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TRAFFIC LOAD SPECTRA DEVELOPMENT FOR THE 2002 AASHTO PAVEMENT DESIGN GUIDE

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16. Abstract

Accurate knowledge of traffic volumes and loading is essential to structural pavement design and performance. Underestimation of design traffic can result in premature pavement failures and excessive rehabilitation costs. Overestimation can result in overly conservative pavement designs that are not cost effective for the owner agency.

Traffic input for the anticipated National Cooperative Highway Research Program (NCHRP) 1-37A Design Guide will be in terms of axle load spectra along with several other important traffic parameters. Axle load spectra consists of classifying traffic loading in terms of the number of load applications of various axles configurations (single, dual, and tridem) within a given weight classification range.

Long term pavement performance (LTPP) data from Mississippi sites were extensively reviewed to determine vehicle class distribution, monthly and hourly distribution factors, and axle load spectra. This data will serve as baseline data for Mississippi Department of Transportation (MDOT) implementation of the new mechanistic-empirical structural pavement design guide.

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CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

Accurate knowledge of traffic volumes and loading is essential to structural pavement design and performance. Underestimation of design traffic can result in premature pavement failures and excessive rehabilitation costs. Overestimation can result in overly conservative pavement designs that are not cost effective for the owner agency.

Currently, the American Society of State Highway and Transportation Officials (AASHTO) structural pavement design utilizes design traffic input in terms of equivalent single axle loads (ESALs) [18 kip single axle load]. Traffic input for the anticipated National Cooperative Highway Research Program (NCHRP) 1-37A Design Guide (i.e., new design guide) will be in terms of axle load spectra along with other important traffic parameters.

Axle load spectra is a change from ESAL calculation and consists of classifying traffic loading in terms of the number of load applications of various axles configurations (single, dual, tridem, and quad) within a given weight classification range. Example load spectra data from NCHRP 1-37A is provided in Table 1.1. Load spectra analysis is conducted by counting, classifying, and weighing vehicles for a given time period. Design traffic (load spectra) for the pavement design life can then be calculated in a similar manner as currently used for ESALs, through application of a traffic growth factor based on historical and anticipated traffic and traffic volume adjustments.

Table 1.1 Load Spectra Example (1)

Axle Load (1000 lb)	Axle Configuration			
	Single	Tandem	Tridem	Quad
11 - 14	5,000	400	100	5
15 - 18	3,000	2,000	500	10
19 - 22	200	5,000	800	30
23 - 26	50	4,000	1,000	80
27 - 30	6	2,000	1,500	100

Load spectra analysis accuracy is dependent upon an accurate traffic distribution profile. The Mississippi Department of Transportation (MDOT) will ultimately be responsible for developing traffic classification for use with the new guide. Among the traffic classifications are buses, single unit trucks, single-trailer, multi-trailer, etc. Volumes of each traffic classification are calculated and load spectra developed accordingly.

In addition to developed load spectra several other items commonly obtained by traffic agencies are utilized in the design guide. Among these are directional and lane distribution factors, monthly and hourly truck traffic volume adjustments, axle spacing, traffic wander, and tire pressure.

1.2 OBJECTIVES AND SCOPE

This study's objective was to assist MDOT in developing load spectra and other traffic inputs for the new design guide. Load spectra development will allow MDOT to evaluate the new guide, compare it to existing guide procedures and results, and make any necessary adjustments to existing specifications.

Traffic data (volume, classification, and axle load) for Mississippi test sections within the Long Term Pavement Performance (LTPP) database were obtained and analyzed to develop traffic inputs for the new guide.

CHAPTER 2 LITERATURE REVIEW

In this chapter a brief discussion of various traffic data (volume, classification, and axle weight) and collection methods are provided along with an overview of the traffic requirements for the new design guide.

2.1 TRAFFIC DATA TYPES

The three basic traffic data types are volume, classification, and axle/weight data. Current traffic data methods follow a hierarchical approach as described below.

