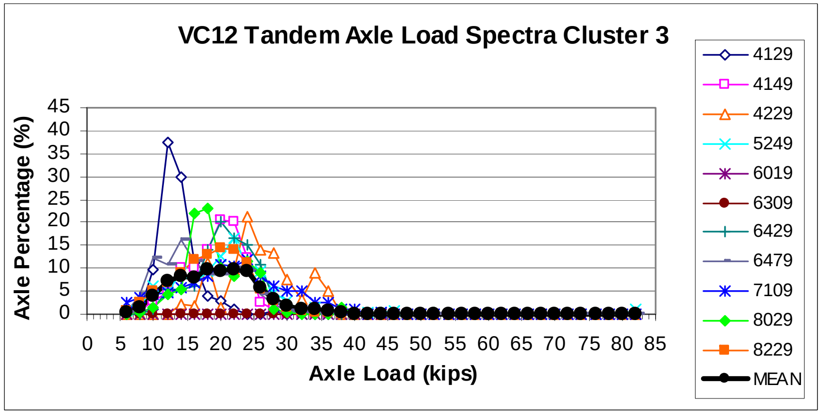

Figure D52. VC12 Tandem Axle LS for Cluster 3

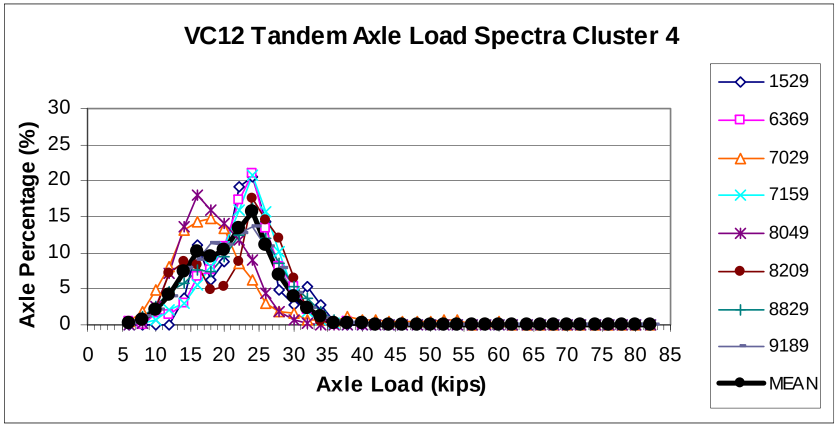

Figure D53. VC12 Tandem Axle LS for Cluster 4

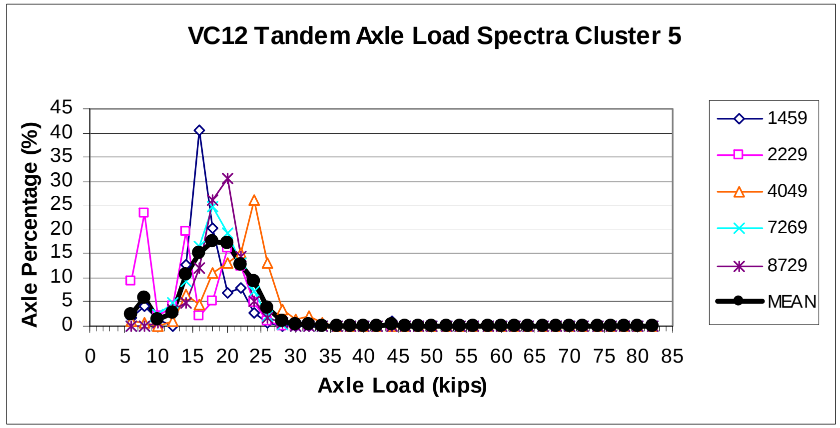

Figure D54. VC12 Tandem Axle LS for Cluster 5

VC13 Tandem Axle LS Clustering

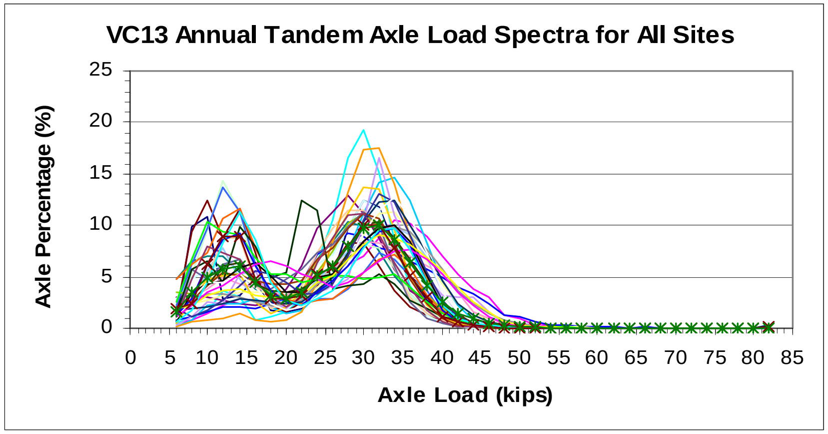

Figure D55. VC13 Tandem Axle LS for all Analyzed Sites

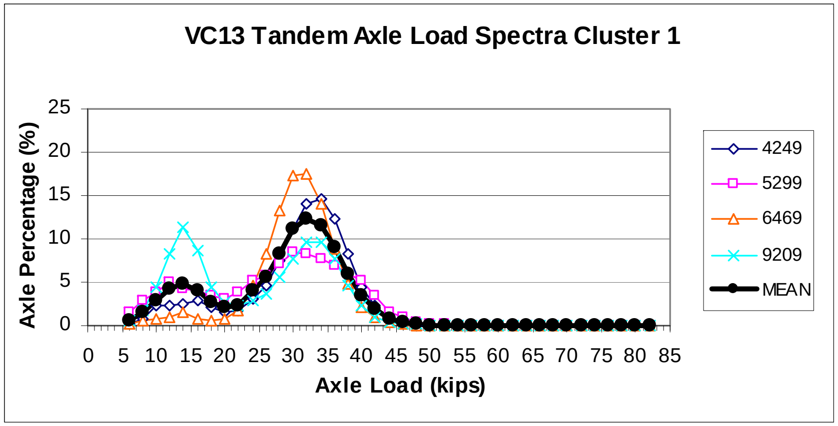

Figure D56. VC13 Tandem Axle LS for Cluster 1

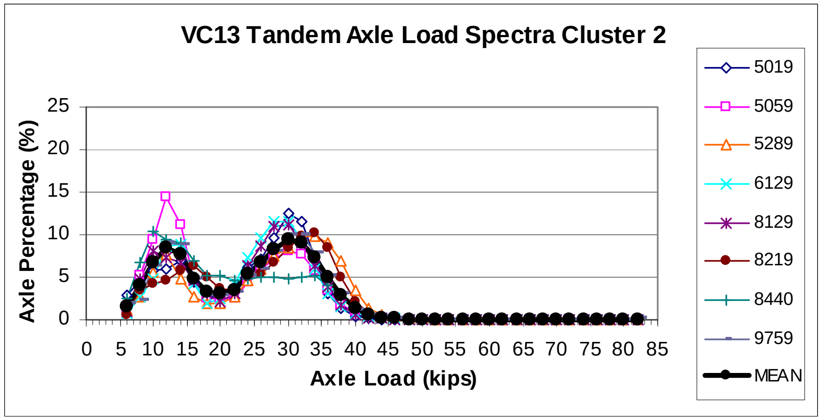

Figure D57. VC13 Tandem Axle LS for Cluster 2

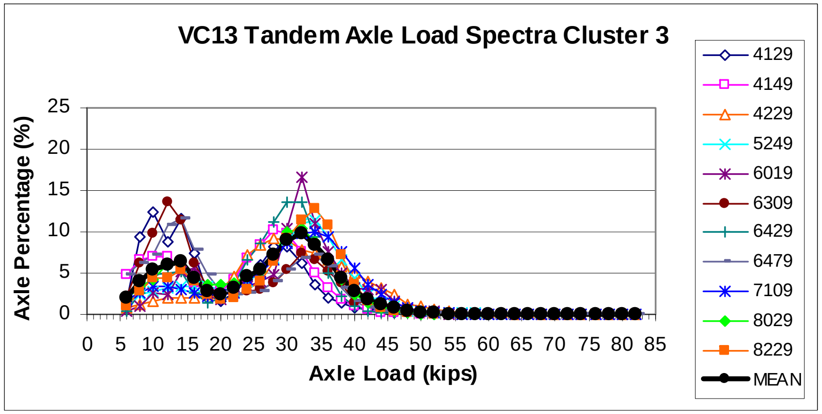

Figure D58. VC13 Tandem Axle LS for Cluster 3

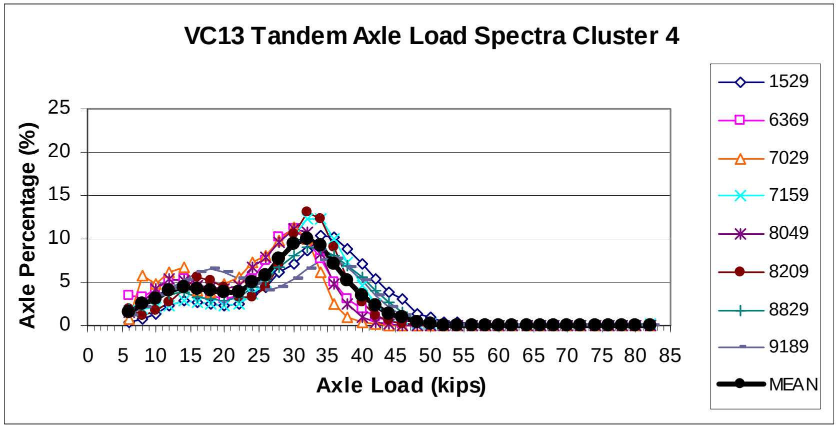

Figure D59. VC13 Tandem Axle LS for Cluster 4

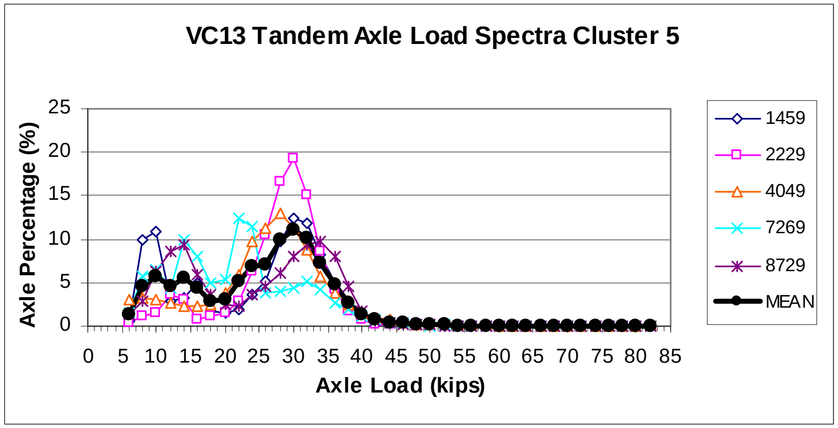

Figure D60. VC13 Tandem Axle LS for Cluster 5

Appendix E

Cluster Analysis Results-Tridem Axle Load Spectra

All Tridem Axle LS Clustering

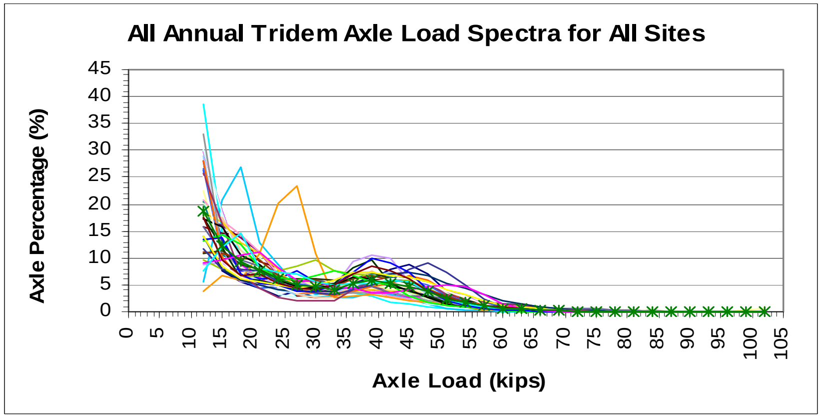

Figure E1. All Tridem Axle LS for all Analyzed Sites

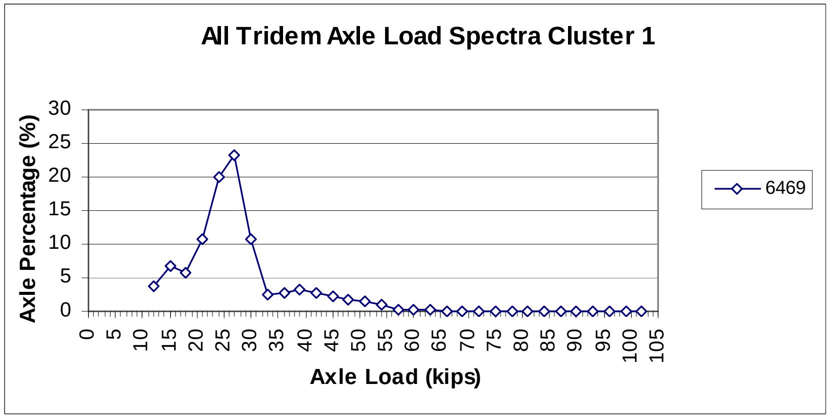

Figure E2. All Tridem Axle LS for Cluster 1

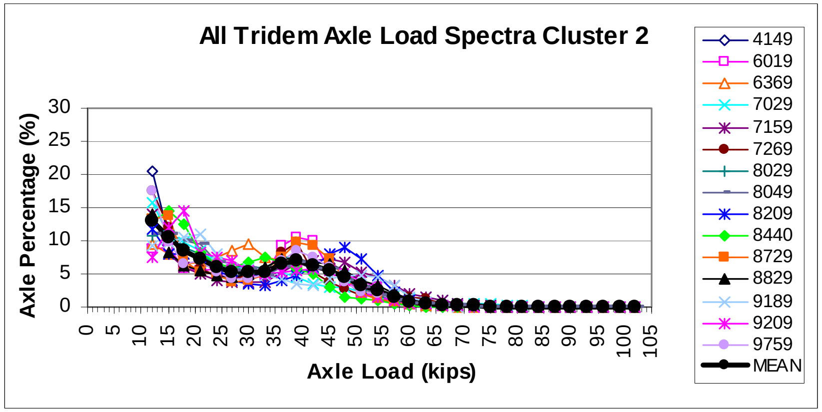

Figure E3. All Tridem Axle LS for Cluster 2

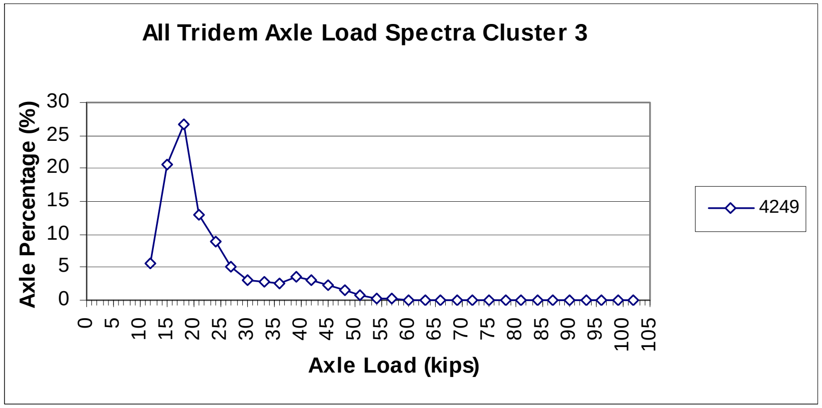

Figure E4. All Tridem Axle LS for Cluster 3

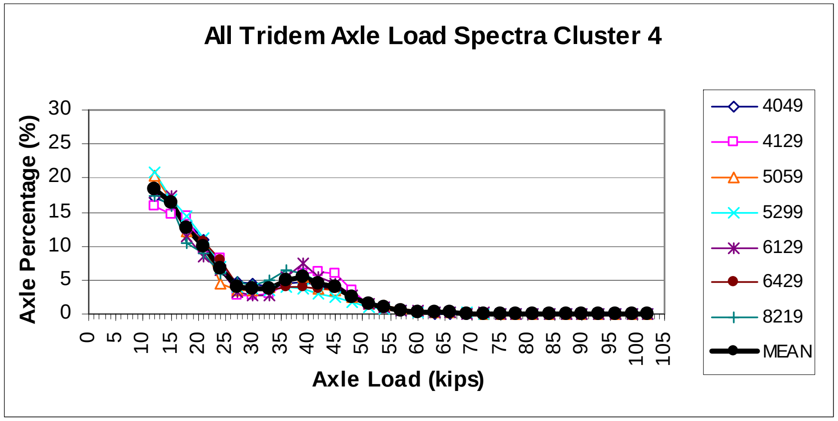

Figure E5. All Tridem Axle LS for Cluster 4

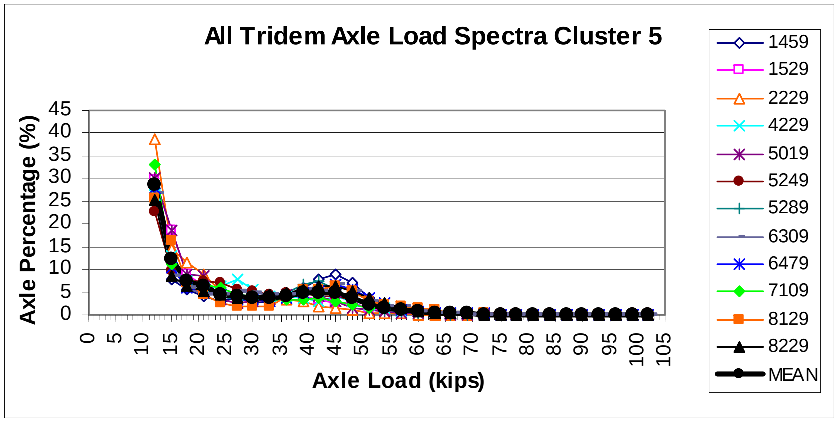

Figure E6. All Tridem Axle LS for Cluster 5

VC7 Tridem Axle LS Clustering

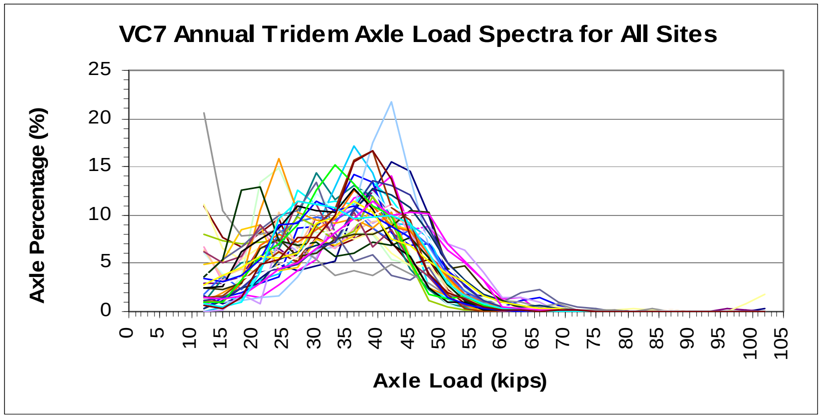

Figure E7. VC7 Tridem Axle LS for all Analyzed Sites

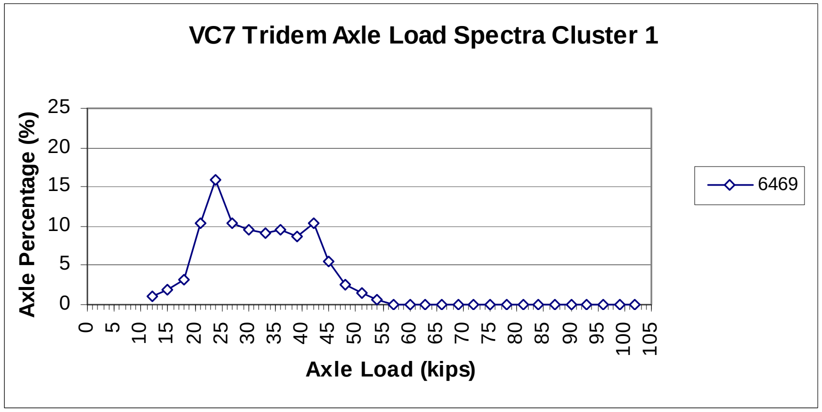

Figure E8. VC7 Tridem Axle LS for Cluster 1

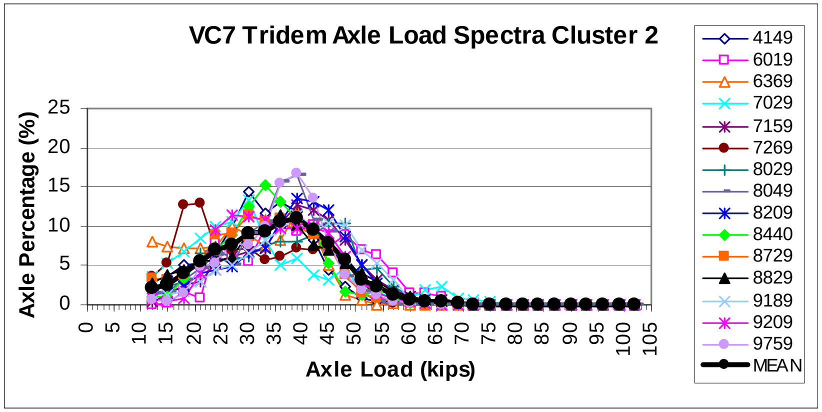

Figure E9. VC7 Tridem Axle LS for Cluster 2

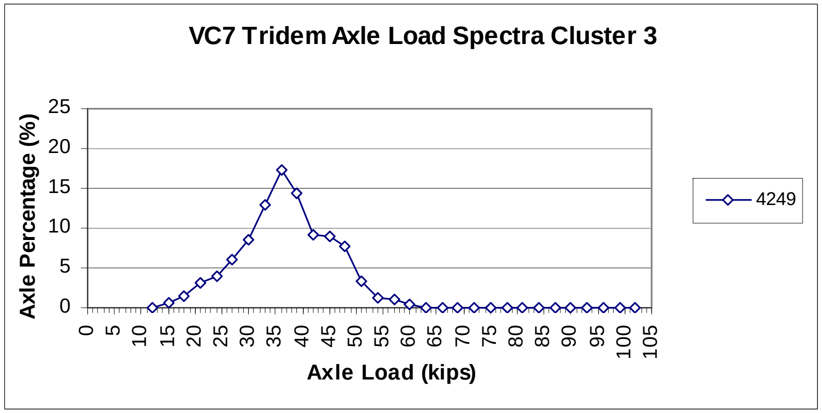

Figure E10. VC7 Tridem Axle LS for Cluster 3