2.1.1 Volume

Traffic volume is generally determined using automatic traffic recorders (ATR). Automatic traffic recorders are typically road tubes, which are essentially air switches that record load applications. The most primitive type of volume recording is through human vehicle count techniques. Counts are recorded throughout a given time period and allow an average annual daily traffic (AADT) to be determined.

2.1.2 Vehicle Classification

Vehicle classification (VC) and volume data are normally conducted using automatic vehicle classifiers (AVC). Vehicle classification systems can either be intrusive or non-intrusive technologies (*2*). Intrusive VC systems include road tubes, piezoelectric sensors, fiber optic cable, preformed inductance loops, and magnetometers. Road tubes, piezoelectric sensors, and fiber optic cable deflect (i.e., pressure sensitive) as loads are applied resulting in signals being captured and interpreted as axle configuration and then as vehicle classification. Inductance loops and magnetometers detect vehicles through changes in sensor inductance through presence of metal in the vehicle. These presence detectors classify vehicles based on measured vehicle length (*2*).

Non-intrusive classification technology, a relatively new technology, includes video, radar, infared, acoustic, and ultrasonic technologies. All these methods classify vehicles according to length similar to presence detectors (*2*).

2.1.2.1 Federal Highway Administration Vehicle Classes

The Federal Highway Administration (FHWA) has developed 13 vehicle classifications (VC), shown in Table 2.1, to assist agencies in collection and analysis of traffic data. Accurately knowing the VC distribution of a traffic stream is crucial to properly estimating traffic for any design procedure, especially in the new design guide.

Table 2.1 FHWA Vehicle Classifications

Vehicle Class	Description
1	Motorcycles
2	Passenger Cars
3	Other 2-axle, 4-tire single-unit vehicles
4	Buses
5	2-axle, 6-tire single-unit trucks
6	3-axle single-unit trucks
7	4+ axle single-unit trucks
8	4-axle or fewer single trailer trucks
9	5-axle single trailer trucks
10	6+ axle single trailer trucks
11	5-axle or fewer multi-trailer trucks
12	6-axle multi-trailer trucks
13	7+ axle multi-trailer trucks

Traffic can be classified by automatic vehicle classification (AVC) or weigh-in-motion (WIM) sites. Regardless of the method, classification variability is present. Typically, transportation agencies will use computer algorithms to convert axle sensor data to vehicle classification data. These computer algorithms must be calibrated based on the typical truck axle spacing characteristics for a particular area (i.e., state or city). Generally, algorithm calibration is conducted to ensure correct classification of the predominant truck categories on a particular roadway.

2.1.3 Axle Configuration and Weight

Weigh-in-motion (WIM) devices provide the most extensive traffic data, specifically axle/weight data, while also providing vehicle classification and volume data. WIM measures applied transient vehicle tire force and then calculates static axle weight through computer algorithms.

Both portable and permanent WIM are available for use. Portable WIM measurement is conducted with capacitance mats or piezoelectric sensors. The main problem with portable WIM measurement is reduced accuracy resulting from dynamic load introduction since measurement devices are located slightly above the pavement surface. Permanent WIM are installed to be flush with the pavement surface, which improves measurement accuracy. Piezoceramic, piezopolymer, piezoquartz, bending plate, hydraulic load cells are typically used permanent WIM types (2).

2.2 EQUIVALENT SINGLE AXLE LOADS (ESALs)

Traffic, for many years, has been estimated in terms of an equivalent single axle load (ESAL). An ESAL, one 80 kN (18,000 lb.) single axle load, originated from the American Association of Highway Officials (AASHO) Road Test near Chicago, Illinois, in the early 1960's. Currently, ESALs exist for different axle configurations (single, tandem, and tridem) and associated axle weight, with ESALs being slightly greater for rigid pavements than flexible and also varying with pavement thicknesses and serviceability. ESALs can be used to establish relative damage from the pass of one vehicle compared to another. For example, a 360 kN (80,000 lb.) VC 5 vehicle with 2.2 ESALs results in approximately 5,000 times more pavement damage than an 18 kN (4,000 lb.) VC 1 vehicle with 0.0004 ESALs.