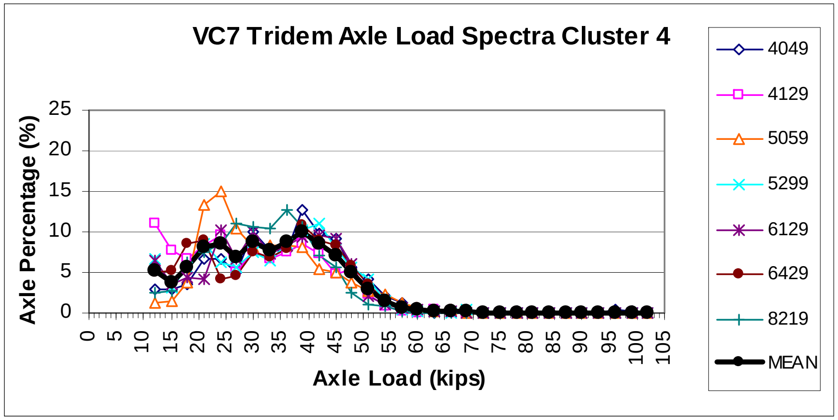

Figure E11. VC7 Tridem Axle LS for Cluster 4

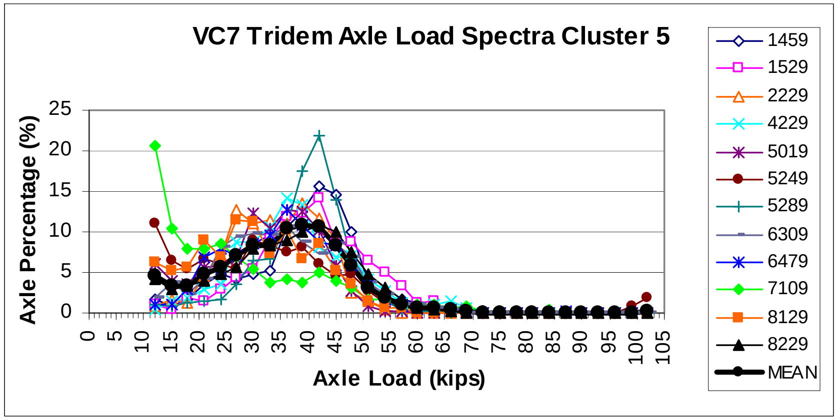

Figure E12. VC7 Tridem Axle LS for Cluster 5

VC10 Tridem Axle LS Clustering

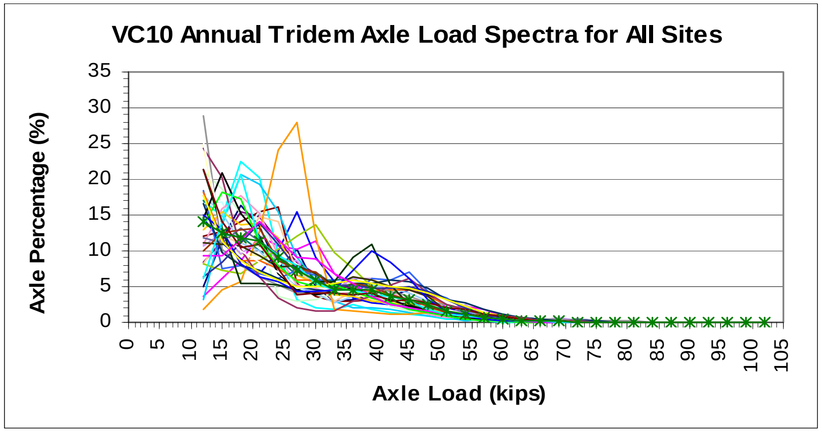

Figure E13. VC10 Tridem Axle LS for all Analyzed Sites

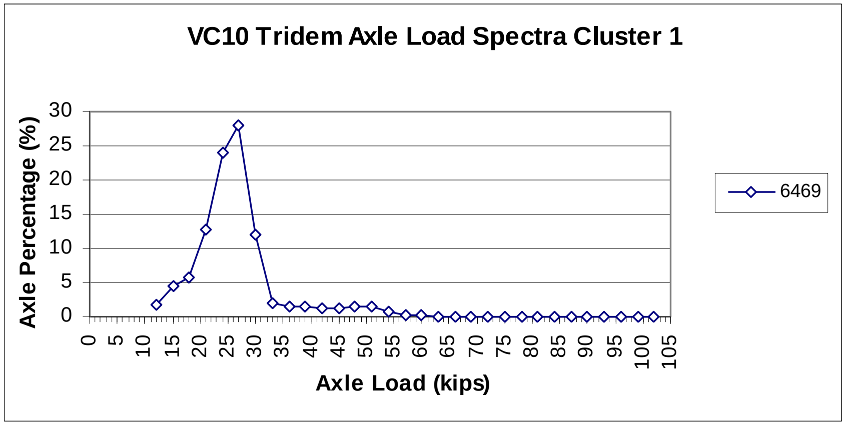

Figure E14. VC10 Tridem Axle LS for Cluster 1

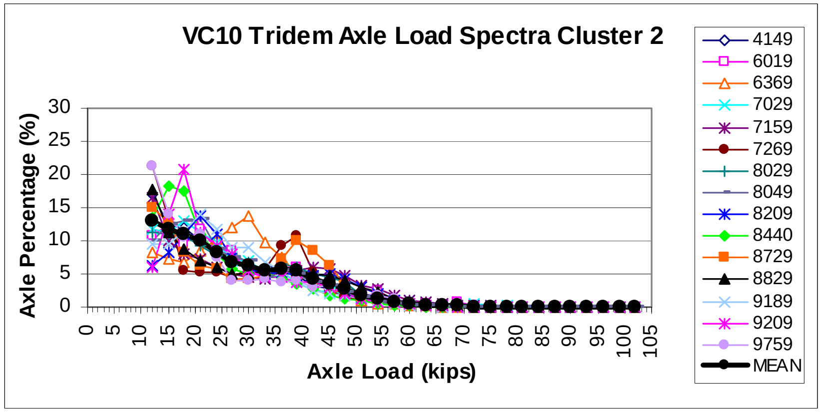

Figure E15. VC10 Tridem Axle LS for Cluster 2

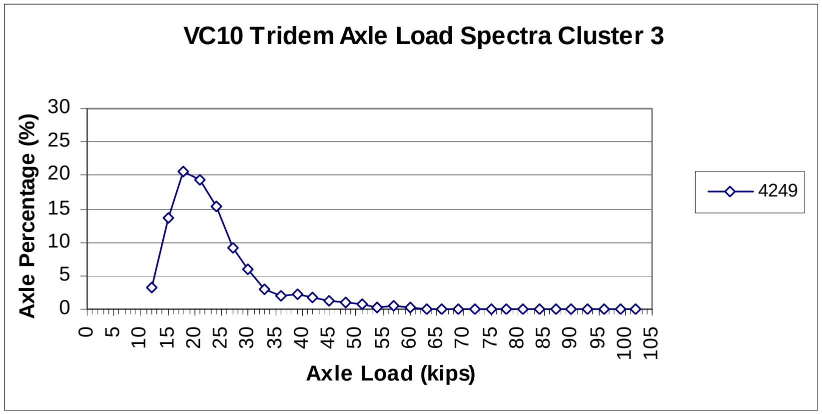

Figure E16. VC10 Tridem Axle LS for Cluster 3

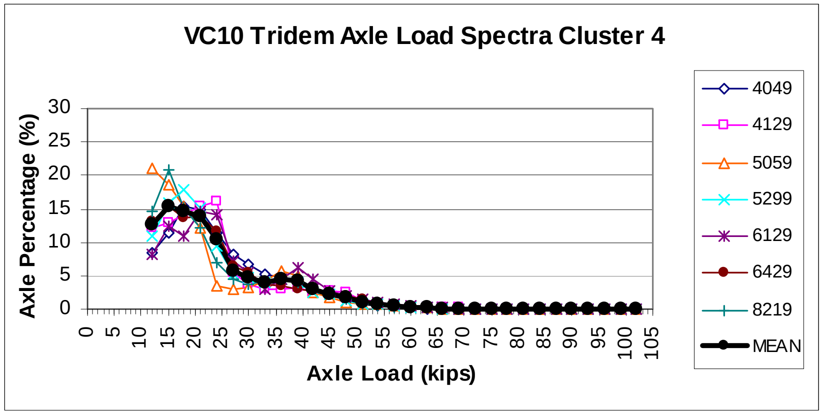

Figure E17. VC10 Tridem Axle LS for Cluster 4

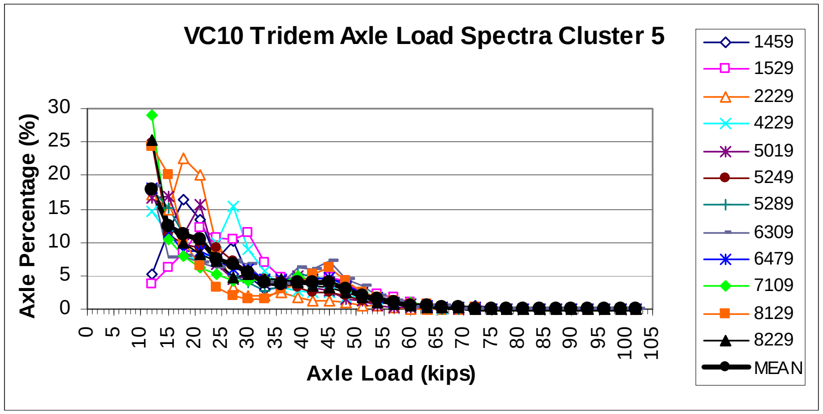

Figure E18. VC10 Tridem Axle LS for Cluster 5

VC13 Tridem Axle LS Clustering

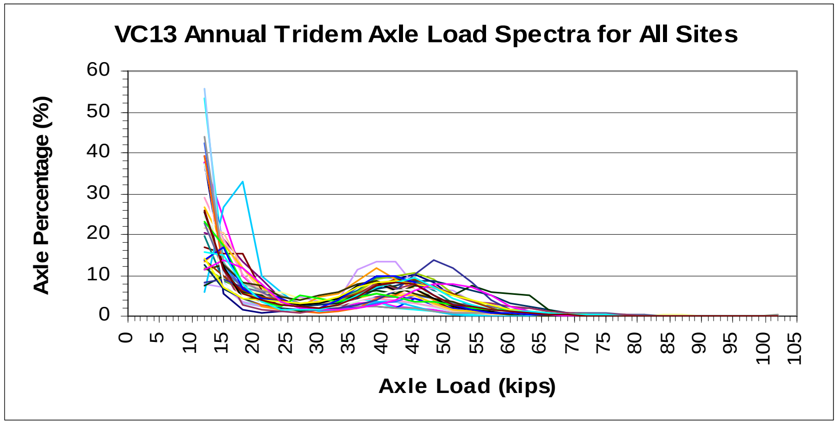

Figure E19. VC13 Tridem Axle LS for all Analyzed Sites

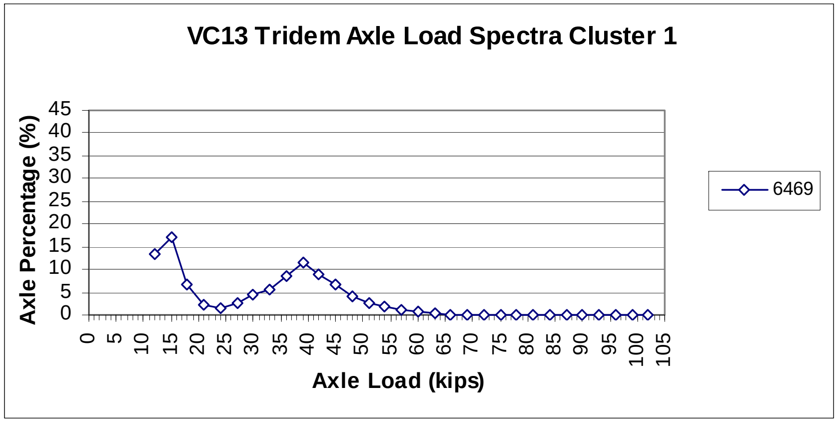

Figure E20. VC13 Tridem Axle LS for Cluster 1

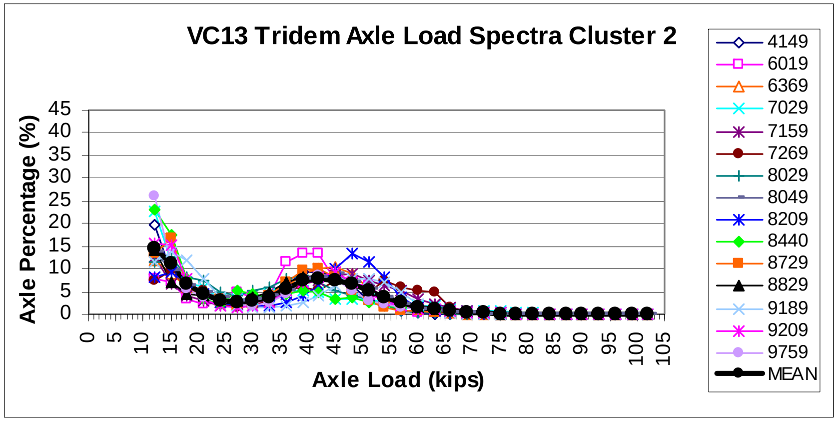

Figure E21. VC13 Tridem Axle LS for Cluster 2

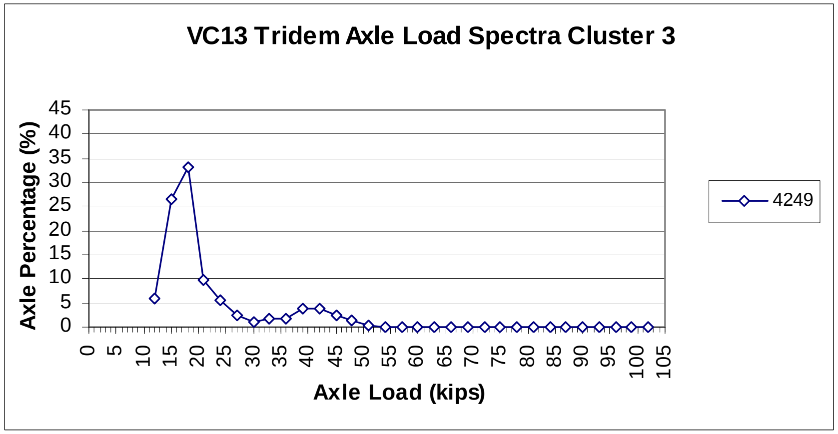

Figure E22. VC13 Tridem Axle LS for Cluster 3

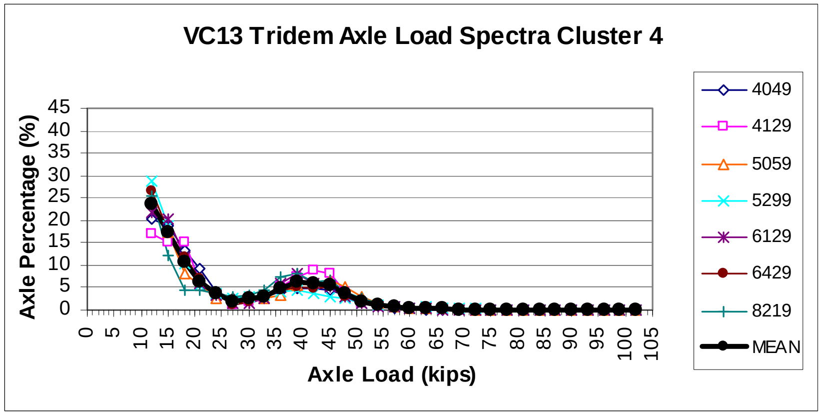

Figure E23. VC13 Tridem Axle LS for Cluster 4

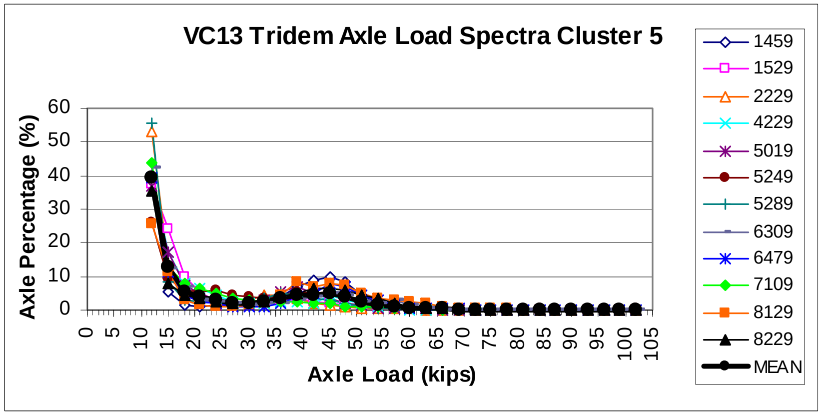

Figure E24. VC13 Tridem Axle LS for Cluster 5

Appendix F

Cluster Analysis Results-Quad Axle Load Spectra

All Quad Axle LS Clustering

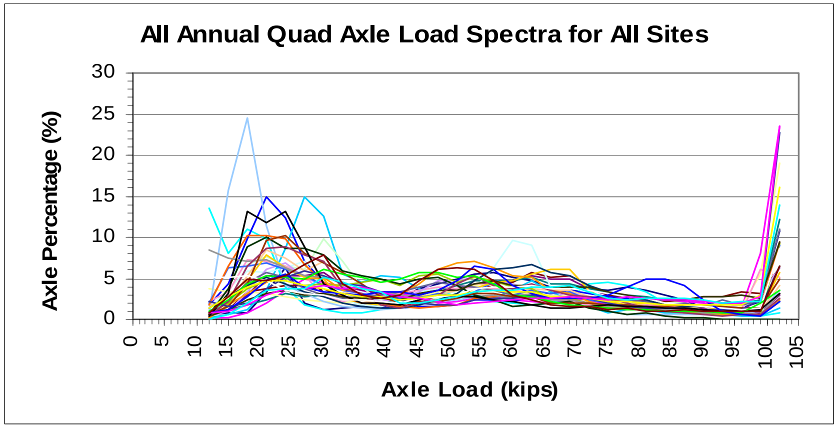

Figure F1. All Quad Axle LS for all Analyzed Sites

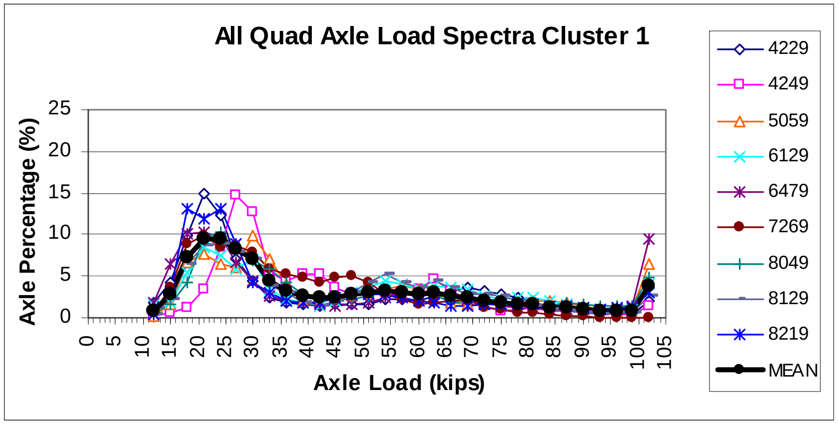

Figure F2. All Quad Axle LS for Cluster 1

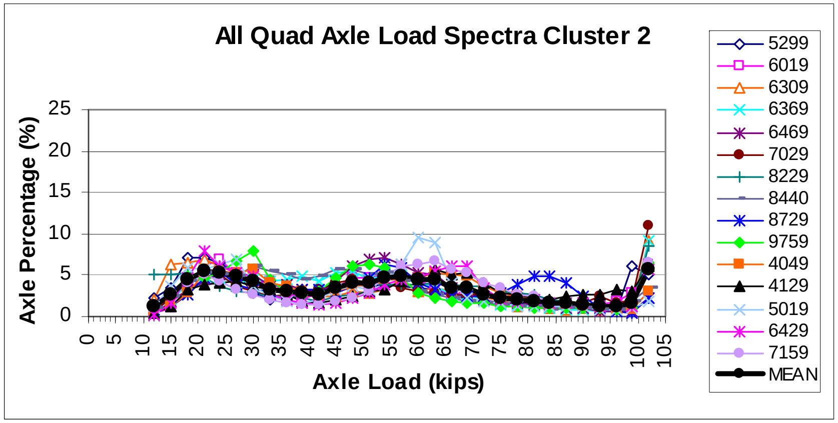

Figure F3. All Quad Axle LS for Cluster 2

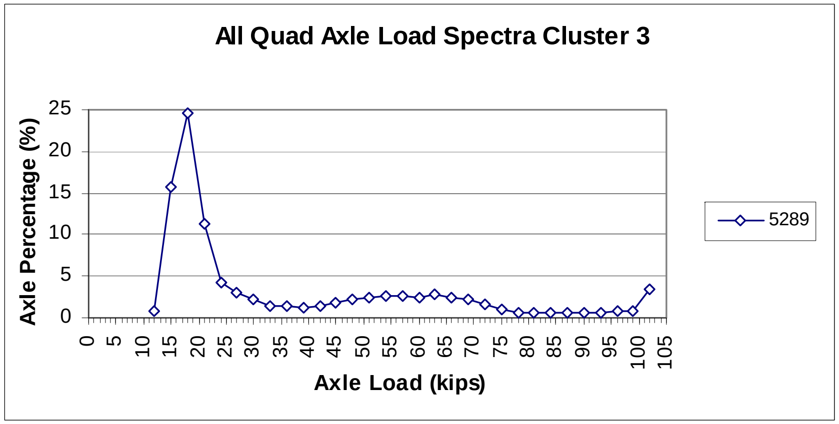

Figure F4. All Quad Axle LS for Cluster 3

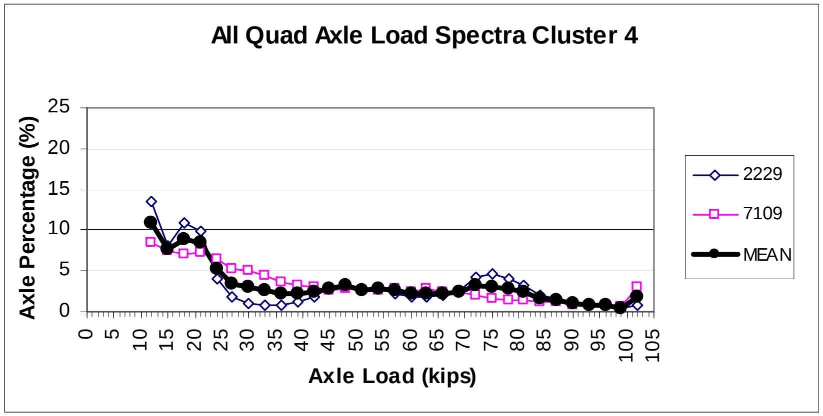

Figure F5. All Quad Axle LS for Cluster 4

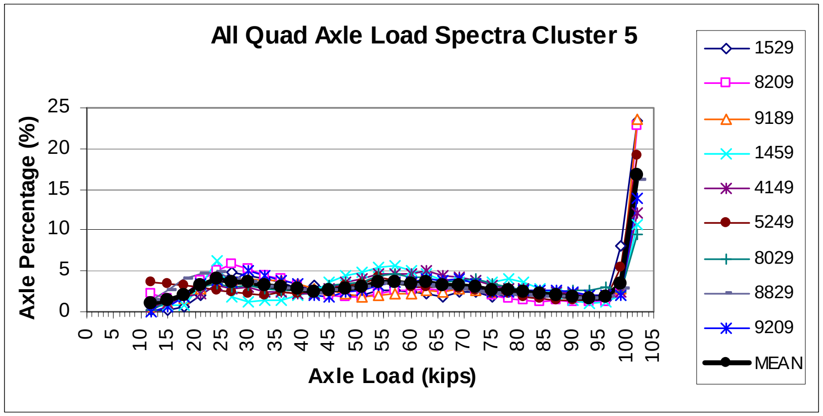

Figure F6. All Quad Axle LS for Cluster 5

VC7 Quad Axle LS Clustering

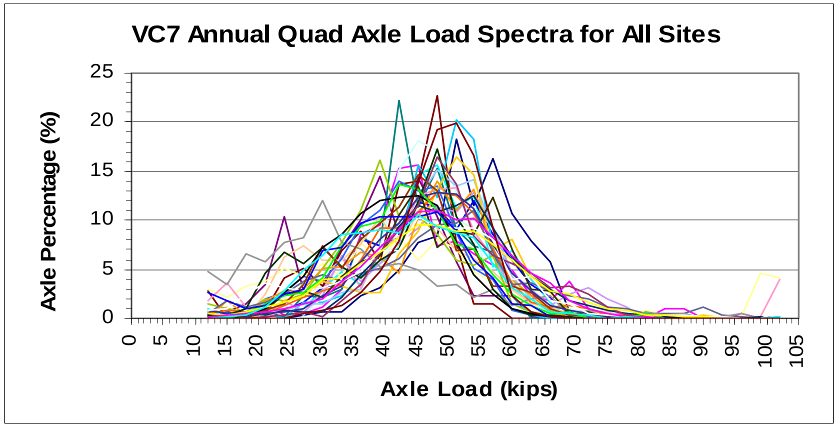

Figure F7. VC7 Quad Axle LS for all Analyzed Sites

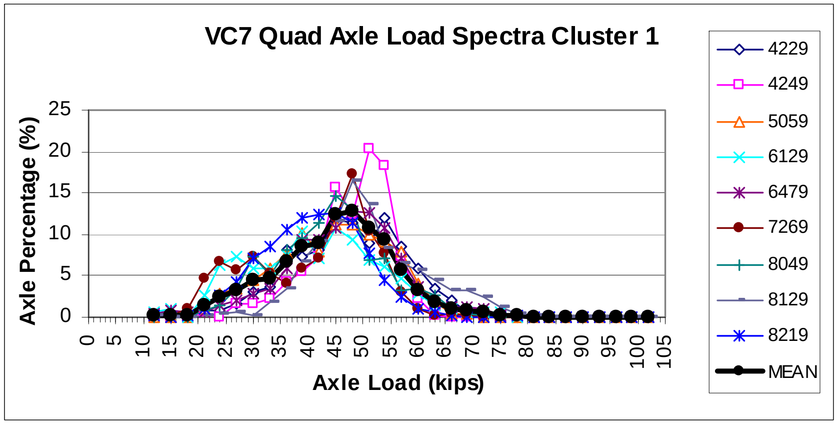

Figure F8. VC7 Quad Axle LS for Cluster 1

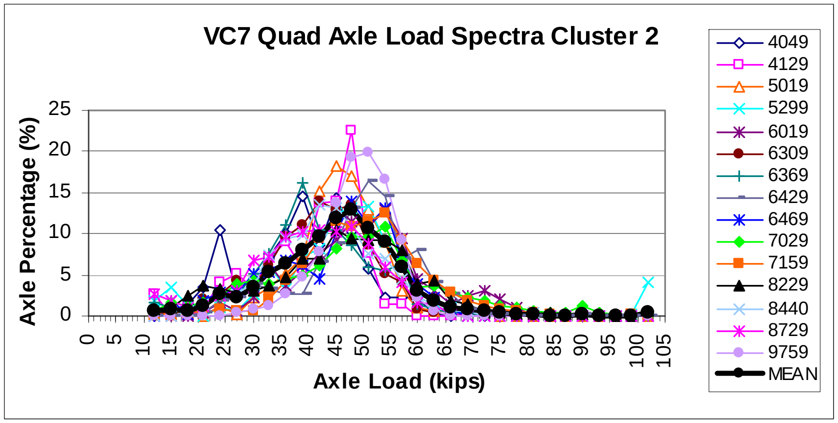

Figure F9. VC7 Quad Axle LS for Cluster 2

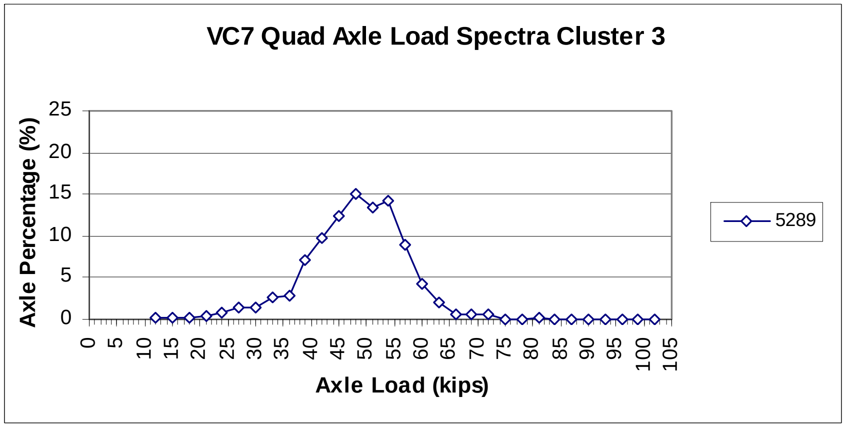

Figure F10. VC7 Quad Axle LS for Cluster 3

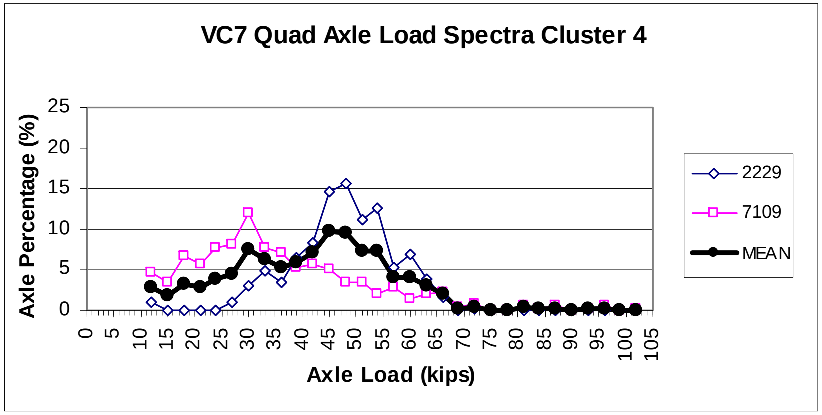

Figure F11. VC7 Quad Axle LS for Cluster 4

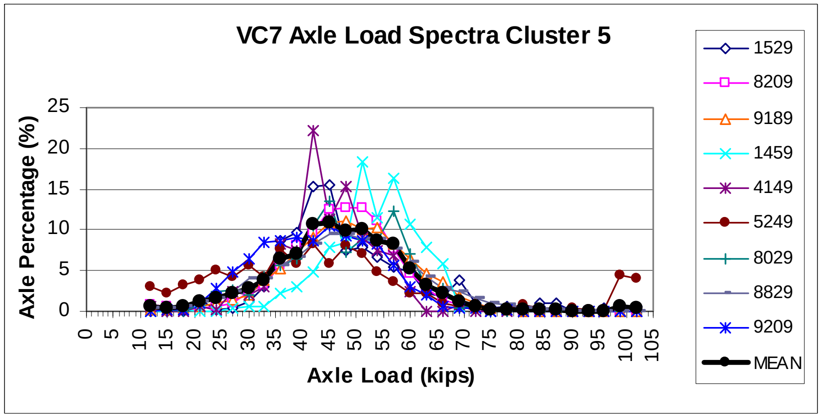

Figure F12. VC7 Quad Axle LS for Cluster 5

VC10 Quad Axle LS Clustering

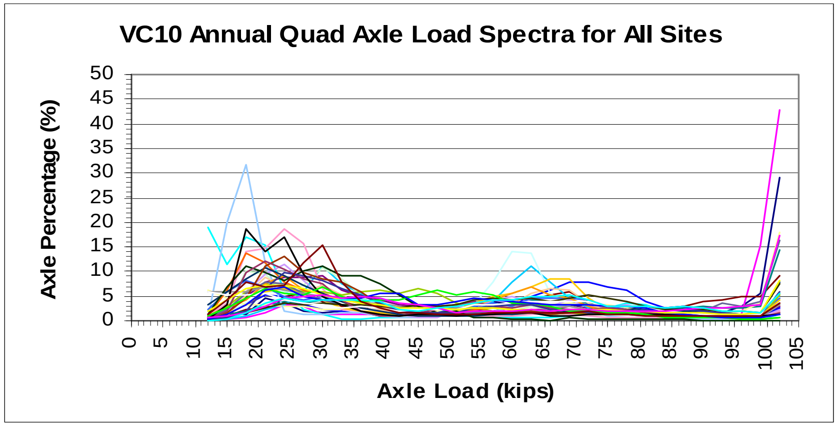

Figure F13. VC10 Quad Axle LS for all Analyzed Sites

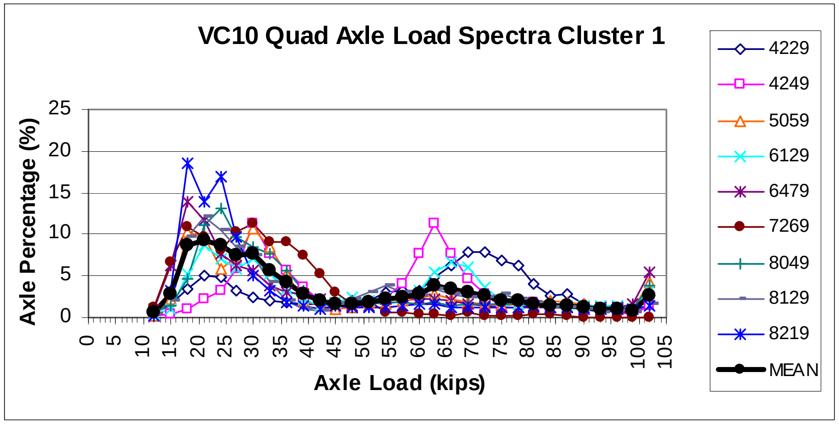

Figure F14. VC10 Quad Axle LS for Cluster 1

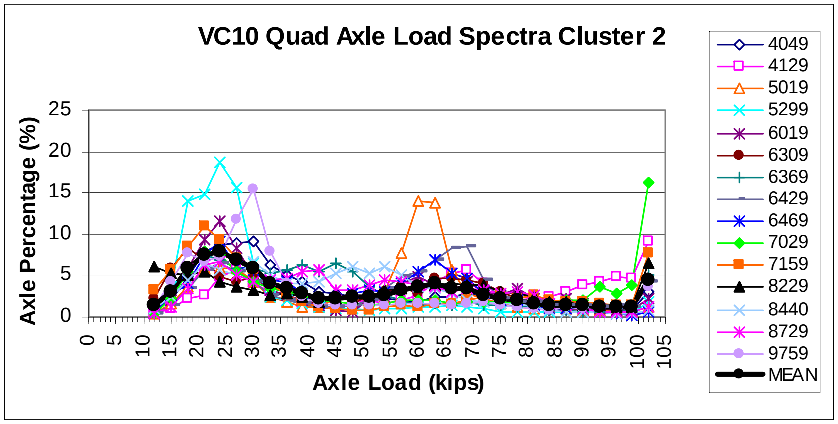

Figure F15. VC10 Quad Axle LS for Cluster 2

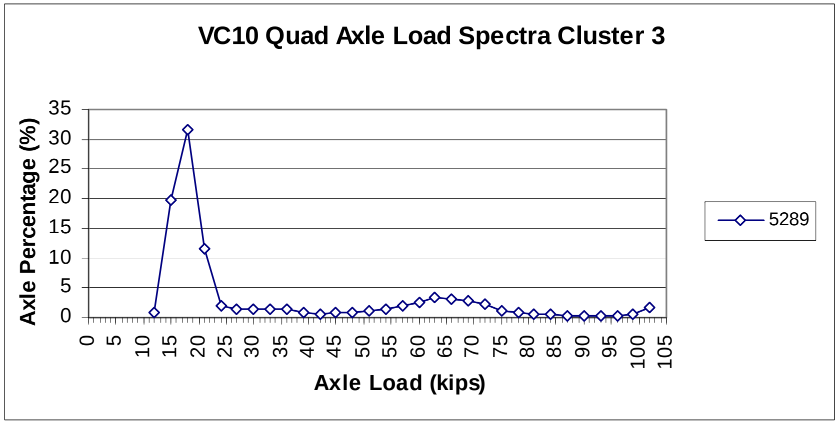

Figure F16. VC10 Quad Axle LS for Cluster 3

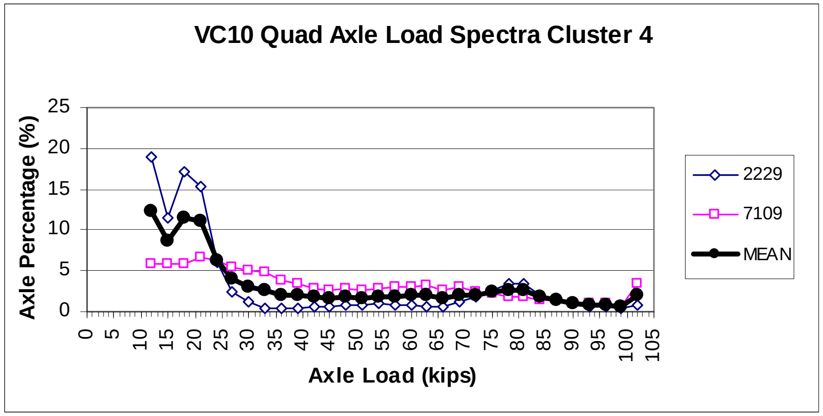

Figure F17. VC10 Quad Axle LS for Cluster 4

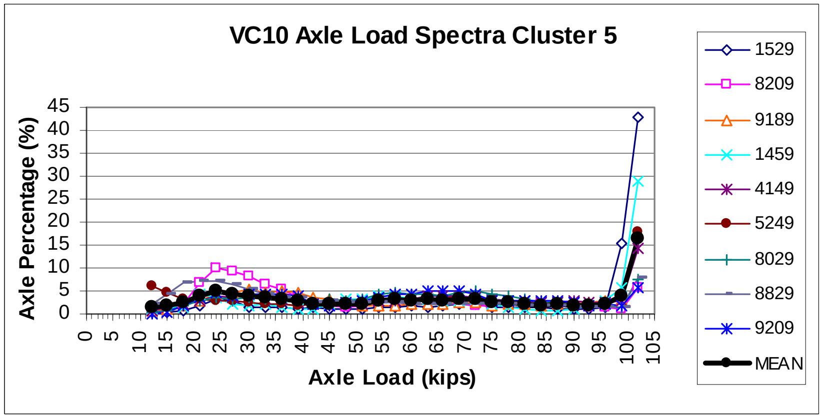

Figure F18. VC10 Quad Axle LS for Cluster 5

VC13 Quad Axle LS Clustering

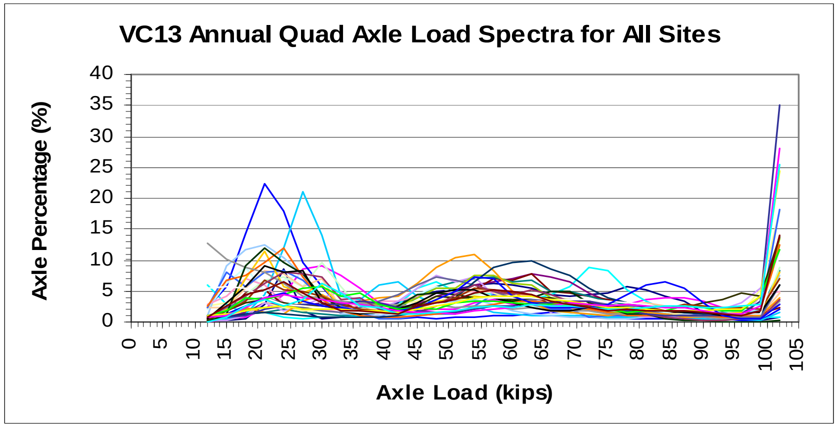

Figure F19. VC13 Quad Axle LS for all Analyzed Sites

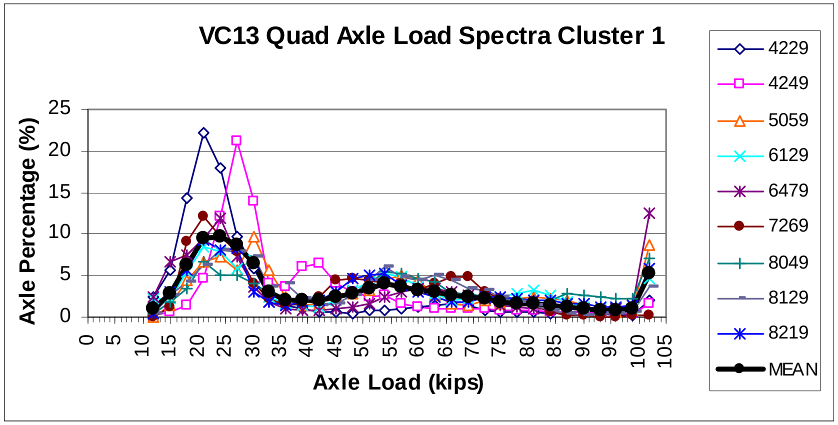

Figure F20. VC13 Quad Axle LS for Cluster 1

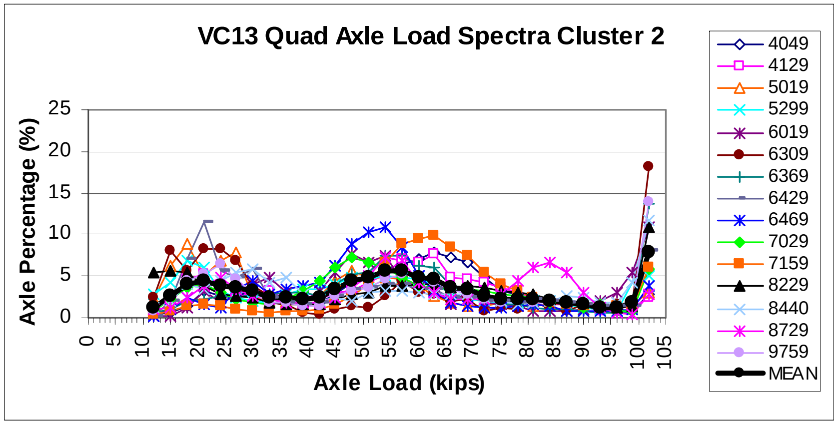

Figure F21. VC13 Quad Axle LS for Cluster 2

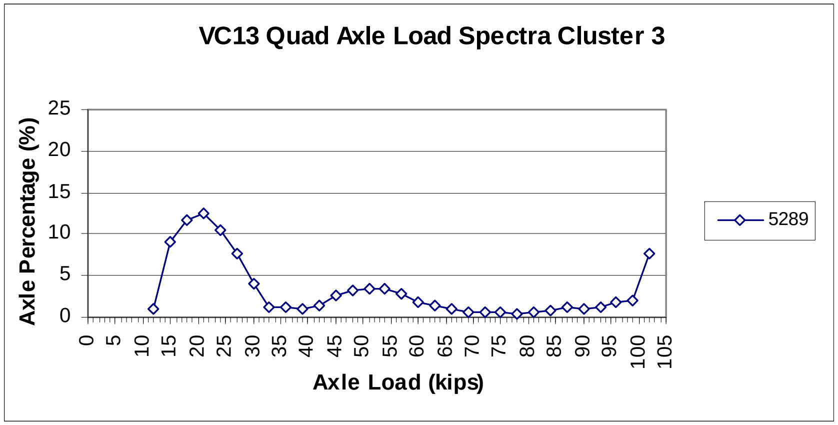

Figure F22. VC13 Quad Axle LS for Cluster 3

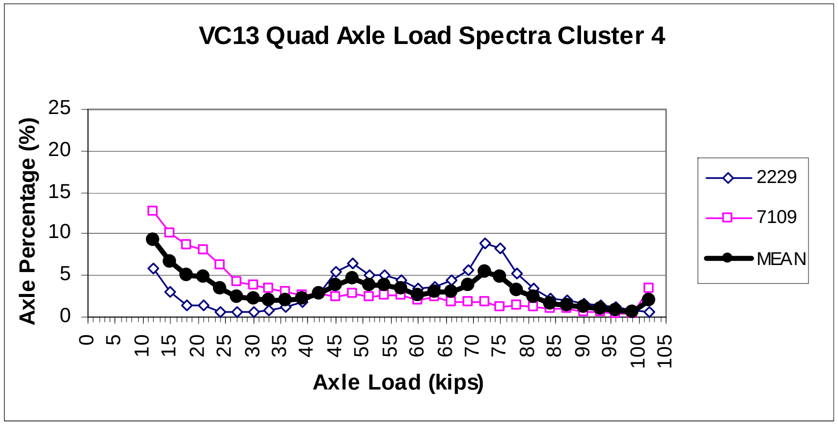

Figure F23. VC13 Quad Axle LS for Cluster 4

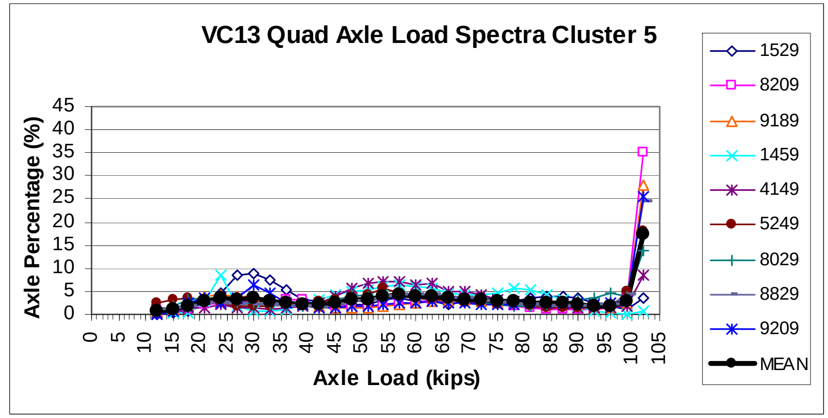

Figure F24. VC13 Quad Axle LS for Cluster 5

Appendix G

Statewide Axle Load Spectra vs. M-E PDG Defaults

Comparison Between Statewide Single Axle LS and M-E PDG Default Values for All VCs