The major disadvantage of using ESALs lies in their empirical development. Conditions (loading, pavement layer materials, and thicknesses) at the AASHO road test were limited. Furthermore, truck tire pressures averaged 480 kPa (70 psi), which are significantly below today's truck tire pressures. Additionally, ESAL estimation requires traffic stream conversion to given axle types (single, tandem, tridem, and quad). Without accurate axle load breakdown known, accurate ESAL estimation can not be obtained.

While ESAL has been successfully used for many years with empirically based structural pavement designs, today's mechanistic-empirical design procedures require much more detailed traffic data in terms of vehicle classification, axle configuration and weight data.

2.3 AXLE LOAD SPECTRA

Axle load spectra (ALS) represent the distribution of axle configurations (single, tandem, tridem, and quad) with respect to axle weight. Axle load spectra use results in more accurate predictions of design traffic. The new design guide will predict pavement responses of stress, strain and displacement using layered elastic analysis procedures. These procedures require a quantifiable load input and axle configuration or, in other words, axle load spectra.

2.4 NEW DESIGN GUIDE TRAFFIC HIERARCHICAL OVERVIEW

Three hierarchical levels (Levels 1, 2, and 3) of traffic input exist within the new guide. Level 1 is most accurate and provides the greatest reliability. Level 1 requires extensive traffic knowledge in terms of accurate site specific or near site specific axle load spectra, classification, and volume data. A near specific site refers to a highway segment near the design location with no influencing intersecting roadways.

Level 2 is the intermediate design input level and requires substantial traffic data. Essential to Level 2 data is accurate knowledge of design traffic volume and vehicle classification. Through the use of truck traffic classification groups (i.e., groups developed based on the vehicle class distribution) an estimate of axle load spectra can be made through axle load spectra for similar classification groups.

Level 3 is the least accurate input level and requires only an estimate of the truck volume. Determining truck volume requires average annual daily traffic (AADT) and an estimate of percent trucks. Level 3 input can be further divided into two subsets: 3A and 3B. Subset 3A has regional truck volume and load distributions, while 3B does not. Table 2.2 illustrates required traffic input variables required for the three levels (*3*).

Table 2.2 Hierarchical Traffic Levels Input Requirements (3)

Data Element / Input Variable		Input Level 1	2	3A	3B
Traffic Load/Volume Data	WIM Data - Site/Segment Specific	x			
	WIM Data - Regional Weight Summaries		x	x	
	AVC Data - Site/Segment Specific	x	x		
	AVC Data - Regional Weight Summaries			x	
	Vehicle Counts - Site Specific			x	x
Input Variables - Truck Traffic and Tire Factors	Truck Directional Distribution Factor	x	x	x	
	Truck Lane Distribution Factor	x	x	x	
	Number of Axles Per Truck Class	x	x	x	x
	Axle and Tire Spacing	x	x	x	x
	Tire Pressure	x	x	x	x
	Truck Traffic Growth Function	x	x	x	x
	Truck Traffic Monthly Distribution Factors	x	x	x	
	Truck Hourly Distribution Factors	x	x	x	
Input Variables - Truck Traffic Distribution and Volume Variables	AADTT for Base Year	x	x	x	
	Truck Distribution/Spectra by Truck Class for Base Year	x	x	x	
	Axle Load Distribution/Spectra by Truck Class and Axle Type	x	x	x	
	Truck Traffic Classification Group for Pavement Design				x
	AADT for Base Year				x
	Percentage of Trucks				x

CHAPTER 3 TRAFFIC INPUT DEVELOPMENT

In the study it was originally planned to use traffic data provided by MDOT and supplement accordingly with FHWA Long Term Pavement Performance (LTPP) Mississippi site data. Data were obtained from MDOT; however there were problems with the data. During a review of the data, Mr. Grant Perkins with MDOT noticed several monthly W CARDS contained only a few days of data. (usually the last 2 to 4 days of the month). It was soon apparent that every site had identical problems. Further investigation showed the problem was occurring during data download and export to the FHWA CARD files.