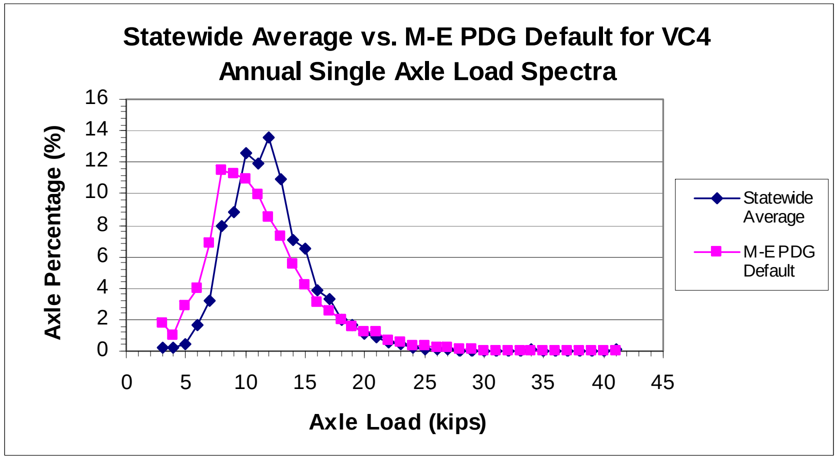

Figure G1. State Avg. vs. M-E PDG Default for Single VC4 LS

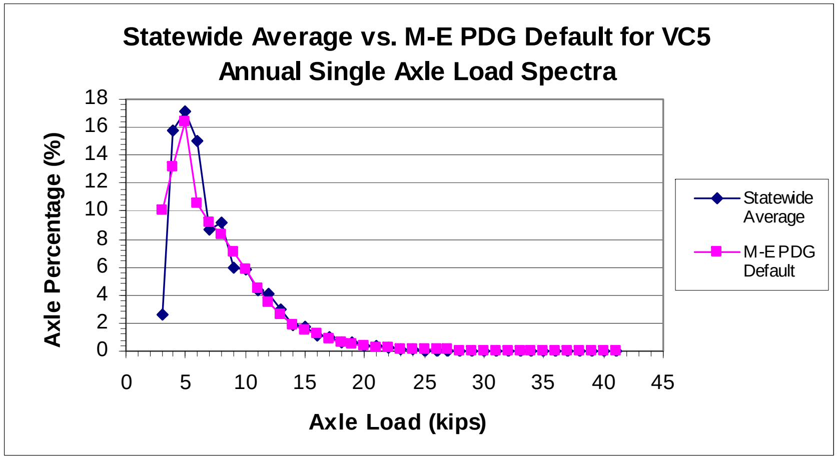

Figure G2. State Avg. vs. M-E PDG Default for Single VC5 LS

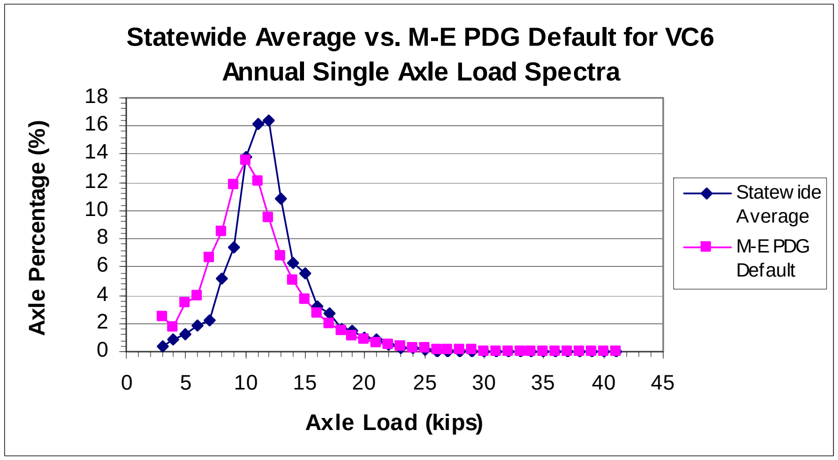

Figure G3. State Avg. vs. M-E PDG Default for Single VC6 LS

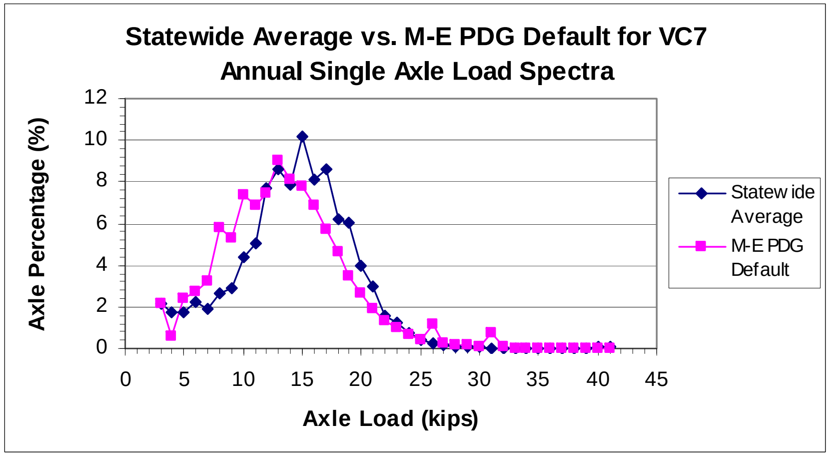

Figure G4. State Avg. vs. M-E PDG Default for SingleVC7 LS

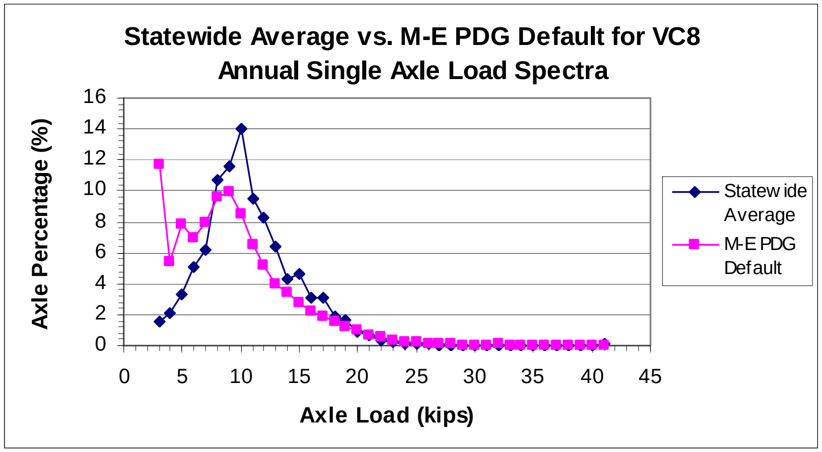

Figure G5. State Avg. vs. M-E PDG Default for Single VC8 LS

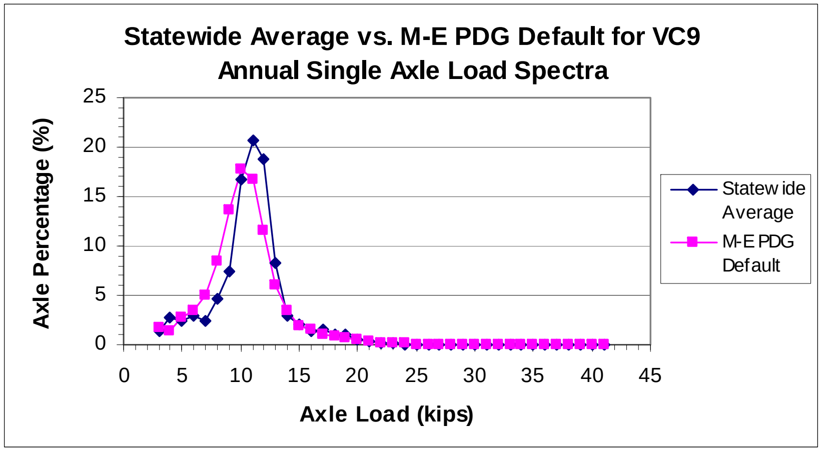

Figure G6. State Avg. vs. M-E PDG Default for Single VC9 LS

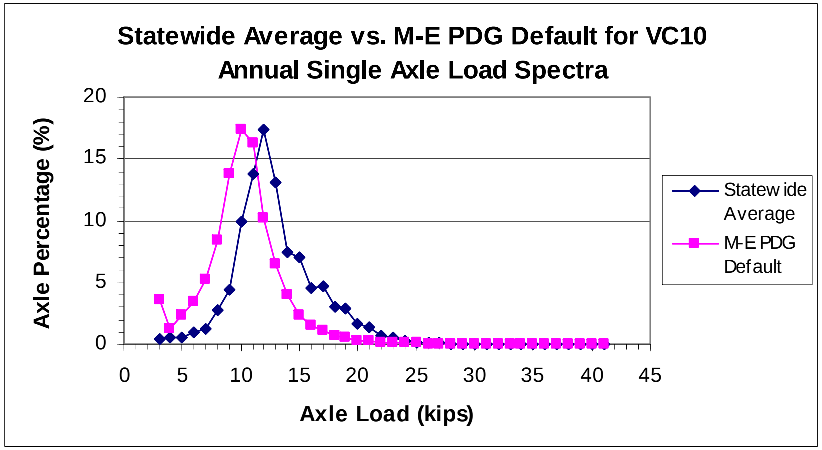

Figure G7. State Avg. vs. M-E PDG Default for Single VC10 LS

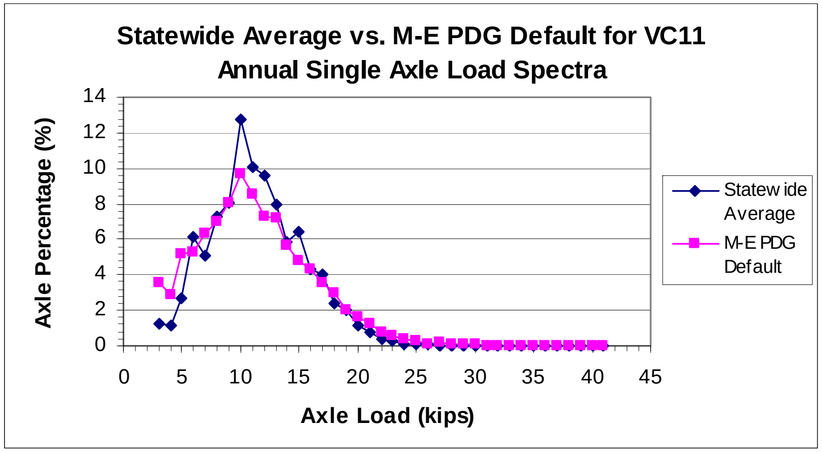

Figure G8. State Avg. vs. M-E PDG Default for Single VC11 LS

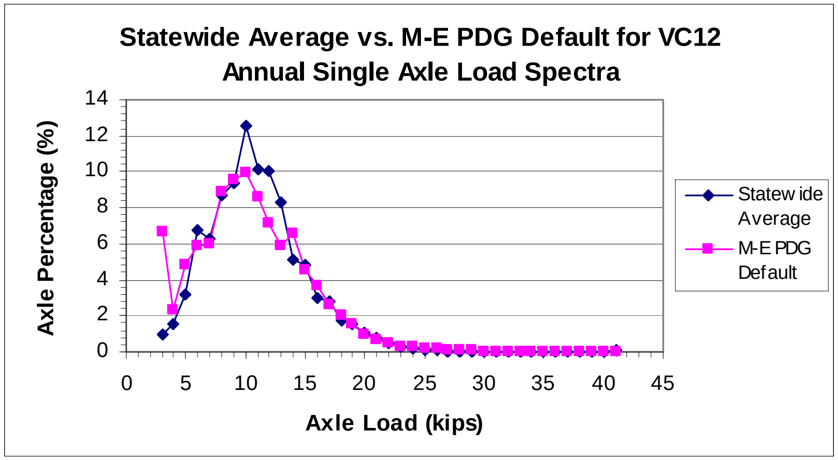

Figure G9. State Avg. vs. M-E PDG Default for Single VC12 LS

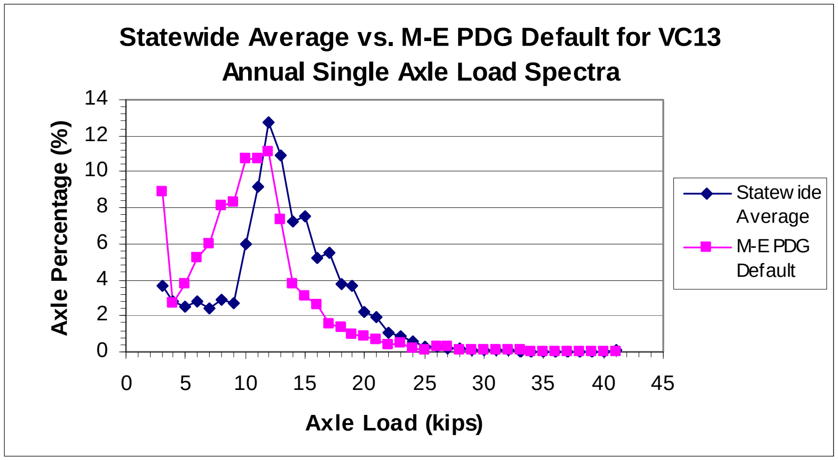

Figure G10. State Avg. vs. M-E PDG Default for Single VC13 LS

Comparison Between Statewide Tandem Axle LS and M-E PDG Default Values for All VCs

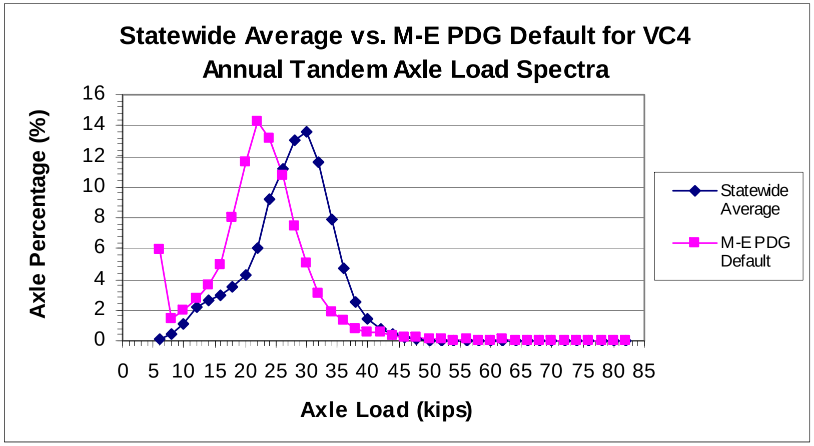

Figure G11.State Avg. vs. M-E PDG Default for TandemVC4 LS

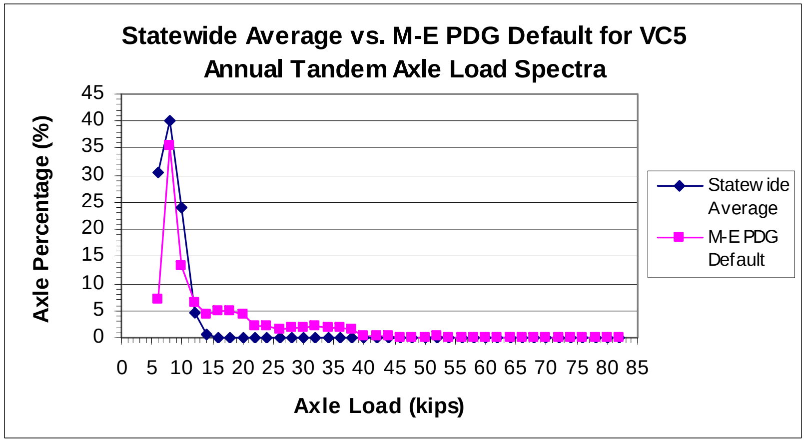

Figure G12.State Avg. vs. M-E PDG Default for Tandem VC5 LS

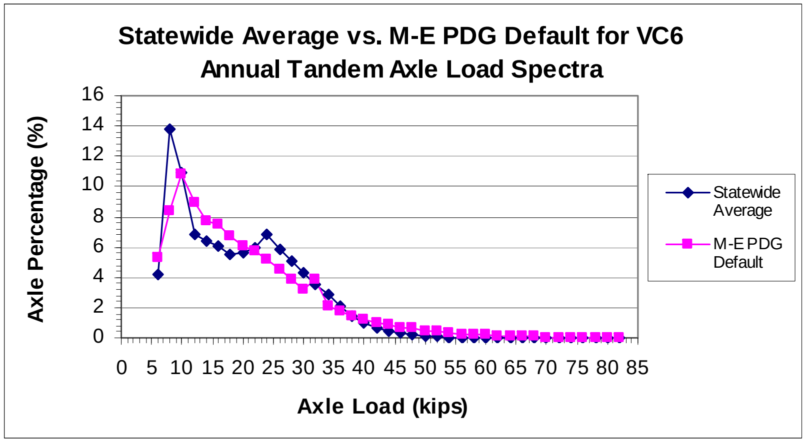

Figure G13.State Avg. vs. M-E PDG Default for TandemVC6 LS

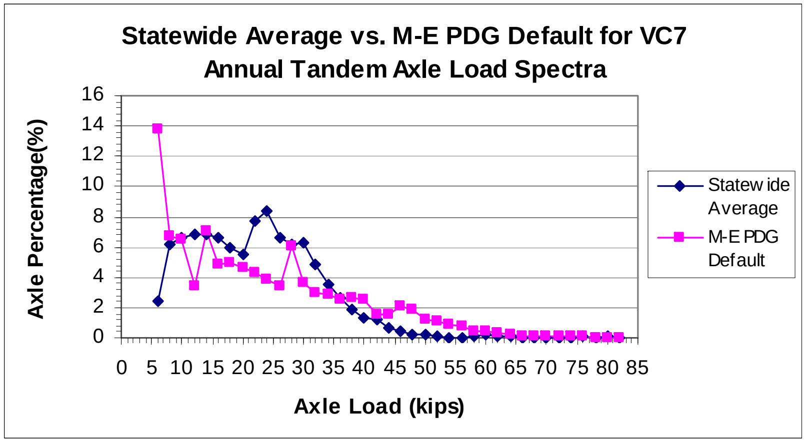

Figure G14.State Avg. vs. M-E PDG Default for TandemVC7 LS

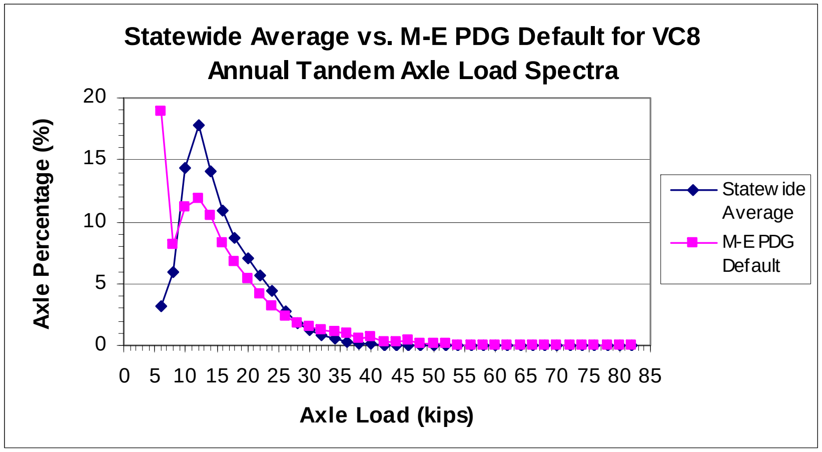

Figure G15.State Avg. vs. M-E PDG Default for Tandem VC8 LS

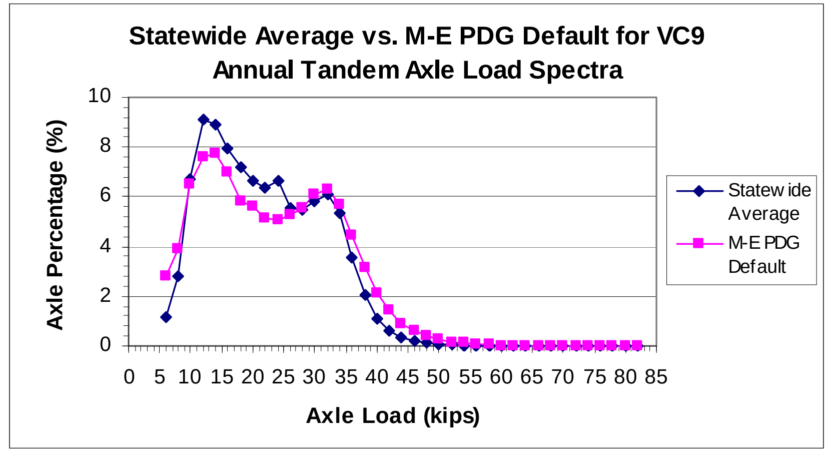

Figure G16.State Avg. vs. M-E PDG Default for TandemVC9 LS

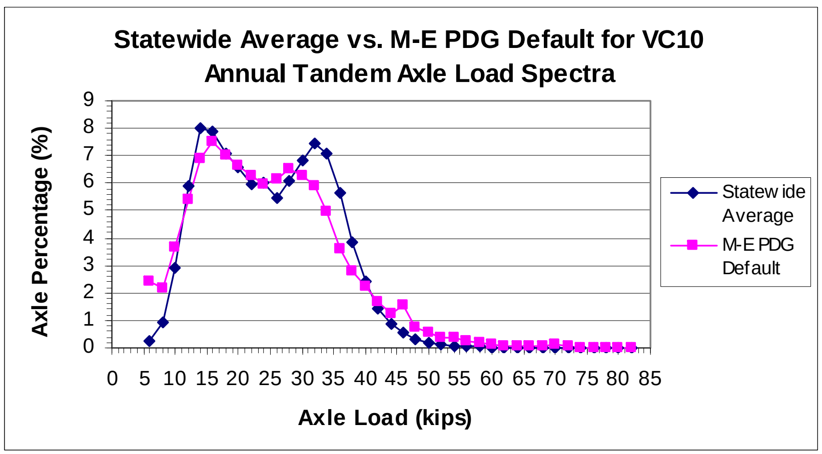

Figure G17.State Avg. vs. M-E PDG Default for TandemVC10 LS

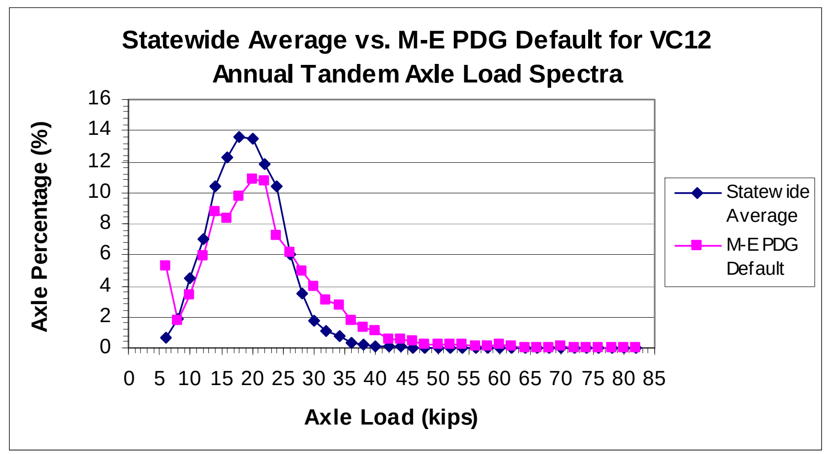

Figure G18.State Avg. vs. M-E PDG Default for TandemVC12 LS

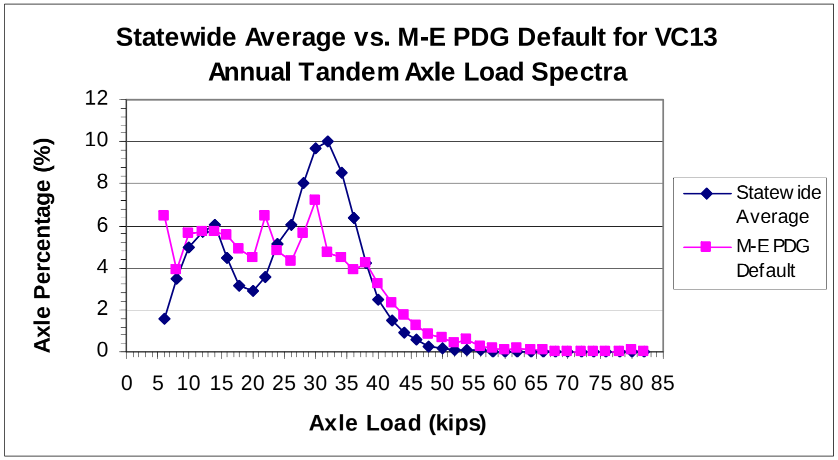

Figure G19.State Avg. vs. M-E PDG Default for Tandem VC13 LS

Comparison Between Statewide Tridem Axle LS and M-E PDG Default Values for All VCs

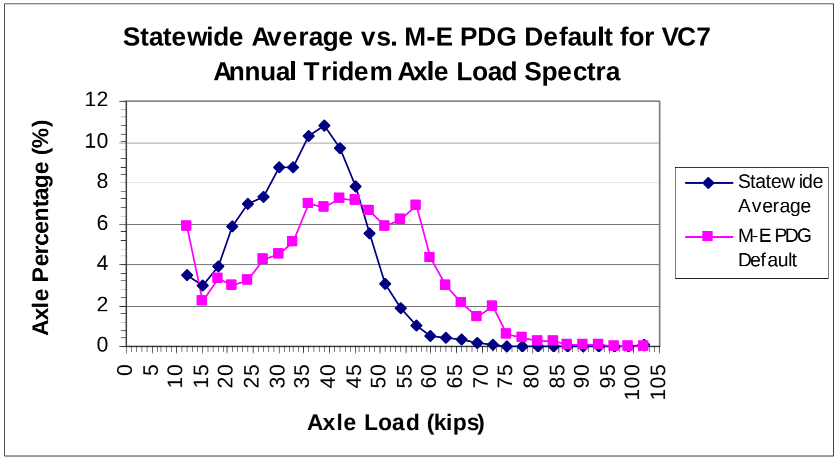

Figure G20.State Avg. vs. M-E PDG Default for Tridem VC7 LS

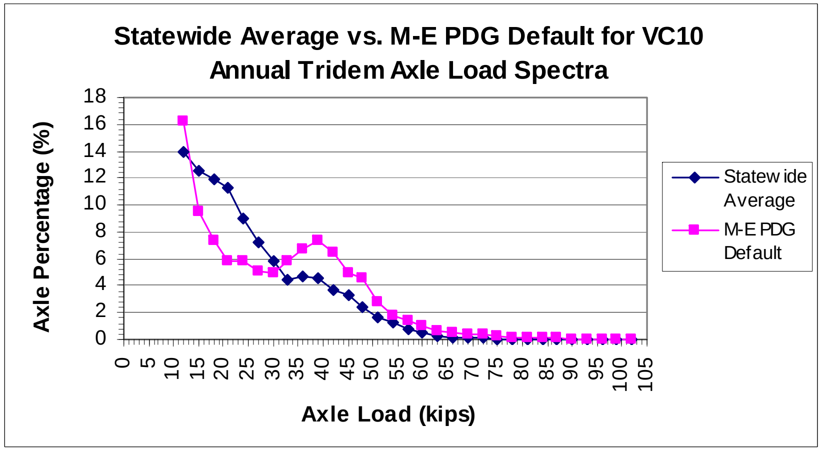

Figure G21.State Avg. vs. M-E PDG Default for TridemVC10 LS

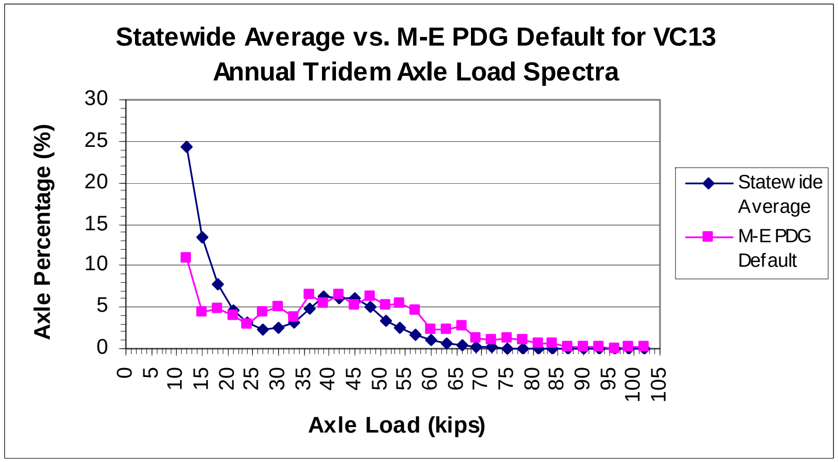

Figure G22.State Avg. vs. M-E PDG Default for Tridem VC13 LS

Comparison Between Statewide Quad Axle LS and M-E PDG Default Values for All VCs

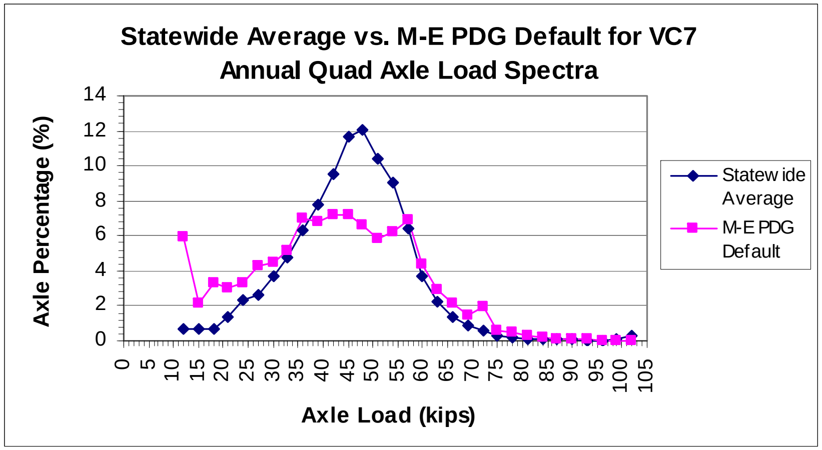

Figure G23. State Avg. vs. M-E PDG Default for Quad VC7 LS

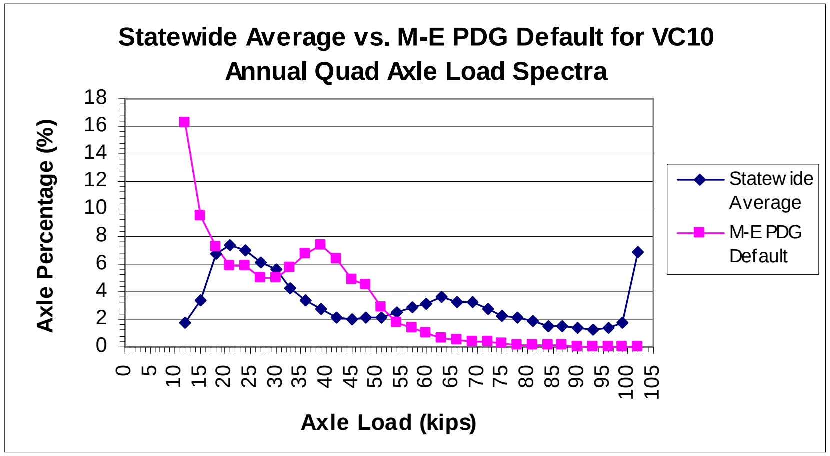

Figure G24. State Avg. vs. M-E PDG Default for QuadVC10 LS

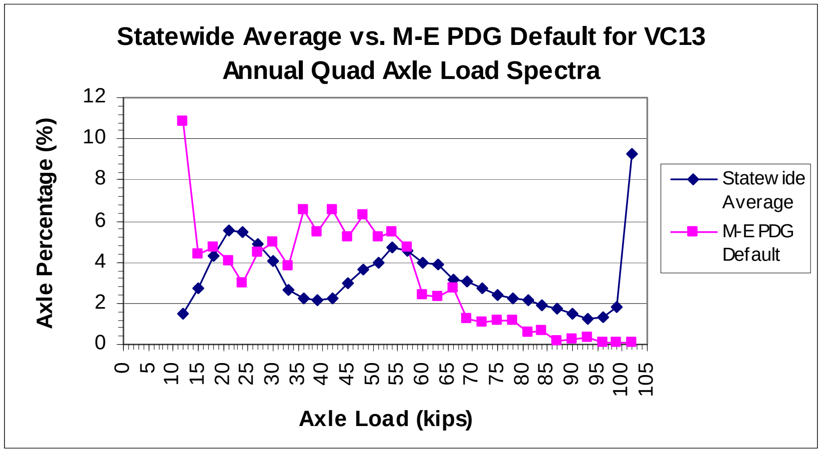

Figure G25. State Avg. vs. M-E PDG Default for Quad VC13 LS

Appendix H

Traffic Characterization Design Values

Truck Traffic Classification Design Values

Table H1. Statewide and Cluster Averages for Truck Traffic Classification

	Cluster 1	Cluster 2	Cluster 3	Statewide Average
4	1.66	1.68	2.08	1.76
5	13.01	27.35	49.78	27.37
6	3.27	5.57	6.62	5.01
7	0.33	0.95	1.09	0.77
8	3.86	4.93	4.27	4.42
9	64.35	42.39	22.08	45.43
10	6.42	7.90	6.43	7.07
11	1.59	1.11	0.41	1.12
12	0.41	0.17	0.04	0.22
13	5.11	7.95	7.20	6.82

Monthly Distribution Factor Design Values (Note M-E PDG is 1)

Table H2. Statewide Monthly Distribution Factors (All Classes)

Month	VC4	VC5	VC6	VC7	VC8	VC9	VC10	VC11	VC12	VC13
1	0.81	0.81	0.81	0.81	0.90	0.90	0.90	0.87	0.87	0.87
2	0.89	0.89	0.89	0.89	0.95	0.95	0.95	0.89	0.89	0.89
3	0.88	0.88	0.88	0.88	0.98	0.98	0.98	0.88	0.88	0.88
4	0.93	0.93	0.93	0.93	1.01	1.01	1.01	0.96	0.96	0.96
5	1.02	1.02	1.02	1.02	1.06	1.06	1.06	1.05	1.05	1.05
6	1.14	1.14	1.14	1.14	1.12	1.12	1.12	1.16	1.16	1.16
7	1.18	1.18	1.18	1.18	0.98	0.98	0.98	1.07	1.07	1.07
8	1.19	1.19	1.19	1.19	1.08	1.08	1.08	1.10	1.10	1.10
9	1.13	1.13	1.13	1.13	1.03	1.03	1.03	1.07	1.07	1.07
10	1.06	1.06	1.06	1.06	1.05	1.05	1.05	1.11	1.11	1.11
11	0.96	0.96	0.96	0.96	0.96	0.96	0.96	1.00	1.00	1.00
12	0.82	0.82	0.82	0.82	0.87	0.87	0.87	0.83	0.83	0.83

Table H3. Cluster Average Monthly Distribution Factors for VC 4-7

Month	Cluster 1	Cluster 2	Cluster 3
1	0.93	0.75	0.70
2	0.96	0.87	0.75
3	0.94	0.88	0.71
4	0.95	0.99	0.73
5	1.00	1.05	0.96
6	1.04	1.22	1.22
7	0.96	1.31	1.40
8	1.05	1.23	1.46
9	1.05	1.10	1.35
10	1.07	0.99	1.15
11	1.09	0.88	0.83
12	0.95	0.73	0.74

Table H4. Cluster Average Monthly Distribution Factors for VC 8-10

Month	Cluster 1	Cluster 2	Cluster 3	Cluster 4
1	0.770	0.903	0.948	0.889
2	0.820	1.044	0.989	0.925
3	0.867	1.050	1.022	0.963
4	0.990	1.057	1.024	1.000
5	1.249	1.085	1.047	1.053
6	1.327	1.110	1.083	1.121
7	1.109	0.988	0.907	1.013
8	1.159	1.094	1.006	1.104
9	1.062	0.990	1.000	1.049
10	1.038	0.858	1.070	1.069
11	0.860	0.971	1.005	0.943
12	0.748	0.851	0.900	0.870

Table H5. Cluster Average Monthly Distribution Factors for VC 11-13

Month	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
1	0.85	0.70	0.96	0.90	1.08
2	0.81	0.72	1.00	0.89	1.06
3	0.83	0.79	0.97	0.94	0.90
4	0.94	1.02	1.07	0.98	0.71
5	1.00	1.13	1.06	1.09	0.98
6	1.10	1.30	1.03	1.23	1.07
7	1.04	1.18	0.93	1.11	0.98
8	1.10	1.18	1.00	1.10	1.10
9	1.13	1.14	1.05	1.03	0.98
10	1.24	1.12	1.07	0.99	1.22
11	1.09	1.02	0.97	0.95	0.88
12	0.87	0.71	0.87	0.79	1.04

Hourly Distribution Factor Design Values

Table H6. Statewide, Cluster Average and M-E PDG Default Monthly Distribution Factors

	Cluster 1	Cluster 2	Cluster 3	Statewide Avg.	M-E PDG Default
0	2.52	1.78	1.05	1.62	2.30
1	2.22	1.64	0.89	1.45	2.30
2	2.11	1.66	0.97	1.46	2.30
3	2.33	2.00	1.22	1.75	2.30
4	2.67	2.59	1.74	2.27	2.30
5	3.11	3.68	2.60	3.16	2.30
6	3.71	4.49	4.32	4.29	5.00
7	4.16	5.24	6.08	5.38	5.00
8	4.91	6.06	7.42	6.39	5.00
9	5.32	6.51	7.43	6.67	5.00
10	5.58	6.60	7.33	6.71	5.90
11	5.68	6.50	7.41	6.71	5.90
12	5.60	6.31	7.24	6.55	5.90
13	5.58	6.16	7.12	6.44	5.90
14	5.48	5.89	6.97	6.24	5.90
15	5.36	5.54	6.62	5.93	5.90
16	5.33	5.01	5.49	5.25	4.60
17	4.98	4.44	4.54	4.57	4.60
18	4.70	3.94	3.46	3.88	4.60
19	4.48	3.39	2.82	3.35	4.60
20	4.13	2.95	2.30	2.90	3.10
21	3.75	2.64	2.00	2.58	3.10
22	3.37	2.42	1.63	2.27	3.10

Axle Groups per Vehicle Design Values

Table H7. Statewide, Cluster Average and M-E PDG Default Single Axle Groups per Vehicle

VC	Cluster 1	Cluster 2	Cluster 3	Statewide Avg.	M-E PDG Default
4	1.76	1.64	1.61	1.65	1.62
5	2.00	2.01	2.00	2.00	2
6	1.00	1.00	1.00	1.00	1.02
7	1.07	1.08	1.05	1.06	1
8	2.28	2.30	2.26	2.28	2.38
9	1.20	1.26	1.32	1.29	1.13
10	1.43	1.49	1.61	1.54	1.19
11	5.00	4.99	4.99	4.99	4.29
12	4.05	3.98	3.99	3.85	3.52
13	1.61	2.70	2.09	2.03	2.15

Table H8. Statewide, Cluster Average and M-E PDG Default Tandem Axle Groups per Vehicle

VC	Cluster 1	Cluster 2	Cluster 3	Statewide Avg.	M-E PDG Default
4	0.21	0.30	0.60	0.36	0.39
5	0.02	0.05	0.07	0.05	0
6	1.00	1.00	1.00	1.00	0.99
7	0.06	0.06	0.06	0.06	0.26
8	0.77	0.78	0.69	0.74	0.67
9	1.89	1.87	1.77	1.85	1.93
10	0.96	1.02	1.00	1.00	1.09
11	0.00	0.01	0.00	0.00	0.26
12	0.99	1.00	1.08	0.96	1.14
13	1.16	1.54	1.49	1.40	2.13

Table H9. Statewide, Cluster Average and M-E PDG Default Tridem Axle Groups per Vehicle

VC	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Statewide Avg.	M-E PDG Default
4	0.00	0.00	0.00	0.00	0.00	0
5	0.00	0.00	0.00	0.00	0.00	0
6	0.00	0.00	0.00	0.00	0.00	0
7	0.58	0.72	0.63	0.45	0.59	0.83
8	0.00	0.00	0.00	0.00	0.00	0
9	0.00	0.01	0.00	0.01	0.00	0
10	0.30	0.29	0.64	0.31	0.31	0.89
11	0.00	0.00	0.00	0.00	0.00	0.06
12	0.00	0.00	0.00	0.00	0.00	0.06
13	0.28	0.41	0.51	0.48	0.36	0.35

Table H10. Statewide, Cluster Average and M-E PDG Default Quad Axle Groups per Vehicle

VC	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Statewide Avg.	M-E PDG Default
4	0.00	0.00	0.00	0.00	0.00	0.00	0
5	0.00	0.00	0.00	0.00	0.00	0.00	0
6	0.00	0.00	0.00	0.00	0.00	0.00	0
7	0.31	0.30	0.17	0.45	0.40	0.35	0
8	0.00	0.00	0.00	0.00	0.00	0.00	0
9	0.00	0.00	0.00	0.00	0.00	0.00	0
10	0.19	0.54	0.59	0.68	0.51	0.56	0
11	0.00	0.00	0.00	0.00	0.00	0.00	0
12	0.00	0.01	0.00	0.00	0.00	0.00	0
13	0.43	0.85	0.59	0.69	0.58	0.61	0

Single Axle Load Spectra Design Values

Table H11. Statewide Single Axle Load Spectra

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
3	0.19	2.63	0.33	2.19	1.56	1.42	0.44	1.23	0.93	3.69
4	0.22	15.77	0.88	1.74	2.15	2.76	0.52	1.14	1.57	2.81
5	0.48	17.16	1.22	1.77	3.32	2.48	0.56	2.66	3.14	2.50
6	1.65	15.08	1.81	2.23	5.07	2.88	0.96	6.12	6.75	2.82
7	3.15	8.65	2.18	1.91	6.18	2.47	1.24	5.05	6.29	2.41
8	7.91	9.15	5.14	2.65	10.68	4.72	2.76	7.28	8.68	2.86
9	8.85	5.93	7.38	2.87	11.56	7.33	4.36	8.05	9.41	2.73
10	12.59	5.89	13.84	4.35	14.11	16.74	9.98	12.82	12.69	6.00
11	11.91	4.38	16.11	5.04	9.46	20.72	13.74	10.09	10.09	9.20
12	13.73	4.09	16.50	7.72	8.24	18.78	17.48	9.60	10.07	12.80
13	10.92	3.00	10.85	8.58	6.43	8.21	13.12	8.00	8.35	10.91
14	7.02	1.86	6.30	7.88	4.31	2.89	7.45	5.85	5.11	7.23
15	6.56	1.75	5.55	10.34	4.58	2.04	7.10	6.43	4.82	7.55
16	3.91	1.09	3.18	8.10	3.05	1.30	4.59	4.31	3.01	5.21
17	3.33	1.03	2.71	8.62	3.05	1.55	4.67	4.01	2.81	5.54
18	1.97	0.63	1.62	6.23	1.91	1.12	3.05	2.38	1.76	3.78
19	1.69	0.60	1.47	6.04	1.65	1.06	2.89	2.06	1.51	3.66
20	1.09	0.37	0.94	3.96	0.89	0.57	1.65	1.11	1.03	2.24
21	0.92	0.34	0.82	3.00	0.69	0.41	1.35	0.81	0.75	1.91
22	0.53	0.19	0.44	1.61	0.36	0.20	0.68	0.38	0.46	1.06

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
23	0.41	0.15	0.30	1.26	0.27	0.15	0.52	0.26	0.27	0.88
24	0.28	0.10	0.19	0.74	0.16	0.08	0.31	0.14	0.15	0.59
25	0.15	0.05	0.09	0.40	0.09	0.04	0.16	0.07	0.12	0.33
26	0.11	0.04	0.05	0.27	0.07	0.03	0.13	0.05	0.11	0.31
27	0.06	0.02	0.04	0.17	0.04	0.02	0.08	0.03	0.03	0.18
28	0.04	0.02	0.02	0.12	0.04	0.01	0.06	0.02	0.02	0.17
29	0.03	0.01	0.01	0.06	0.02	0.01	0.03	0.01	0.02	0.10
30	0.03	0.01	0.01	0.05	0.02	0.01	0.03	0.01	0.01	0.09
31	0.02	0.01	0.01	0.03	0.01	0.00	0.02	0.01	0.01	0.06
32	0.02	0.00	0.01	0.02	0.01	0.00	0.02	0.01	0.02	0.06
33	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.04
34	0.14	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.04
35	0.04	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03
36	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.02
37	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02
38	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
39	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10

Table H12. Cluster 1 Single Axle Load Spectra

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
3	0.11	2.07	0.14	2.27	1.12	0.90	0.34	0.21	0.32	4.02
4	0.12	14.11	0.51	1.80	1.74	2.32	0.40	0.60	0.82	2.66
5	0.25	15.79	0.81	1.65	2.77	2.03	0.41	1.78	2.10	2.40
6	1.07	14.16	1.22	2.34	4.02	1.92	0.72	5.33	5.89	2.39
7	2.69	9.18	1.61	2.02	5.29	1.48	0.85	4.23	5.59	2.07
8	7.94	10.62	4.56	3.27	10.20	3.11	2.00	6.05	8.18	2.29
9	10.50	7.02	7.71	3.56	12.69	6.75	3.52	7.29	10.27	2.41
10	15.45	6.91	16.03	5.47	16.58	18.57	9.54	14.32	15.54	6.18
11	12.84	4.61	18.81	5.94	9.80	23.27	14.18	10.92	11.17	9.75
12	12.80	4.24	18.33	8.83	8.10	21.30	18.56	9.32	10.05	13.32
13	9.99	3.05	10.43	9.38	6.17	8.13	13.23	8.20	8.24	10.61
14	6.56	1.88	5.51	7.88	4.20	2.42	7.17	6.24	5.53	6.72
15	6.12	1.81	4.86	9.96	4.57	1.67	7.18	7.37	5.06	7.13
16	3.68	1.11	2.62	7.21	3.07	1.17	4.92	5.07	3.11	5.20
17	3.03	1.06	2.32	7.62	3.16	1.48	5.15	4.70	2.89	5.81
18	1.78	0.65	1.32	5.54	1.99	1.08	3.44	2.84	1.72	4.10
19	1.57	0.60	1.18	5.40	1.76	1.01	3.28	2.46	1.45	4.04
20	0.96	0.36	0.74	3.41	0.94	0.53	1.79	1.27	0.78	2.40
21	0.80	0.30	0.62	2.54	0.72	0.38	1.40	0.94	0.53	2.04
22	0.43	0.16	0.29	1.37	0.37	0.18	0.68	0.40	0.25	1.14
23	0.33	0.12	0.20	1.01	0.27	0.13	0.48	0.25	0.17	0.92
24	0.18	0.07	0.10	0.59	0.17	0.08	0.29	0.11	0.10	0.62