Data from traffic counters were downloaded several times during the week, typically every Monday, Wednesday, and Friday between 2 and 5 a.m., and then exported to FHWA text formats later that day. One option of vendor software is to create daily, monthly, or yearly CARD files. MDOT was creating monthly files. Each time a counter download was exported to the FHWA text, it would create a new monthly file. This would create duplicate files each time. To handle the duplicates, data processing personnel would select from a menu one of the following options: OVERWRITE, APPEND, or CANCEL. The OVERWRITE command was wrongly selected as a result of lack of training and understanding of the procedure. This protocol was conducted for some time; perhaps a couple of years.

Raw binary code files downloaded were still available, which would allow the reprocessing of the raw machine language data files to recreate the monthly CARD files. However, with the limited staff available and the study duration, this was deemed unfeasible. The data processing format protocol problem was addressed and remedied in January 2004.

Therefore, with the absence of MDOT traffic data, the study relied totally on the LTPP Mississippi site traffic data, which is discussed below.

3.1 LONG TERM PAVEMENT PERFORMANCE (LTPP) SITES

The Long Term Pavement Performance (LTPP) national database has extensive traffic volume, classification, and load spectra data available for use. Default traffic inputs for the new design guide were developed through an extensive analysis of LTPP sites throughout the United States (*2*).

Table 3.1 provides 22 Mississippi LTPP traffic sites with associated routes, location and highway functional classification. The prevailing functional classification (FC) represented was rural principal arterial-other (14 sites), followed by rural principal arterial interstate (5 sites). Urban principal arterials (2 sites) and urban principal interstate (1 site) were also represented to a very limited degree. Each Mississippi LTPP site, shown in Figure 3.1, had WIM data in addition to classification and volume data available for analysis. Extensive data were obtained from the LTPP DataPave website (http://www.datapave.com/) in Microsoft Access™ format and then converted into Microsoft Excel™ for analysis. Table 3.2 illustrates the amount of available monitored traffic data for each site. As mentioned by other researchers (*3*) in the past, LTPP data often has substantial missing data; therefore, each site was individually analyzed to insure accurate interpretation of the data.

It is important to note that the obtained data had previously been checked for accuracy and summarized into the Microsoft Access format. If this had not been the case, extensive time would have been required to manually process and edit the large amount of traffic data. Traffic data files for volume, classification, and axle weight are typically formatted in accordance with the Federal Highway Administration Traffic Monitoring Guide. This format typically consists of a continuous line or row of data, with parameters assigned to various columns. Data analysis requires the user to input each individual file into an external software package (e.g., Microsoft Excel™). This process takes considerable time due to file formatting requirements for importing.

The use of automated software that processes, checks, analyzes and prepares traffic data in the format required for input into the design guide would greatly reduce time and result in more accurate and efficient use of the guide.