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
25	0.08	0.04	0.04	0.32	0.09	0.04	0.14	0.05	0.06	0.38
26	0.07	0.03	0.02	0.24	0.07	0.03	0.11	0.03	0.05	0.35
27	0.04	0.02	0.01	0.14	0.04	0.01	0.06	0.01	0.04	0.21
28	0.03	0.01	0.01	0.07	0.04	0.01	0.05	0.01	0.02	0.19
29	0.02	0.01	0.00	0.04	0.02	0.00	0.03	0.00	0.02	0.12
30	0.02	0.01	0.00	0.04	0.01	0.00	0.03	0.00	0.01	0.11
31	0.01	0.00	0.00	0.03	0.01	0.00	0.02	0.00	0.01	0.07
32	0.01	0.00	0.00	0.03	0.01	0.00	0.01	0.00	0.01	0.06
33	0.01	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.04
34	0.35	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.04
35	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
38	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
39	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09

Table H13. Cluster 2 Single Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
3	0.30	3.37	0.55	2.36	1.71	2.06	0.61	0.62	1.20	3.80
4	0.35	15.80	1.15	1.69	2.48	3.03	0.65	1.20	2.03	3.17
5	0.69	15.53	1.37	1.61	3.43	2.32	0.65	2.57	2.96	2.68
6	2.19	15.14	2.16	2.12	5.47	2.67	1.05	6.16	5.21	2.98
7	3.63	8.79	2.65	1.75	6.52	2.75	1.39	5.13	5.88	2.38
8	7.43	8.74	5.72	2.30	10.87	5.91	3.26	8.08	8.94	2.94
9	7.65	5.53	7.39	2.32	10.63	8.20	5.18	8.74	8.66	2.93
10	10.54	5.49	12.77	3.59	12.06	15.77	10.69	11.59	10.29	6.01
11	11.55	4.67	15.00	4.76	9.56	19.70	13.88	9.32	9.89	9.11
12	14.16	4.45	15.60	7.48	8.56	17.22	16.23	9.90	10.89	12.36
13	11.61	3.32	11.26	8.41	6.64	8.10	12.05	8.23	9.31	11.14
14	7.52	2.08	6.71	8.27	4.42	3.20	7.24	5.89	5.54	7.70
15	6.98	1.94	5.86	10.64	4.73	2.24	6.99	6.33	5.47	7.84
16	4.12	1.20	3.36	8.52	3.16	1.36	4.40	4.23	3.40	5.13
17	3.58	1.13	2.77	9.16	3.13	1.57	4.48	4.02	3.15	5.30
18	2.14	0.68	1.66	6.59	1.95	1.10	2.92	2.42	2.09	3.47
19	1.76	0.65	1.43	6.29	1.70	1.07	2.84	2.11	1.58	3.34
20	1.09	0.40	0.86	4.05	0.96	0.61	1.67	1.20	1.07	2.04
21	0.84	0.36	0.74	2.88	0.77	0.47	1.41	0.90	0.76	1.73
22	0.52	0.20	0.37	1.60	0.40	0.23	0.73	0.46	0.68	0.96
23	0.41	0.17	0.22	1.47	0.31	0.17	0.57	0.33	0.37	0.85
24	0.30	0.12	0.15	0.88	0.18	0.10	0.36	0.19	0.19	0.57

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
25	0.17	0.06	0.07	0.47	0.10	0.05	0.19	0.10	0.15	0.30
26	0.14	0.05	0.07	0.27	0.08	0.04	0.16	0.08	0.19	0.29
27	0.08	0.03	0.04	0.18	0.05	0.02	0.10	0.06	0.02	0.17
28	0.06	0.03	0.02	0.13	0.04	0.02	0.08	0.04	0.02	0.16
29	0.05	0.02	0.01	0.05	0.02	0.01	0.04	0.02	0.02	0.09
30	0.04	0.01	0.01	0.05	0.02	0.01	0.04	0.02	0.01	0.08
31	0.02	0.01	0.01	0.02	0.01	0.00	0.02	0.01	0.01	0.06
32	0.02	0.01	0.01	0.01	0.01	0.00	0.03	0.01	0.01	0.05
33	0.02	0.01	0.00	0.00	0.01	0.00	0.02	0.01	0.01	0.04
34	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.00	0.00	0.04
35	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.03
36	0.01	0.00	0.00	0.02	0.00	0.00	0.01	0.01	0.00	0.03
37	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.02
38	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.02
39	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.02
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12

Table H14. Cluster 3 Single Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
3	0.02	1.67	0.12	1.43	2.26	0.74	0.13	6.18	1.97	2.40
4	0.04	20.54	1.02	1.77	2.15	3.03	0.41	2.43	2.33	2.02
5	0.44	26.18	1.86	2.65	4.51	4.25	0.65	5.41	7.49	2.13
6	1.47	17.45	2.28	2.29	6.62	6.29	1.34	8.20	15.96	3.51
7	2.86	6.66	2.17	2.16	7.49	4.26	1.84	7.04	10.38	3.47
8	9.45	6.45	4.80	2.12	11.39	5.16	3.19	8.02	9.40	4.19
9	8.32	4.24	6.43	2.83	11.53	5.97	3.91	7.82	9.36	2.99
10	11.74	4.36	11.38	3.82	14.21	14.94	8.78	12.81	11.61	5.46
11	10.49	2.76	12.46	3.45	8.22	17.10	12.05	10.40	7.17	8.11
12	14.76	2.45	14.39	5.44	7.55	17.00	18.63	9.39	7.58	12.76
13	11.21	1.76	10.63	6.95	6.44	8.78	16.50	6.64	4.86	10.96
14	6.56	1.07	7.09	6.53	4.23	3.20	8.95	4.59	1.96	7.05
15	6.36	0.99	6.45	10.16	4.14	2.39	7.27	4.13	1.34	7.76
16	3.80	0.62	4.11	9.12	2.57	1.47	4.32	2.46	1.11	5.50
17	3.32	0.60	3.62	9.59	2.49	1.73	3.98	2.02	1.14	5.61
18	1.95	0.40	2.33	6.93	1.55	1.28	2.41	0.97	0.61	3.96
19	1.80	0.44	2.38	6.97	1.18	1.21	1.94	0.75	1.48	3.71
20	1.45	0.35	1.78	5.22	0.53	0.53	1.18	0.39	1.79	2.42
21	1.48	0.36	1.67	4.71	0.36	0.32	0.98	0.18	1.48	2.17
22	0.84	0.22	1.12	2.32	0.18	0.14	0.53	0.07	0.37	1.21
23	0.64	0.18	0.84	1.24	0.14	0.09	0.42	0.04	0.23	0.87
24	0.45	0.12	0.56	0.68	0.09	0.06	0.21	0.02	0.13	0.56

	Vehicle Class									
Load (kips)	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
25	0.24	0.06	0.27	0.41	0.06	0.02	0.12	0.03	0.19	0.27
26	0.15	0.04	0.10	0.35	0.02	0.02	0.10	0.00	0.00	0.28
27	0.05	0.02	0.10	0.23	0.03	0.01	0.07	0.00	0.00	0.11
28	0.04	0.01	0.02	0.24	0.02	0.01	0.03	0.00	0.00	0.10
29	0.02	0.00	0.00	0.18	0.01	0.00	0.01	0.00	0.00	0.08
30	0.01	0.00	0.01	0.11	0.01	0.00	0.02	0.00	0.00	0.06
31	0.00	0.00	0.01	0.10	0.01	0.00	0.01	0.00	0.00	0.04
32	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.05
33	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.03
34	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
35	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
36	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04

Table H15. M-E PDG Default Single Axle Load Spectra

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
3	1.80	10.05	2.47	2.14	11.65	1.74	3.64	3.55	6.68	8.88
4	0.96	13.21	1.78	0.55	5.37	1.37	1.24	2.91	2.29	2.67
5	2.91	16.42	3.45	2.42	7.84	2.84	2.36	5.19	4.87	3.81
6	3.99	10.61	3.95	2.70	6.99	3.53	3.38	5.27	5.86	5.23
7	6.80	9.22	6.70	3.21	7.99	4.93	5.18	6.32	5.97	6.03
8	11.47	8.27	8.45	5.81	9.63	8.43	8.35	6.98	8.86	8.10
9	11.30	7.12	11.85	5.26	9.93	13.67	13.85	8.08	9.58	8.35
10	10.97	5.85	13.57	7.39	8.51	17.68	17.35	9.68	9.94	10.69
11	9.88	4.53	12.13	6.85	6.47	16.71	16.21	8.55	8.59	10.69
12	8.54	3.46	9.48	7.42	5.19	11.57	10.27	7.29	7.11	11.11
13	7.33	2.56	6.83	8.99	3.99	6.09	6.52	7.16	5.87	7.32
14	5.55	1.92	5.05	8.15	3.38	3.52	3.94	5.65	6.61	3.78
15	4.23	1.54	3.74	7.77	2.73	1.91	2.33	4.77	4.55	3.10
16	3.11	1.19	2.66	6.84	2.19	1.55	1.57	4.35	3.63	2.58
17	2.54	0.90	1.92	5.67	1.83	1.10	1.07	3.56	2.56	1.52
18	1.98	0.68	1.43	4.63	1.53	0.88	0.71	3.02	2.00	1.32
19	1.53	0.52	1.07	3.50	1.16	0.73	0.53	2.06	1.54	1.00
20	1.19	0.40	0.82	2.64	0.97	0.53	0.32	1.63	0.98	0.83
21	1.16	0.31	0.64	1.90	0.61	0.38	0.29	1.27	0.71	0.64
22	0.66	0.31	0.49	1.31	0.55	0.25	0.19	0.76	0.51	0.38
23	0.56	0.18	0.38	0.97	0.36	0.17	0.15	0.59	0.29	0.52
24	0.37	0.14	0.26	0.67	0.26	0.13	0.17	0.41	0.27	0.22

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
25	0.31	0.15	0.24	0.43	0.19	0.08	0.09	0.25	0.19	0.13
26	0.18	0.12	0.13	1.18	0.16	0.06	0.05	0.14	0.15	0.26
27	0.18	0.08	0.13	0.26	0.11	0.04	0.03	0.21	0.12	0.28
28	0.14	0.05	0.08	0.17	0.08	0.03	0.02	0.07	0.08	0.12
29	0.08	0.05	0.08	0.17	0.05	0.02	0.03	0.09	0.09	0.13
30	0.05	0.02	0.05	0.08	0.04	0.01	0.02	0.06	0.02	0.05
31	0.04	0.02	0.03	0.72	0.04	0.01	0.03	0.03	0.03	0.05
32	0.04	0.02	0.03	0.06	0.12	0.01	0.01	0.04	0.01	0.08
33	0.04	0.02	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.06
34	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.00	0.01	0.02
35	0.02	0.02	0.01	0.02	0.02	0.00	0.01	0.00	0.00	0.01
36	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01
37	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
38	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.01	0.01
39	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01
40	0.01	0.00	0.01	0.01	0.00	0.00	0.04	0.02	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tandem Axle Load Spectra Design Values

Table H16. Statewide Tandem Axle Load Spectra

	Vehicle Class									
Load (kips)	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6	0.08	30.65	4.14	2.48	3.22	1.16	0.25	0.00	0.70	1.54
8	0.40	39.99	13.85	6.14	5.91	2.84	0.96	0.00	1.81	3.51
10	1.13	23.94	10.93	6.66	14.40	6.69	2.90	0.00	4.45	4.99
12	2.17	4.76	6.84	6.79	17.89	9.16	5.88	0.00	6.99	5.69
14	2.60	0.48	6.42	6.82	14.04	8.89	8.08	0.00	10.39	6.00
16	2.91	0.06	6.01	6.67	10.92	7.96	7.86	0.00	12.28	4.44
18	3.48	0.03	5.50	5.95	8.65	7.17	7.06	0.00	13.68	3.15
20	4.26	0.02	5.58	5.53	7.06	6.62	6.59	0.00	13.50	2.90
22	6.01	0.02	5.90	7.67	5.68	6.39	5.96	0.00	11.86	3.54
24	9.23	0.01	6.80	8.36	4.46	6.61	6.01	0.00	10.37	5.09
26	11.21	0.01	5.81	6.66	2.74	5.53	5.47	0.00	6.01	6.05
28	12.99	0.01	5.08	6.15	1.81	5.46	6.11	0.00	3.47	8.03
30	13.64	0.01	4.28	6.29	1.18	5.82	6.85	0.00	1.79	9.68
32	11.61	0.00	3.57	4.82	0.80	6.12	7.44	0.00	1.06	10.11
34	7.94	0.00	2.87	3.54	0.52	5.36	7.07	0.00	0.72	8.54
36	4.76	0.01	2.09	2.66	0.31	3.57	5.62	0.00	0.35	6.36
38	2.56	0.00	1.42	1.89	0.16	2.05	3.83	0.00	0.17	4.20
40	1.42	0.00	0.96	1.36	0.10	1.13	2.40	0.00	0.07	2.51
42	0.74	0.00	0.65	1.26	0.05	0.63	1.44	0.00	0.07	1.50
44	0.41	0.00	0.45	0.61	0.03	0.36	0.84	0.00	0.09	0.88

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
46	0.21	0.00	0.32	0.39	0.02	0.22	0.53	0.00	0.04	0.55
48	0.09	0.00	0.19	0.20	0.02	0.11	0.30	0.00	0.03	0.26
50	0.05	0.00	0.12	0.20	0.01	0.06	0.20	0.00	0.02	0.17
52	0.03	0.00	0.07	0.10	0.01	0.04	0.11	0.00	0.04	0.10
54	0.02	0.00	0.05	0.03	0.01	0.02	0.08	0.00	0.02	0.06
56	0.01	0.00	0.03	0.02	0.00	0.01	0.05	0.00	0.01	0.04
58	0.01	0.00	0.02	0.10	0.00	0.01	0.04	0.00	0.00	0.03
60	0.01	0.00	0.01	0.19	0.00	0.01	0.02	0.00	0.01	0.02
62	0.01	0.00	0.01	0.10	0.00	0.00	0.02	0.00	0.00	0.02
64	0.01	0.00	0.01	0.11	0.00	0.00	0.01	0.00	0.00	0.01
66	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01
68	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00

Table H17. Cluster 1 Tandem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6	0.01	19.37	1.37	3.41	1.75	0.21	0.05	0.00	0.14	0.66
8	0.08	45.73	14.37	6.69	3.77	1.09	0.20	0.00	0.16	1.55
10	0.55	29.95	9.53	4.24	14.75	5.27	1.49	0.00	3.32	2.85
12	2.25	4.67	5.87	1.42	21.34	10.01	4.85	0.00	5.87	4.14
14	3.65	0.27	7.51	5.41	15.36	11.30	7.31	0.00	8.47	4.88
16	3.63	0.01	7.49	7.38	12.02	11.01	7.31	0.00	15.34	4.08
18	3.36	0.00	6.13	5.79	9.35	10.15	9.24	0.00	18.04	2.62
20	3.93	0.00	5.66	3.30	7.62	9.04	12.54	0.00	16.32	2.03
22	4.46	0.00	5.27	11.13	5.64	7.28	8.49	0.00	12.08	2.38
24	6.26	0.00	7.00	11.47	3.75	6.37	5.16	0.00	7.54	3.94
26	9.81	0.00	6.81	7.90	2.10	4.79	4.35	0.00	5.28	5.56
28	14.77	0.00	6.20	7.19	1.09	4.66	4.79	0.00	4.69	8.34
30	19.52	0.00	4.82	6.13	0.60	5.07	5.59	0.00	0.95	11.14
32	16.58	0.00	3.78	4.62	0.33	5.23	6.58	0.00	1.01	12.42
34	7.32	0.00	3.00	4.17	0.21	4.30	7.16	0.00	0.45	11.47
36	2.46	0.00	1.86	3.73	0.15	2.57	6.43	0.00	0.09	8.94
38	0.74	0.00	1.05	2.94	0.08	1.11	4.30	0.00	0.06	5.90
40	0.26	0.00	0.80	0.52	0.03	0.35	2.19	0.00	0.02	3.53
42	0.16	0.00	0.51	0.55	0.03	0.12	0.90	0.00	0.06	1.90
44	0.12	0.00	0.33	0.43	0.01	0.04	0.50	0.00	0.01	0.79
46	0.06	0.00	0.28	0.97	0.01	0.02	0.24	0.00	0.02	0.43
48	0.01	0.00	0.15	0.00	0.01	0.01	0.11	0.00	0.07	0.16

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
50	0.00	0.00	0.10	0.10	0.00	0.00	0.09	0.00	0.00	0.08
52	0.01	0.00	0.05	0.00	0.00	0.00	0.05	0.00	0.01	0.06
54	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.00	0.00	0.04
56	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.03
58	0.00	0.00	0.01	0.47	0.00	0.00	0.01	0.00	0.00	0.03
60	0.00	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.01
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table H18. Cluster 2 Tandem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
6	0.02	17.18	5.00	2.51	1.29	0.73	0.13	0.00	0.55	1.47
8	0.07	41.93	18.48	8.59	5.61	3.96	1.45	0.00	1.64	4.10
10	0.65	33.52	9.66	7.99	19.22	11.04	5.24	0.00	9.03	6.80
12	1.76	6.86	6.11	6.18	23.13	13.16	10.63	0.00	10.92	8.38
14	2.62	0.47	6.93	6.97	15.95	10.76	12.04	0.00	14.38	7.76
16	2.75	0.02	6.22	5.84	11.23	8.61	9.07	0.00	14.07	4.83
18	3.61	0.00	5.59	6.06	8.25	7.44	6.39	0.00	15.15	3.19
20	4.76	0.00	5.70	7.33	5.71	6.46	4.84	0.00	15.33	2.98
22	6.88	0.00	5.94	6.18	3.86	5.40	4.21	0.00	9.85	3.45
24	12.36	0.00	6.78	8.36	2.33	5.29	4.91	0.00	6.01	5.48
26	14.65	0.00	5.57	6.02	1.19	4.35	5.25	0.00	1.58	6.71
28	15.70	0.00	4.60	6.05	0.76	4.35	6.27	0.00	0.55	8.32
30	14.60	0.02	3.64	6.99	0.51	4.97	6.34	0.00	0.74	9.47
32	10.37	0.00	2.77	3.32	0.33	5.50	6.48	0.00	0.02	9.02
34	5.48	0.00	2.07	3.19	0.24	4.25	5.99	0.00	0.00	7.31
36	2.45	0.00	1.48	2.37	0.19	2.11	4.42	0.00	0.02	5.03
38	0.70	0.00	1.11	1.96	0.08	0.87	2.74	0.00	0.04	2.98
40	0.27	0.00	0.78	1.20	0.06	0.40	1.61	0.00	0.03	1.39
42	0.12	0.00	0.52	1.02	0.02	0.19	0.86	0.00	0.04	0.61
44	0.07	0.00	0.36	0.95	0.01	0.09	0.43	0.00	0.04	0.28
46	0.04	0.00	0.24	0.59	0.01	0.04	0.28	0.00	0.01	0.16
48	0.03	0.00	0.14	0.06	0.01	0.02	0.14	0.00	0.00	0.09

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
50	0.01	0.00	0.11	0.11	0.01	0.01	0.12	0.00	0.00	0.05
52	0.01	0.00	0.06	0.16	0.00	0.00	0.06	0.00	0.00	0.04
54	0.01	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.03
56	0.00	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.03
58	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.01
60	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01
62	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01
64	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
66	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table H19. Cluster 3 Tandem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
6	0.17	34.94	5.80	3.02	5.28	2.46	0.48	0.00	0.55	1.94
8	0.89	37.27	10.52	5.18	7.44	4.24	1.23	0.00	1.60	4.03
10	2.12	21.60	9.50	6.45	14.12	7.90	2.80	0.00	4.79	5.48
12	3.17	4.93	6.49	8.74	16.63	9.81	4.75	0.00	8.80	6.06
14	2.70	0.72	5.56	6.46	12.99	9.28	6.81	0.00	10.29	6.44
16	2.96	0.17	5.48	6.87	10.04	7.86	7.23	0.00	9.77	4.50
18	3.74	0.08	5.34	6.01	8.25	6.78	6.42	0.00	11.70	2.89
20	3.97	0.07	5.60	6.64	7.04	6.14	5.66	0.00	11.30	2.48
22	5.35	0.05	6.25	9.31	5.71	6.23	5.45	0.00	12.01	3.11
24	9.03	0.03	7.10	9.13	4.42	6.55	5.79	0.00	11.45	4.51
26	11.09	0.03	6.01	6.20	2.74	5.49	5.05	0.00	7.10	5.47
28	12.43	0.02	5.41	4.86	1.87	5.34	5.78	0.00	3.93	7.11
30	12.16	0.03	4.63	5.07	1.25	5.21	6.81	0.00	2.09	8.98
32	11.43	0.00	4.00	3.87	0.82	4.99	7.76	0.00	1.29	9.94
34	8.72	0.01	3.47	2.53	0.54	4.32	7.92	0.00	1.51	8.48
36	5.11	0.03	2.77	2.70	0.32	3.11	6.78	0.00	0.96	6.52
38	2.37	0.01	1.89	1.87	0.18	1.83	4.93	0.00	0.32	4.42
40	1.21	0.01	1.32	1.63	0.11	1.02	3.23	0.00	0.13	2.74
42	0.58	0.00	0.90	1.45	0.08	0.55	2.01	0.00	0.10	1.81
44	0.31	0.00	0.66	0.80	0.05	0.32	1.16	0.00	0.12	1.21
46	0.19	0.00	0.49	0.29	0.03	0.20	0.77	0.00	0.09	0.76
48	0.13	0.00	0.30	0.32	0.03	0.11	0.41	0.00	0.03	0.39