Table 3.1 Mississippi LTPP Traffic Sites

LTPP SECTION	ROUTE	FUNCTIONAL CLASSIFICATION	FUNCATIONAL CLASSIFICATION DESCRIPTION	LOCATION
0500	I 55	1	RURAL PRINCIPAL ARTERIAL - INTERSTATE	YAZOO COUNTY
0900	I 55	1	RURAL PRINCIPAL ARTERIAL - INTERSTATE	TATE COUNTY
1001	US 45	2	RURAL PRINCIPAL ARTERIAL - OTHER	VERONA, LEE COUNTY
1016	MS 35	14	URBAN PRINCIPAL ARTERIAL - OTHER	KOSCIUSKO, ATTALA COUNTY
1802	US 84	2	RURAL PRINCIPAL ARTERIAL - OTHER	COLLINS, COVINGSTON COUNTY
2807	MS 6	2	RURAL PRINCIPAL ARTERIAL - OTHER	OXFORD, LAFAYETTE COUNTY
3018	US 72	2	RURAL PRINCIPAL ARTERIAL - OTHER	IUKA, TISHOMINGO COUNTY
3081	US 78	2	RURAL PRINCIPAL ARTERIAL - OTHER	FULTON, ITAWAMBA COUNTY
3082	US 82	2	RURAL PRINCIPAL ARTERIAL - OTHER	WINONA, MONTGOMERY COUNTY
3083	MS 310	2	RURAL PRINCIPAL ARTERIAL - OTHER	HOLLY SPRINGS, MARSHALL COUNTY
3087	MS 7	2	RURAL PRINCIPAL ARTERIAL - OTHER	OXFORD, LAFAYETTE COUNTY
3090	MS 315	2	RURAL PRINCIPAL ARTERIAL - OTHER	SARDIS, PANOLA COUNTY
3091	US 45	2	RURAL PRINCIPAL ARTERIAL - OTHER	LAUDERDALE, LAUDERDALE COUNTY
3093	I 10	2	RURAL PRINCIPAL ARTERIAL - OTHER	GAUTIER, JACKSON COUNTY
3097	I 55	1	RURAL PRINCIPAL ARTERIAL - INTERSTATE	SOUTHAVEN, DESOTO COUNTY
3099	I 20	1	RURAL PRINCIPAL ARTERIAL - INTERSTATE	FOREST, SCOTT COUNTY
4024	MS 1	14	URBAN PRINCIPAL ARTERIAL - OTHER	GREENVILLE, WASHINGTON COUNTY
5006	US 78	2	RURAL PRINCIPAL ARTERIAL - OTHER	SHERMAN, PONTOTOC COUNTY
5025	US 84	2	RURAL PRINCIPAL ARTERIAL - OTHER	BROOKHAVEN, LINCOLN COUNTY
5803	US 78	2	RURAL PRINCIPAL ARTERIAL - OTHER	HOLLY SPRINGS, MARSHALL CO.
5805	I 10	11	URBAN PRINCIPAL ARTERIAL - INTERSTATE	GULFPORT, HARRISON COUNTY
9030	I 20	1	RURAL PRINCIPAL ARTERIAL - INTERSTATE	VICKSBURG, WARREN COUNTY