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
50	0.07	0.00	0.17	0.35	0.02	0.07	0.24	0.00	0.00	0.27
52	0.03	0.00	0.11	0.15	0.01	0.05	0.15	0.00	0.05	0.15
54	0.03	0.00	0.07	0.04	0.01	0.04	0.12	0.00	0.01	0.09
56	0.01	0.00	0.03	0.00	0.01	0.03	0.07	0.00	0.01	0.06
58	0.01	0.00	0.03	0.00	0.01	0.02	0.05	0.00	0.00	0.04
60	0.00	0.00	0.02	0.06	0.00	0.01	0.03	0.00	0.00	0.02
62	0.01	0.00	0.02	0.00	0.00	0.01	0.03	0.00	0.00	0.03
64	0.01	0.00	0.02	0.00	0.00	0.01	0.02	0.00	0.00	0.02
66	0.00	0.00	0.02	0.00	0.00	0.01	0.02	0.00	0.00	0.02
68	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01
70	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01
72	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table H20. Cluster 4 Tandem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
6	0.10	47.17	4.24	2.46	4.23	0.81	0.23	0.00	0.20	1.61
8	0.42	34.29	11.13	5.55	6.17	1.58	0.83	0.00	0.64	2.52
10	0.97	15.06	13.09	6.94	9.86	3.24	2.25	0.00	2.07	3.15
12	1.54	3.13	9.41	5.56	12.03	5.12	4.27	0.00	4.26	4.01
14	2.20	0.33	7.04	6.70	11.30	6.29	6.23	0.00	7.37	4.50
16	3.22	0.02	5.86	5.78	10.06	6.71	6.87	0.00	10.06	4.17
18	3.76	0.00	5.39	5.40	8.69	6.62	6.83	0.00	9.50	3.95
20	4.83	0.00	5.33	4.60	8.08	6.81	6.88	0.00	10.46	3.79
22	6.63	0.00	5.72	7.25	7.62	7.68	7.23	0.00	13.32	3.85
24	8.12	0.00	6.36	6.72	7.35	8.66	7.62	0.00	15.70	4.92
26	7.94	0.00	5.31	7.81	5.02	7.13	6.35	0.00	11.03	5.77
28	8.37	0.00	4.66	7.66	3.53	6.63	6.60	0.00	6.88	7.68
30	9.16	0.00	4.14	7.72	2.33	6.52	7.29	0.00	3.86	9.40
32	10.42	0.00	3.45	6.04	1.53	6.43	7.54	0.00	2.25	10.13
34	9.80	0.00	2.84	3.83	0.99	5.85	6.64	0.00	1.06	9.17
36	8.11	0.00	2.03	2.65	0.55	4.77	5.29	0.00	0.32	7.20
38	6.03	0.00	1.36	2.17	0.30	3.60	3.84	0.00	0.26	5.21
40	3.84	0.00	0.90	2.29	0.16	2.37	2.58	0.00	0.12	3.53
42	2.22	0.00	0.60	1.17	0.08	1.43	1.65	0.00	0.10	2.25
44	1.25	0.00	0.39	0.27	0.05	0.82	1.07	0.00	0.08	1.38
46	0.57	0.00	0.27	0.22	0.02	0.48	0.69	0.00	0.07	0.87
48	0.20	0.00	0.18	0.36	0.03	0.22	0.44	0.00	0.07	0.37

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
50	0.10	0.00	0.11	0.26	0.01	0.11	0.29	0.00	0.06	0.23
52	0.06	0.00	0.07	0.06	0.01	0.06	0.17	0.00	0.09	0.09
54	0.03	0.00	0.04	0.07	0.00	0.03	0.11	0.00	0.07	0.07
56	0.02	0.00	0.03	0.06	0.00	0.02	0.07	0.00	0.01	0.04
58	0.03	0.00	0.02	0.07	0.00	0.01	0.05	0.00	0.02	0.03
60	0.02	0.00	0.01	0.16	0.00	0.00	0.03	0.00	0.05	0.02
62	0.01	0.00	0.01	0.17	0.00	0.00	0.03	0.00	0.00	0.01
64	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01
66	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
68	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
70	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table H21. Cluster 5 Tandem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
6	0.00	25.33	1.19	0.56	1.30	0.45	0.13	0.00	2.50	1.38
8	0.06	47.38	17.34	4.88	4.35	1.75	0.37	0.00	5.69	4.56
10	0.42	23.20	13.94	6.49	14.26	4.69	1.55	0.00	1.26	5.66
12	1.55	3.71	5.46	9.88	19.00	8.08	4.15	0.00	2.73	4.49
14	2.17	0.37	5.61	8.69	16.66	8.44	7.71	0.00	10.55	5.54
16	1.99	0.01	5.94	8.44	12.84	7.52	9.40	0.00	15.03	4.40
18	2.33	0.00	5.37	6.67	9.53	6.66	8.16	0.00	17.47	2.79
20	3.50	0.00	5.66	3.52	7.18	6.00	6.24	0.00	17.17	2.98
22	6.32	0.00	5.89	5.05	5.46	5.46	5.85	0.00	12.60	5.07
24	8.83	0.00	6.73	6.70	3.89	5.50	6.48	0.00	9.25	6.95
26	12.34	0.00	5.77	5.92	2.04	4.99	6.27	0.00	3.71	7.09
28	16.15	0.00	4.91	5.93	1.14	5.73	6.83	0.00	0.90	9.87
30	17.46	0.00	4.31	5.67	0.70	7.49	8.06	0.00	0.33	11.09
32	12.07	0.00	3.92	7.52	0.74	9.57	8.76	0.00	0.44	10.04
34	7.66	0.00	2.77	5.36	0.43	9.13	7.85	0.00	0.12	7.29
36	4.17	0.00	1.88	2.20	0.22	5.31	4.88	0.00	0.01	4.73
38	1.84	0.00	1.30	0.53	0.11	2.11	2.77	0.00	0.01	2.69
40	0.78	0.00	0.72	0.22	0.10	0.67	1.71	0.00	0.01	1.34
42	0.22	0.00	0.48	1.89	0.01	0.24	1.18	0.00	0.01	0.72
44	0.06	0.00	0.31	0.38	0.02	0.10	0.73	0.00	0.21	0.40
46	0.05	0.00	0.19	0.10	0.01	0.05	0.39	0.00	0.00	0.31
48	0.00	0.00	0.10	0.05	0.00	0.03	0.21	0.00	0.00	0.16

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
50	0.01	0.00	0.09	0.00	0.01	0.01	0.14	0.00	0.00	0.11
52	0.01	0.00	0.03	0.00	0.00	0.01	0.07	0.00	0.00	0.10
54	0.00	0.00	0.03	0.00	0.00	0.01	0.07	0.00	0.00	0.06
56	0.00	0.00	0.01	0.01	0.00	0.00	0.03	0.00	0.00	0.04
58	0.00	0.00	0.01	0.20	0.00	0.00	0.01	0.00	0.00	0.04
60	0.00	0.00	0.02	0.93	0.00	0.00	0.00	0.00	0.00	0.02
62	0.01	0.00	0.01	0.44	0.00	0.00	0.00	0.00	0.00	0.02
64	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.02
66	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.01
68	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.01
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
72	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
74	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table H22. M-E PDG Default Tandem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6	5.88	7.06	5.28	13.76	18.93	2.78	2.45	7.93	5.23	6.42
8	1.44	35.44	8.43	6.72	8.07	3.92	2.19	3.15	1.75	3.85
10	1.94	13.24	10.83	6.50	11.17	6.52	3.65	5.21	3.35	5.59
12	2.73	6.32	8.99	3.46	11.87	7.62	5.40	8.23	5.89	5.67
14	3.63	4.33	7.72	7.07	10.53	7.75	6.90	8.88	8.73	5.74
16	4.96	5.08	7.50	4.83	8.26	7.01	7.49	8.45	8.38	5.54
18	7.95	5.05	6.76	4.97	6.78	5.83	6.99	7.08	9.77	4.90
20	11.58	4.39	6.06	4.58	5.33	5.60	6.62	5.49	10.84	4.50
22	14.20	2.31	5.71	4.26	4.13	5.17	6.26	5.14	10.78	6.45
24	13.15	2.28	5.17	3.85	3.12	5.05	5.95	5.99	7.24	4.77
26	10.73	1.53	4.52	3.44	2.34	5.28	6.16	5.73	6.14	4.34
28	7.47	1.96	3.90	6.03	1.82	5.53	6.54	4.37	4.93	5.63
30	5.08	1.89	3.21	3.68	1.58	6.13	6.24	6.58	3.93	7.24
32	3.12	2.19	3.91	2.98	1.20	6.28	5.92	4.61	3.09	4.69
34	1.87	1.74	2.12	2.89	1.05	5.67	4.99	4.48	2.74	4.51
36	1.30	1.78	1.74	2.54	0.94	4.46	3.63	2.91	1.73	3.93
38	0.76	1.67	1.44	2.66	0.56	3.16	2.79	1.83	1.32	4.20
40	0.53	0.38	1.26	2.50	0.64	2.13	2.24	1.12	1.07	3.22
42	0.52	0.36	1.01	1.57	0.28	1.41	1.69	0.84	0.58	2.28
44	0.30	0.19	0.83	1.53	0.28	0.91	1.26	0.68	0.51	1.77
46	0.21	0.13	0.71	2.13	0.41	0.59	1.54	0.32	0.43	1.23
48	0.18	0.13	0.63	1.89	0.20	0.39	0.73	0.21	0.22	0.85

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
50	0.11	0.14	0.49	1.17	0.14	0.26	0.57	0.21	0.22	0.64
52	0.06	0.20	0.39	1.07	0.11	0.17	0.40	0.07	0.23	0.39
54	0.04	0.06	0.32	0.87	0.06	0.11	0.38	0.13	0.20	0.60
56	0.08	0.06	0.26	0.81	0.05	0.08	0.25	0.15	0.12	0.26
58	0.01	0.02	0.19	0.47	0.03	0.05	0.16	0.09	0.07	0.18
60	0.02	0.02	0.17	0.49	0.02	0.03	0.15	0.03	0.19	0.08
62	0.10	0.01	0.13	0.38	0.06	0.02	0.09	0.06	0.09	0.14
64	0.01	0.01	0.08	0.24	0.02	0.02	0.08	0.01	0.04	0.07
66	0.02	0.00	0.06	0.15	0.02	0.02	0.06	0.01	0.02	0.08
68	0.01	0.00	0.07	0.16	0.00	0.02	0.05	0.01	0.04	0.03
70	0.01	0.02	0.04	0.06	0.00	0.01	0.11	0.00	0.12	0.01
72	0.00	0.01	0.04	0.13	0.00	0.01	0.04	0.00	0.00	0.04
74	0.00	0.00	0.02	0.06	0.00	0.01	0.01	0.00	0.00	0.02
76	0.00	0.00	0.01	0.06	0.00	0.00	0.01	0.00	0.00	0.04
78	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.02
80	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.08
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tridem Axle Load Spectra Design Values

Table H23. Statewide Tridem Axle Load Spectra

	Vehicle Class									
Load (kips)	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
12	66.67	48.28	29.51	3.45	20.89	59.19	14.02	23.31	13.28	24.40
15	0.00	1.08	9.20	2.96	2.33	13.03	12.57	20.89	6.38	13.34
18	0.00	0.43	7.60	3.94	3.34	7.89	11.89	15.88	6.74	7.79
21	0.00	0.15	10.35	5.86	4.26	6.51	11.26	12.00	6.00	4.71
24	0.00	0.73	4.73	6.99	3.71	2.78	9.06	5.80	4.37	3.05
27	0.00	3.13	3.55	7.34	4.32	1.87	7.22	2.61	4.53	2.32
30	0.00	3.83	6.27	8.79	5.24	2.51	5.85	2.08	8.01	2.54
33	0.00	0.70	4.18	8.78	4.89	1.02	4.47	2.06	5.61	3.14
36	0.00	15.59	2.11	10.33	3.91	0.66	4.65	2.94	6.25	4.83
39	0.00	0.70	2.22	10.85	5.00	0.55	4.57	1.10	8.04	6.25
42	26.66	3.48	1.79	9.73	3.99	0.59	3.71	2.98	6.70	6.14
45	6.67	2.93	1.70	7.82	4.53	0.84	3.30	1.95	6.08	6.12
48	0.00	3.33	1.19	5.51	4.96	0.36	2.44	1.87	3.48	5.01
51	0.00	1.78	3.12	3.08	4.98	0.46	1.64	0.72	5.81	3.40
54	0.00	4.48	0.96	1.90	5.98	0.27	1.21	1.27	2.22	2.46
57	0.00	0.00	0.00	1.02	5.00	0.23	0.79	0.41	0.98	1.60
60	0.00	0.00	0.10	0.52	3.10	0.32	0.48	0.40	0.89	1.00
63	0.00	0.00	2.09	0.39	1.51	0.12	0.30	0.16	0.96	0.72
66	0.00	0.00	1.96	0.30	1.40	0.10	0.18	0.99	1.39	0.39
69	0.00	6.25	1.47	0.17	1.59	0.25	0.14	0.20	0.38	0.24

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
72	0.00	0.00	2.94	0.06	1.16	0.12	0.09	0.38	0.11	0.18
75	0.00	0.00	0.02	0.03	0.99	0.09	0.06	0.00	0.08	0.10
78	0.00	0.00	0.00	0.03	1.12	0.07	0.03	0.00	0.23	0.08
81	0.00	0.00	1.47	0.01	1.42	0.05	0.02	0.00	0.20	0.05
84	0.00	3.13	0.00	0.02	0.06	0.02	0.01	0.00	0.41	0.03
87	0.00	0.00	0.45	0.01	0.05	0.04	0.01	0.00	0.07	0.03
90	0.00	0.00	0.00	0.00	0.10	0.02	0.01	0.00	0.09	0.01
93	0.00	0.00	0.04	0.00	0.01	0.02	0.00	0.00	0.35	0.02
96	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.03	0.01
99	0.00	0.00	0.98	0.03	0.10	0.00	0.01	0.00	0.10	0.01
102	0.00	0.00	0.00	0.07	0.06	0.00	0.01	0.00	0.23	0.03

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H24. Cluster 1 Tridem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.67	48.28	29.51	2.10	20.89	59.19	13.15	23.31	13.28	14.69
15	0.00	1.08	9.20	2.56	2.33	13.03	11.86	20.89	6.38	11.04
18	0.00	0.43	7.60	3.99	3.34	7.89	11.11	15.88	6.74	6.62
21	0.00	0.15	10.35	5.43	4.26	6.51	10.08	12.00	6.00	4.59
24	0.00	0.73	4.73	6.90	3.71	2.78	8.27	5.80	4.37	3.01
27	0.00	3.13	3.55	7.59	4.32	1.87	6.84	2.61	4.53	2.72
30	0.00	3.83	6.27	9.09	5.24	2.51	6.29	2.08	8.01	2.88
33	0.00	0.70	4.18	9.33	4.89	1.02	5.39	2.06	5.61	3.57
36	0.00	15.59	2.11	10.58	3.91	0.66	5.87	2.94	6.25	5.69
39	0.00	0.70	2.22	11.11	5.00	0.55	5.49	1.10	8.04	7.37
42	26.66	3.48	1.79	9.56	3.99	0.59	4.23	2.98	6.70	7.70
45	6.67	2.93	1.70	7.83	4.53	0.84	3.53	1.95	6.08	7.59
48	0.00	3.33	1.19	5.61	4.96	0.36	2.63	1.87	3.48	6.80
51	0.00	1.78	3.12	3.20	4.98	0.46	1.67	0.72	5.81	5.11
54	0.00	4.48	0.96	2.28	5.98	0.27	1.36	1.27	2.22	3.90
57	0.00	0.00	0.00	1.24	5.00	0.23	0.85	0.41	0.98	2.47
60	0.00	0.00	0.10	0.57	3.10	0.32	0.51	0.40	0.89	1.58
63	0.00	0.00	2.09	0.42	1.51	0.12	0.31	0.16	0.96	1.16
66	0.00	0.00	1.96	0.35	1.40	0.10	0.18	0.99	1.39	0.57
69	0.00	6.25	1.47	0.14	1.59	0.25	0.15	0.20	0.38	0.31
72	0.00	0.00	2.94	0.07	1.16	0.12	0.10	0.38	0.11	0.21
75	0.00	0.00	0.02	0.04	0.99	0.09	0.06	0.00	0.08	0.14

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
78	0.00	0.00	0.00	0.00	1.12	0.07	0.03	0.00	0.23	0.09
81	0.00	0.00	1.47	0.00	1.42	0.05	0.02	0.00	0.20	0.05
84	0.00	3.13	0.00	0.00	0.06	0.02	0.01	0.00	0.41	0.03
87	0.00	0.00	0.45	0.00	0.05	0.04	0.00	0.00	0.07	0.03
90	0.00	0.00	0.00	0.00	0.10	0.02	0.00	0.00	0.09	0.01
93	0.00	0.00	0.04	0.00	0.01	0.02	0.00	0.00	0.35	0.02
96	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.01
99	0.00	0.00	0.98	0.00	0.10	0.00	0.01	0.00	0.10	0.01
102	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.00	0.23	0.03

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H25. Cluster 2 Tridem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.67	48.28	29.51	5.11	20.89	59.19	12.60	23.31	13.28	23.54
15	0.00	1.08	9.20	3.84	2.33	13.03	15.33	20.89	6.38	17.18
18	0.00	0.43	7.60	5.53	3.34	7.89	14.68	15.88	6.74	10.70
21	0.00	0.15	10.35	8.21	4.26	6.51	13.99	12.00	6.00	6.32
24	0.00	0.73	4.73	8.64	3.71	2.78	10.46	5.80	4.37	3.53
27	0.00	3.13	3.55	6.88	4.32	1.87	5.72	2.61	4.53	2.01
30	0.00	3.83	6.27	8.78	5.24	2.51	4.71	2.08	8.01	2.47
33	0.00	0.70	4.18	7.68	4.89	1.02	3.92	2.06	5.61	3.02
36	0.00	15.59	2.11	8.71	3.91	0.66	4.38	2.94	6.25	4.94
39	0.00	0.70	2.22	10.13	5.00	0.55	4.21	1.10	8.04	6.22
42	26.66	3.48	1.79	8.44	3.99	0.59	2.99	2.98	6.70	5.77
45	6.67	2.93	1.70	7.15	4.53	0.84	2.30	1.95	6.08	5.52
48	0.00	3.33	1.19	4.97	4.96	0.36	1.66	1.87	3.48	3.55
51	0.00	1.78	3.12	2.83	4.98	0.46	1.01	0.72	5.81	1.88
54	0.00	4.48	0.96	1.43	5.98	0.27	0.74	1.27	2.22	1.15
57	0.00	0.00	0.00	0.66	5.00	0.23	0.47	0.41	0.98	0.73
60	0.00	0.00	0.10	0.34	3.10	0.32	0.33	0.40	0.89	0.44
63	0.00	0.00	2.09	0.21	1.51	0.12	0.17	0.16	0.96	0.35
66	0.00	0.00	1.96	0.17	1.40	0.10	0.12	0.99	1.39	0.22
69	0.00	6.25	1.47	0.13	1.59	0.25	0.08	0.20	0.38	0.15
72	0.00	0.00	2.94	0.03	1.16	0.12	0.05	0.38	0.11	0.12
75	0.00	0.00	0.02	0.00	0.99	0.09	0.03	0.00	0.08	0.06

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
78	0.00	0.00	0.00	0.04	1.12	0.07	0.03	0.00	0.23	0.05
81	0.00	0.00	1.47	0.01	1.42	0.05	0.01	0.00	0.20	0.04
84	0.00	3.13	0.00	0.01	0.06	0.02	0.01	0.00	0.41	0.02
87	0.00	0.00	0.45	0.00	0.05	0.04	0.00	0.00	0.07	0.01
90	0.00	0.00	0.00	0.00	0.10	0.02	0.00	0.00	0.09	0.01
93	0.00	0.00	0.04	0.00	0.01	0.02	0.00	0.00	0.35	0.00
96	0.00	0.00	0.00	0.05	0.00	0.02	0.00	0.00	0.03	0.00
99	0.00	0.00	0.98	0.02	0.10	0.00	0.00	0.00	0.10	0.00
102	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.23	0.00

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H26. Cluster 3 Tridem Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.67	48.28	29.51	4.65	20.89	59.19	17.94	23.31	13.28	39.50
15	0.00	1.08	9.20	3.24	2.33	13.03	12.42	20.89	6.38	12.56
18	0.00	0.43	7.60	3.24	3.34	7.89	11.06	15.88	6.74	5.55
21	0.00	0.15	10.35	4.86	4.26	6.51	10.34	12.00	6.00	3.69
24	0.00	0.73	4.73	5.68	3.71	2.78	7.45	5.80	4.37	2.73
27	0.00	3.13	3.55	7.18	4.32	1.87	6.67	2.61	4.53	1.96
30	0.00	3.83	6.27	8.37	5.24	2.51	5.45	2.08	8.01	2.11
33	0.00	0.70	4.18	8.37	4.89	1.02	3.99	2.06	5.61	2.59
36	0.00	15.59	2.11	10.45	3.91	0.66	3.77	2.94	6.25	3.61
39	0.00	0.70	2.22	10.86	5.00	0.55	4.08	1.10	8.04	4.64
42	26.66	3.48	1.79	10.68	3.99	0.59	3.84	2.98	6.70	4.38
45	6.67	2.93	1.70	8.29	4.53	0.84	3.93	1.95	6.08	4.92
48	0.00	3.33	1.19	5.77	4.96	0.36	2.86	1.87	3.48	4.01
51	0.00	1.78	3.12	3.18	4.98	0.46	2.05	0.72	5.81	2.50
54	0.00	4.48	0.96	1.87	5.98	0.27	1.41	1.27	2.22	1.67
57	0.00	0.00	0.00	1.04	5.00	0.23	0.97	0.41	0.98	1.20
60	0.00	0.00	0.10	0.61	3.10	0.32	0.60	0.40	0.89	0.72
63	0.00	0.00	2.09	0.52	1.51	0.12	0.41	0.16	0.96	0.47
66	0.00	0.00	1.96	0.38	1.40	0.10	0.24	0.99	1.39	0.30
69	0.00	6.25	1.47	0.25	1.59	0.25	0.18	0.20	0.38	0.24
72	0.00	0.00	2.94	0.06	1.16	0.12	0.12	0.38	0.11	0.18
75	0.00	0.00	0.02	0.03	0.99	0.09	0.08	0.00	0.08	0.09

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
78	0.00	0.00	0.00	0.05	1.12	0.07	0.04	0.00	0.23	0.09
81	0.00	0.00	1.47	0.02	1.42	0.05	0.03	0.00	0.20	0.07
84	0.00	3.13	0.00	0.05	0.06	0.02	0.01	0.00	0.41	0.05
87	0.00	0.00	0.45	0.02	0.05	0.04	0.02	0.00	0.07	0.04
90	0.00	0.00	0.00	0.01	0.10	0.02	0.01	0.00	0.09	0.02
93	0.00	0.00	0.04	0.01	0.01	0.02	0.00	0.00	0.35	0.02
96	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.01
99	0.00	0.00	0.98	0.07	0.10	0.00	0.01	0.00	0.10	0.02
102	0.00	0.00	0.00	0.19	0.06	0.00	0.02	0.00	0.23	0.06

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H27. M-E PDG Default Tridem Axle Load Spectra

Load (kips)	Vehicle Class 4	5	6	7	8	9	10	11	12	13
12	66.67	48.28	29.51	5.89	20.89	59.19	16.21	23.31	13.28	10.86
15	0.00	1.08	9.20	2.18	2.33	13.03	9.51	20.89	6.38	4.40
18	0.00	0.43	7.60	3.32	3.34	7.89	7.30	15.88	6.74	4.75
21	0.00	0.15	10.35	2.98	4.26	6.51	5.83	12.00	6.00	4.04
24	0.00	0.73	4.73	3.27	3.71	2.78	5.82	5.80	4.37	3.02
27	0.00	3.13	3.55	4.26	4.32	1.87	5.03	2.61	4.53	4.46
30	0.00	3.83	6.27	4.48	5.24	2.51	4.99	2.08	8.01	4.99
33	0.00	0.70	4.18	5.11	4.89	1.02	5.79	2.06	5.61	3.82
36	0.00	15.59	2.11	7.01	3.91	0.66	6.71	2.94	6.25	6.51
39	0.00	0.70	2.22	6.77	5.00	0.55	7.41	1.10	8.04	5.49
42	26.66	3.48	1.79	7.21	3.99	0.59	6.41	2.98	6.70	6.53
45	6.67	2.93	1.70	7.18	4.53	0.84	4.93	1.95	6.08	5.19
48	0.00	3.33	1.19	6.63	4.96	0.36	4.54	1.87	3.48	6.32
51	0.00	1.78	3.12	5.84	4.98	0.46	2.82	0.72	5.81	5.20
54	0.00	4.48	0.96	6.20	5.98	0.27	1.79	1.27	2.22	5.47
57	0.00	0.00	0.00	6.91	5.00	0.23	1.34	0.41	0.98	4.68
60	0.00	0.00	0.10	4.34	3.10	0.32	0.98	0.40	0.89	2.39
63	0.00	0.00	2.09	2.94	1.51	0.12	0.60	0.16	0.96	2.33
66	0.00	0.00	1.96	2.13	1.40	0.10	0.52	0.99	1.39	2.71
69	0.00	6.25	1.47	1.42	1.59	0.25	0.34	0.20	0.38	1.22
72	0.00	0.00	2.94	1.96	1.16	0.12	0.35	0.38	0.11	1.10
75	0.00	0.00	0.02	0.63	0.99	0.09	0.22	0.00	0.08	1.17

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
78	0.00	0.00	0.00	0.46	1.12	0.07	0.17	0.00	0.23	1.13
81	0.00	0.00	1.47	0.28	1.42	0.05	0.13	0.00	0.20	0.55
84	0.00	3.13	0.00	0.24	0.06	0.02	0.07	0.00	0.41	0.68
87	0.00	0.00	0.45	0.12	0.05	0.04	0.07	0.00	0.07	0.17
90	0.00	0.00	0.00	0.09	0.10	0.02	0.04	0.00	0.09	0.22
93	0.00	0.00	0.04	0.08	0.01	0.02	0.03	0.00	0.35	0.30
96	0.00	0.00	0.00	0.02	0.00	0.02	0.03	0.00	0.03	0.07
99	0.00	0.00	0.98	0.02	0.10	0.00	0.01	0.00	0.10	0.11
102	0.00	0.00	0.00	0.03	0.06	0.00	0.01	0.00	0.23	0.12

Quad Axle Load Spectra Design Values

Table H28. Statewide Quad Axle Load Spectra

	Vehicle Class									
Load (kips)	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
12	66.67	48.28	29.51	0.66	20.89	59.19	1.74	23.31	13.28	1.49
15	0.00	1.08	9.20	0.64	2.33	13.03	3.36	20.89	6.38	2.70
18	0.00	0.43	7.60	0.67	3.34	7.89	6.69	15.88	6.74	4.32
21	0.00	0.15	10.35	1.33	4.26	6.51	7.49	12.00	6.00	5.58
24	0.00	0.73	4.73	2.34	3.71	2.78	7.04	5.80	4.37	5.46
27	0.00	3.13	3.55	2.65	4.32	1.87	6.08	2.61	4.53	4.84
30	0.00	3.83	6.27	3.72	5.24	2.51	5.62	2.08	8.01	4.05
33	0.00	0.70	4.18	4.73	4.89	1.02	4.19	2.06	5.61	2.67
36	0.00	15.59	2.11	6.32	3.91	0.66	3.43	2.94	6.25	2.27
39	0.00	0.70	2.22	7.74	5.00	0.55	2.74	1.10	8.04	2.12
42	26.66	3.48	1.79	9.55	3.99	0.59	2.10	2.98	6.70	2.22
45	6.67	2.93	1.70	11.63	4.53	0.84	2.03	1.95	6.08	2.94
48	0.00	3.33	1.19	12.07	4.96	0.36	2.09	1.87	3.48	3.68
51	0.00	1.78	3.12	10.45	4.98	0.46	2.17	0.72	5.81	3.96
54	0.00	4.48	0.96	9.03	5.98	0.27	2.52	1.27	2.22	4.68
57	0.00	0.00	0.00	6.40	5.00	0.23	2.89	0.41	0.98	4.59
60	0.00	0.00	0.10	3.74	3.10	0.32	3.17	0.40	0.89	3.98
63	0.00	0.00	2.09	2.27	1.51	0.12	3.68	0.16	0.96	3.85
66	0.00	0.00	1.96	1.36	1.40	0.10	3.23	0.99	1.39	3.17
69	0.00	6.25	1.47	0.87	1.59	0.25	3.20	0.20	0.38	3.05

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
72	0.00	0.00	2.94	0.56	1.16	0.12	2.73	0.38	0.11	2.75
75	0.00	0.00	0.02	0.28	0.99	0.09	2.23	0.00	0.08	2.37
78	0.00	0.00	0.00	0.18	1.12	0.07	2.08	0.00	0.23	2.23
81	0.00	0.00	1.47	0.11	1.42	0.05	1.83	0.00	0.20	2.14
84	0.00	3.13	0.00	0.09	0.06	0.02	1.50	0.00	0.41	1.87
87	0.00	0.00	0.45	0.08	0.05	0.04	1.51	0.00	0.07	1.77
90	0.00	0.00	0.00	0.07	0.10	0.02	1.41	0.00	0.09	1.53
93	0.00	0.00	0.04	0.03	0.01	0.02	1.30	0.00	0.35	1.26
96	0.00	0.00	0.00	0.04	0.00	0.02	1.33	0.00	0.03	1.29
99	0.00	0.00	0.98	0.14	0.10	0.00	1.79	0.00	0.10	1.79
102	0.00	0.00	0.00	0.25	0.06	0.00	6.83	0.00	0.23	9.38

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H29. Cluster 1 Quad Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.66	48.31	29.50	0.18	20.89	59.19	0.57	23.31	13.28	0.97
15	0.00	1.07	9.20	0.29	2.33	13.03	2.76	20.89	6.38	2.84
18	0.00	0.43	7.60	0.27	3.34	7.89	8.64	15.88	6.74	6.17
21	0.00	0.15	10.36	1.36	4.26	6.51	9.47	12.00	6.00	9.51
24	0.00	0.73	4.73	2.51	3.71	2.78	8.59	5.80	4.37	9.84
27	0.00	3.12	3.55	3.35	4.32	1.87	7.38	2.61	4.53	8.73
30	0.00	3.83	6.27	4.44	5.24	2.51	7.69	2.08	8.01	6.50
33	0.00	0.70	4.18	4.67	4.89	1.02	5.69	2.06	5.61	3.00
36	0.00	15.61	2.11	6.64	3.91	0.66	4.19	2.94	6.25	2.10
39	0.00	0.70	2.22	8.55	5.00	0.55	2.82	1.10	8.04	2.00
42	26.67	3.47	1.79	8.86	3.99	0.59	1.97	2.98	6.70	2.02
45	6.67	2.93	1.70	12.33	4.53	0.84	1.65	1.95	6.08	2.47
48	0.00	3.33	1.19	12.81	4.96	0.36	1.68	1.87	3.48	2.83
51	0.00	1.78	3.12	10.83	4.98	0.46	1.88	0.72	5.81	3.36
54	0.00	4.47	0.96	9.32	5.98	0.27	2.13	1.27	2.22	4.02
57	0.00	0.00	0.00	5.63	5.00	0.23	2.35	0.41	0.98	3.73
60	0.00	0.00	0.10	3.31	3.10	0.32	2.74	0.40	0.89	3.24
63	0.00	0.00	2.09	1.82	1.51	0.12	3.74	0.16	0.96	3.03
66	0.00	0.00	1.96	1.06	1.40	0.10	3.36	0.99	1.39	2.60
69	0.00	6.24	1.47	0.73	1.59	0.25	3.12	0.20	0.38	2.38
72	0.00	0.00	2.94	0.52	1.16	0.12	2.54	0.38	0.11	2.17
75	0.00	0.00	0.02	0.30	0.99	0.09	2.10	0.00	0.08	1.82

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
78	0.00	0.00	0.00	0.11	1.12	0.07	2.00	0.00	0.23	1.71
81	0.00	0.00	1.47	0.05	1.42	0.05	1.69	0.00	0.20	1.65
84	0.00	3.13	0.00	0.00	0.06	0.02	1.35	0.00	0.41	1.33
87	0.00	0.00	0.45	0.02	0.05	0.04	1.38	0.00	0.07	1.23
90	0.00	0.00	0.00	0.02	0.10	0.02	1.16	0.00	0.09	1.07
93	0.00	0.00	0.04	0.02	0.01	0.02	0.97	0.00	0.35	0.80
96	0.00	0.00	0.00	0.00	0.00	0.02	0.95	0.00	0.03	0.81
99	0.00	0.00	0.98	0.00	0.10	0.00	0.84	0.00	0.10	0.92
102	0.00	0.00	0.00	0.00	0.06	0.00	2.60	0.00	0.23	5.15

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H30. Cluster 2 Quad Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.66	48.31	29.50	0.72	20.89	59.19	1.34	23.31	13.28	1.26
15	0.00	1.07	9.20	0.85	2.33	13.03	2.96	20.89	6.38	2.62
18	0.00	0.43	7.60	0.66	3.34	7.89	5.82	15.88	6.74	4.10
21	0.00	0.15	10.36	1.30	4.26	6.51	7.50	12.00	6.00	4.54
24	0.00	0.73	4.73	2.61	3.71	2.78	7.98	5.80	4.37	3.89
27	0.00	3.12	3.55	2.31	4.32	1.87	6.95	2.61	4.53	3.64
30	0.00	3.83	6.27	3.43	5.24	2.51	5.92	2.08	8.01	3.21
33	0.00	0.70	4.18	5.23	4.89	1.02	4.08	2.06	5.61	2.50
36	0.00	15.61	2.11	6.44	3.91	0.66	3.37	2.94	6.25	2.32
39	0.00	0.70	2.22	7.97	5.00	0.55	2.89	1.10	8.04	2.16
42	26.67	3.47	1.79	9.55	3.99	0.59	2.28	2.98	6.70	2.32
45	6.67	2.93	1.70	11.87	4.53	0.84	2.28	1.95	6.08	3.38
48	0.00	3.33	1.19	13.02	4.96	0.36	2.36	1.87	3.48	4.40
51	0.00	1.78	3.12	10.61	4.98	0.46	2.41	0.72	5.81	4.74
54	0.00	4.47	0.96	9.00	5.98	0.27	2.73	1.27	2.22	5.78
57	0.00	0.00	0.00	5.92	5.00	0.23	3.30	0.41	0.98	5.66
60	0.00	0.00	0.10	2.99	3.10	0.32	3.72	0.40	0.89	4.87
63	0.00	0.00	2.09	1.90	1.51	0.12	4.14	0.16	0.96	4.61
66	0.00	0.00	1.96	1.01	1.40	0.10	3.51	0.99	1.39	3.54
69	0.00	6.24	1.47	0.81	1.59	0.25	3.40	0.20	0.38	3.35
72	0.00	0.00	2.94	0.56	1.16	0.12	2.73	0.38	0.11	2.69
75	0.00	0.00	0.02	0.32	0.99	0.09	2.14	0.00	0.08	2.32

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
78	0.00	0.00	0.00	0.19	1.12	0.07	1.98	0.00	0.23	2.22
81	0.00	0.00	1.47	0.10	1.42	0.05	1.69	0.00	0.20	2.21
84	0.00	3.13	0.00	0.07	0.06	0.02	1.37	0.00	0.41	2.01
87	0.00	0.00	0.45	0.06	0.05	0.04	1.40	0.00	0.07	1.84
90	0.00	0.00	0.00	0.11	0.10	0.02	1.35	0.00	0.09	1.57
93	0.00	0.00	0.04	0.03	0.01	0.02	1.31	0.00	0.35	1.24
96	0.00	0.00	0.00	0.01	0.00	0.02	1.28	0.00	0.03	1.25
99	0.00	0.00	0.98	0.03	0.10	0.00	1.28	0.00	0.10	1.84
102	0.00	0.00	0.00	0.32	0.06	0.00	4.53	0.00	0.23	7.92

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H31. Cluster 3 Quad Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.66	48.31	29.50	0.61	20.89	59.19	1.33	23.31	13.28	0.69
15	0.00	1.07	9.20	0.43	2.33	13.03	1.62	20.89	6.38	1.14
18	0.00	0.43	7.60	0.57	3.34	7.89	2.35	15.88	6.74	1.85
21	0.00	0.15	10.36	1.11	4.26	6.51	3.93	12.00	6.00	2.80
24	0.00	0.73	4.73	1.55	3.71	2.78	4.86	5.80	4.37	3.67
27	0.00	3.12	3.55	2.21	4.32	1.87	4.34	2.61	4.53	3.18
30	0.00	3.83	6.27	2.91	5.24	2.51	4.04	2.08	8.01	3.39
33	0.00	0.70	4.18	3.86	4.89	1.02	3.52	2.06	5.61	2.88
36	0.00	15.61	2.11	6.42	3.91	0.66	3.29	2.94	6.25	2.51
39	0.00	0.70	2.22	7.04	5.00	0.55	2.78	1.10	8.04	2.27
42	26.67	3.47	1.79	10.78	3.99	0.59	2.16	2.98	6.70	2.22
45	6.67	2.93	1.70	10.90	4.53	0.84	2.21	1.95	6.08	2.51
48	0.00	3.33	1.19	9.90	4.96	0.36	2.23	1.87	3.48	3.15
51	0.00	1.78	3.12	10.16	4.98	0.46	2.30	0.72	5.81	3.34
54	0.00	4.47	0.96	8.60	5.98	0.27	2.84	1.27	2.22	3.97
57	0.00	0.00	0.00	8.18	5.00	0.23	3.06	0.41	0.98	4.10
60	0.00	0.00	0.10	5.27	3.10	0.32	3.03	0.40	0.89	3.78
63	0.00	0.00	2.09	3.22	1.51	0.12	3.25	0.16	0.96	3.90
66	0.00	0.00	1.96	2.20	1.40	0.10	3.02	0.99	1.39	3.38
69	0.00	6.24	1.47	1.30	1.59	0.25	3.22	0.20	0.38	3.32
72	0.00	0.00	2.94	0.63	1.16	0.12	3.12	0.38	0.11	3.07
75	0.00	0.00	0.02	0.28	0.99	0.09	2.60	0.00	0.08	2.70

Load (kips)	Vehicle Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
78	0.00	0.00	0.00	0.26	1.12	0.07	2.34	0.00	0.23	2.74
81	0.00	0.00	1.47	0.15	1.42	0.05	2.18	0.00	0.20	2.62
84	0.00	3.13	0.00	0.19	0.06	0.02	1.94	0.00	0.41	2.38
87	0.00	0.00	0.45	0.15	0.05	0.04	1.99	0.00	0.07	2.31
90	0.00	0.00	0.00	0.05	0.10	0.02	1.96	0.00	0.09	2.04
93	0.00	0.00	0.04	0.02	0.01	0.02	1.81	0.00	0.35	1.80
96	0.00	0.00	0.00	0.07	0.00	0.02	2.02	0.00	0.03	1.86
99	0.00	0.00	0.98	0.51	0.10	0.00	4.03	0.00	0.10	2.83
102	0.00	0.00	0.00	0.47	0.06	0.00	16.63	0.00	0.23	17.60

*Note: Only VC 7, 10 and 13 are changed. The rest are M-E PDG Defaults

Table H32. M-E PDG Default Quad Axle Load Spectra

Load (kips)	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
12	66.66	48.31	29.50	5.89	20.89	59.19	16.21	23.31	13.28	10.87
15	0.00	1.07	9.20	2.18	2.33	13.03	9.51	20.89	6.38	4.40
18	0.00	0.43	7.60	3.32	3.34	7.89	7.29	15.88	6.74	4.75
21	0.00	0.15	10.36	2.98	4.26	6.51	5.83	12.00	6.00	4.04
24	0.00	0.73	4.73	3.27	3.71	2.78	5.82	5.80	4.37	3.02
27	0.00	3.12	3.55	4.26	4.32	1.87	5.04	2.61	4.53	4.46
30	0.00	3.83	6.27	4.48	5.24	2.51	4.99	2.08	8.01	4.99
33	0.00	0.70	4.18	5.11	4.89	1.02	5.79	2.06	5.61	3.82
36	0.00	15.61	2.11	7.01	3.91	0.66	6.71	2.94	6.25	6.51
39	0.00	0.70	2.22	6.77	5.00	0.55	7.41	1.10	8.04	5.49
42	26.67	3.47	1.79	7.21	3.99	0.59	6.41	2.98	6.70	6.52
45	6.67	2.93	1.70	7.18	4.53	0.84	4.93	1.95	6.08	5.19
48	0.00	3.33	1.19	6.63	4.96	0.36	4.54	1.87	3.48	6.32
51	0.00	1.78	3.12	5.84	4.98	0.46	2.82	0.72	5.81	5.20
54	0.00	4.47	0.96	6.20	5.98	0.27	1.79	1.27	2.22	5.47
57	0.00	0.00	0.00	6.91	5.00	0.23	1.34	0.41	0.98	4.68
60	0.00	0.00	0.10	4.34	3.10	0.32	0.98	0.40	0.89	2.39
63	0.00	0.00	2.09	2.94	1.51	0.12	0.60	0.16	0.96	2.33
66	0.00	0.00	1.96	2.13	1.40	0.10	0.52	0.99	1.39	2.71
69	0.00	6.24	1.47	1.42	1.59	0.25	0.34	0.20	0.38	1.22
72	0.00	0.00	2.94	1.96	1.16	0.12	0.35	0.38	0.11	1.10
75	0.00	0.00	0.02	0.63	0.99	0.09	0.22	0.00	0.08	1.17

78	0.00	0.00	0.00	0.46	1.12	0.07	0.17	0.00	0.23	1.13
81	0.00	0.00	1.47	0.28	1.42	0.05	0.13	0.00	0.20	0.55
84	0.00	3.13	0.00	0.24	0.06	0.02	0.07	0.00	0.41	0.68
87	0.00	0.00	0.45	0.12	0.05	0.04	0.07	0.00	0.07	0.17
90	0.00	0.00	0.00	0.09	0.10	0.02	0.04	0.00	0.09	0.22
93	0.00	0.00	0.04	0.08	0.01	0.02	0.03	0.00	0.35	0.30
96	0.00	0.00	0.00	0.02	0.00	0.02	0.03	0.00	0.03	0.07
99	0.00	0.00	0.98	0.02	0.10	0.00	0.01	0.00	0.10	0.11
102	0.00	0.00	0.00	0.03	0.06	0.00	0.01	0.00	0.23	0.12

Appendix I
Cluster Matrix

Table I1. Cluster Grouping Matrix

Site	AADTT	TTC	HDF	MDF (4-7)	MDF (8-10)	MDF (11-13)	Single AGPV	Tandem AGPV TGroup	Tridem AGPV Group	Quad AGPV Group	All Single Axle Load Spectra Groups	All Tandem Axle Load Spectra Groups	All Tridem Axle Load Spectra Groups	All Quad Axle Load Spectra Groups
1459	1	3	3	3	4	5	3	3	4	5	3	5	3	4
1529	1	3	3	EX	4	5	3	3	4	EX	2	4	3	3
2029	1	1	1	3	4	4								
2209	1	2	3	3	1	4								
2229	1	2	2	3	4	5	EX	3	4	EX	2	5	3	EX
4049	1	2	2	3	4	4	2	3	4	5	2	5	2	2
4129	1	3	2	1	4	4	3	3	2	3	3	3	2	2
4149	1	3	3	EX	4	4	3	3	2	3	2	3	1	4
4229	1	2	3	2	4	4	3	2	1	4	2	3	3	1
4249	1	3	3	2	4	EX	3	2	1	5	3	1	EX	1
5019	1	2	2	2	4	2	3	3	4	5	1	2	3	2
5059	2	2	3	1	4	2	3	2	1	5	1	2	2	1
5249	2	2	2	2	3	EX	1	1	1	2	2	3	3	4
5289	1	2	3	2	4	1	1	2	1	4	2	2	3	EX
5299	2	1	2	3	4	EX	EX	EX	1	2	1	1	2	2
6019	1	3	3	EX	4	EX	EX	EX	4	4	3	3	1	2
6129	2	2	2	2	3	4	3	2	1	5	1	2	2	1
6309	1	3	3	1	1	EX	EX	EX	4	4	2	3	3	2

Site	AADTT	TTC	HDF	MDF (4-7)	MDF (8-10)	MDF (11-13)	Single AGPV	Tandem AGPV TGroup	Tridem AGPV Group	Quad AGPV Group	All Single Axle Load Spectra Groups	All Tandem Axle Load Spectra Groups	All Tridem Axle Load Spectra Groups	All Quad Axle Load Spectra Groups
6369	2	1	1	1	3	1	2	2	3	1	1	4	1	2
6429	1	2	2	2	3	3	3	3	2	3	2	3	2	2
6469	2	1	3	2	2	4	2	1	3	1	1	1	EX	2
6479	1	2	3	2	2	1	1	2	1	4	2	3	3	1
7029	3	1	1	2	2	4	2	2	1	3	1	4	1	2
7069	1	1	1	1	4	EX								
7109	1	2	2	2	3	3	2	2	2	5	2	3	3	EX
7159	3	1	1	EX	3	3	3	2	1	5	1	4	1	2
7269	3	1	1	2	3	3	3	2	3	1	1	5	1	1
7329	1	2	3	EX	2	EX								
8029	1	2	3	1	4	2	3	3	1	4	2	3	1	3
8049	2	1	2	2	3	1	3	2	1	5	1	4	1	1
8129	1	2	2	1	3	1	3	2	1	4	2	2	3	1
8209	2	2	2	1	4	EX	1	1	1	2	2	4	1	3
8219	2	1	2	1	EX	1	3	2	1	5	1	2	2	1
8229	2	2	2	2	4	2	3	2	2	3	2	3	3	2
8440	1	3	3	1	1	EX	1	1	1	2	3	2	1	2
8729	3	1	1	2	3	1	3	1	1	5	1	5	1	2
8829	2	1	2	1	3	1	3	1	1	4	2	4	1	3
9189	2	1	2	1	4	EX	1	1	1	4	1	4	1	3

Site	AADTT	TTC	HDF	MDF (4-7)	MDF (8-10)	MDF (11-13)	Single AGPV	Tandem AGPV TGroup	Tridem AGPV Group	Quad AGPV Group	All Single Axle Load Spectra Groups	All Tandem Axle Load Spectra Groups	All Tridem Axle Load Spectra Groups	All Quad Axle Load Spectra Groups
9209	3	2	2	EX	3	2	1	1	1	2	1	1	1	3
9759	1	3	3	1	4	4	3	2	1	5	2	2	1	2
9799	3	1	1	1	3	1								

*Note EX indicates the site was excluded from the cluster groups as the group formed contained two or less sites.