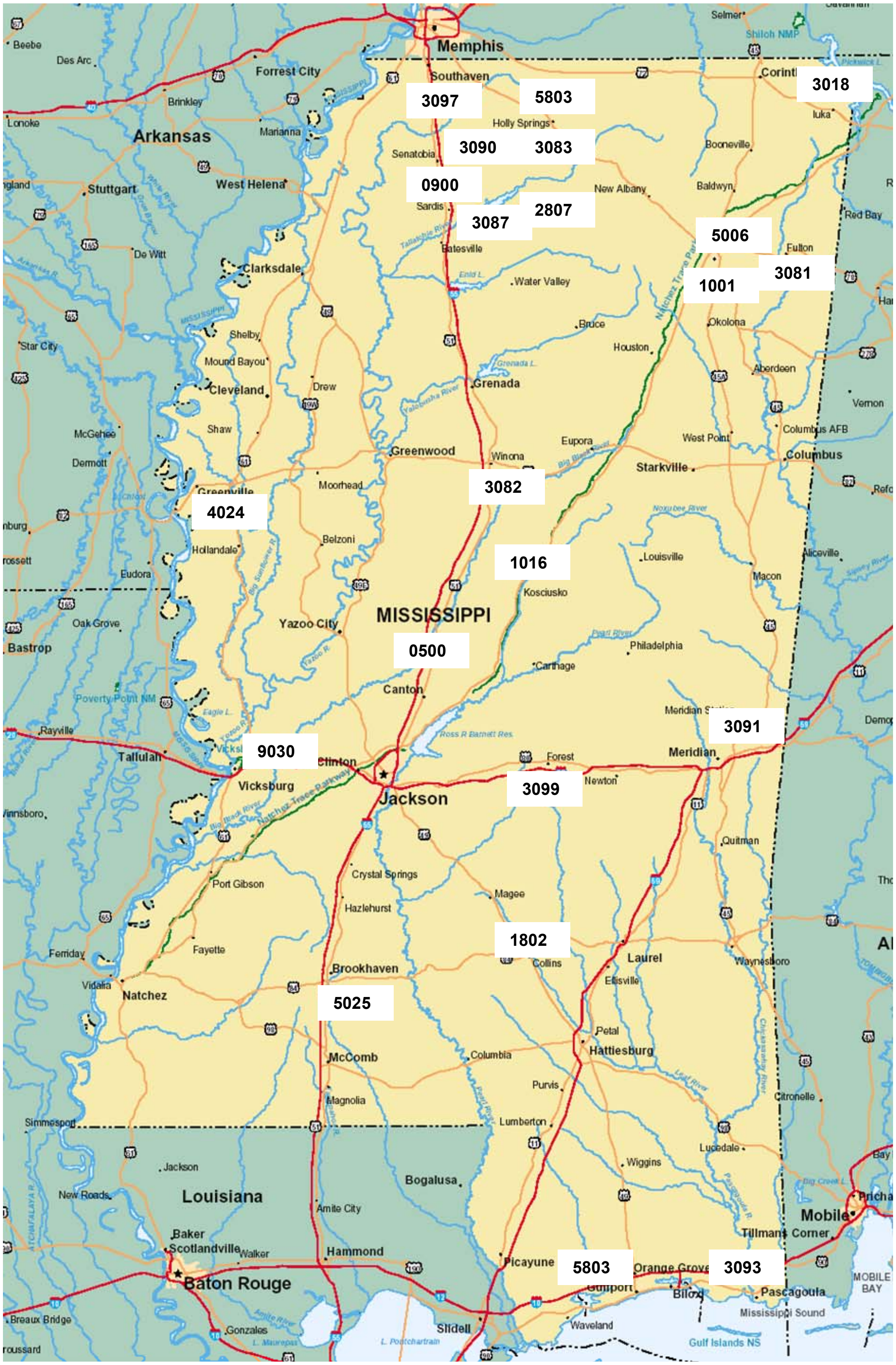

Figure 3.1 LTPP Site Locations

Table 3.2 Monitoring Data Summary

LTPP Section	Data Type		1992	1993	1994	1995	1996	1997	1998	Total
0500	AVC	Days		301	86	338				725
		Months		12	3	12				27
	WIM	Days	145	323	85	338				891
		Months	7	12	3	12				34
0900	AVC	Days				57	364	358		779
		Months				2	12	12		26
	WIM	Days				61	366		218	645
		Months				2	12			14
1001	AVC	Days	179	347	353	241	334	148	127	1729
		Months	6	12	12	9	12	6	5	62
	WIM	Days	272	351	361	252	341	149	37	1763
		Months	9	12	12	9	12	6		60
1016	AVC	Days	274	356	360	160				1150
		Months	9	12	12	6				39
	WIM	Days	275	353	362	162				1152
		Months	9	12	12	6				39
1802	AVC	Days	152	345	352	362	356	317	159	2043
		Months	5	12	12	12	12	12	6	71
	WIM	Days	153	348	352	363	300	85	242	1843
		Months	5	12	12	12	12	3		56
2807	AVC	Days	176	321	350	361	334	319		1861
		Months	6	12	12	12	11	12		65
	WIM	Days	177	330	353	364	365	321	268	2178
		Months	6	12	12	12	12	12		66
3018	AVC	Days	243	176	220	339	364	297	203	1842
		Months	9	9	9	12	12	12	9	72
	WIM	Days	249	183	224	265	301	208	231	1661
		Months	9	9	9	9	12	12		60
3081	AVC	Days	152	300	326	225	175			1178
		Months	6	11	12	9	6			44
	WIM	Days	272	356	237	226	181			1272
		Months	9	12	8	9	7			45
3082	AVC	Days	184		243	290	160	213		1090
		Months	7		10	12	6	9		44
	WIM	Days	185	256	250	222		216		1129
		Months	6	9	10	9		9		43
3083	AVC	Days	142	340	354	314	322	357	30	1859
		Months	6	12	12	12	11	12	1	66
	WIM	Days	133	267	358	315	320	355	257	2005
		Months	6	12	12	12	11	12		65
3087	AVC	Days	178	360	354	339	253			1484
		Months	7	12	12	12	9			52
	WIM	Days	178	357	355	337	217			1444
		Months	7	12	12	12	8			51

LTPP Section	Data Type		1992	1993	1994	1995	1996	1997	1998	Total
3090	AVC	Days	175	328	345	356	358	334		1896
		Months	6	12	12	12	12	12		66
	WIM	Days	259	313	181	263	358	286	272	1932
		Months	9	12	6	9	12	10		58
3091	AVC	Days	268	308	251	216	353	325	20	1741
		Months	9	12	10	9	12	12	1	65
	WIM	Days	273	320	254	230	362	293	231	1963
		Months	9	12	10	9	12	10		62
3093	AVC	Days	100	332	319	342	322	352	338	2105
		Months	6	12	12	12	12	12	11	77
	WIM	Days	107	308	321	341	136	183	218	1614
		Months	6	11	12	9	12	6		56
3097	AVC	Days	266	342	258					866
		Months	9	12	10					31
	WIM	Days	260	31	262					553
		Months	9	1	10					20
3099	AVC	Days	257	309	344	363	290	326	319	2208
		Months	9	12	12	12	12	12	12	81
	WIM	Days	263	311	349	269	297	332	233	2054
		Months	9	11	12	9	12	12		65
4024	AVC	Days	254	303	353	364		193		1467
		Months	9	10	12	12		7		50
	WIM	Days	255	301	358	360	364	324	270	2232
		Months	9	11	12	12	12	12		68
5006	AVC	Days	250	352	337	364	364	323	268	2258
		Months	9	12	12	12	12	12	9	78
	WIM	Days	235	328	345	361		326	163	1758
		Months	9	12	12	12		12		57
5025	AVC	Days	185	176	333	356	199			1249
		Months	8	8	12	12	8			48
	WIM	Days	215	209	346	280	206			1256
		Months	8	8	12	12	8			48
5803	AVC	Days	152	44	307		349	292	140	1284
		Months	5	3	11		12	12	6	49
	WIM	Days	155	51	312		244	279	301	1342
		Months	8	3	11		8	11		41
5805	AVC	Days	266	361	351	363	160			1501
		Months	9	12	12	12	6			51
	WIM	Days	177	333	351	361	161			1383
		Months	6	11	12	12	6			47
9030	AVC	Days	271	262	252	341	348	333	320	2127
		Months	9	9	11	12	12	12	12	77
	WIM	Days	183	264	265	357	281	332	266	1948
		Months	6	9	11	12	10	11		59

3.2 TRAFFIC VOLUME ADJUSTMENT

Traffic distribution with respect to vehicle classification composition and time variation must be understood in order to accurately predict traffic loading. For each LTPP site, volume and classification data were analyzed to determine traffic volume factors.

3.2.1 Percent Trucks and Vehicle Class Distribution

Percent trucks and distribution of the FHWA vehicle classes 4 – 13 are necessary to define the traffic stream composition. Because of their small axle loading VC 1, 2, and 3 (motorcycles, passenger cars and pick-ups, respectively) are not considered in most pavement designs, therefore this report will focus only on VC 4 – 13.

For each LTPP site, available data were analyzed to determine base year percent trucks and truck distribution. In the following section of the report, percent trucks and VC distribution will be presented and discussed for each site.

3.2.1.1 Section 0500, Interstate 55, Yazoo County

Average annual vehicle class distribution calculated for years 1992 through 1995 is provided in Figure 3.2. This site is classified as a rural principal interstate (FC 1) and is a four-lane interstate highway located in west central Mississippi with trucks comprising an average of 25 percent of the traffic. Vehicle class distribution for this site, and all subsequent sites, is summarized in Table 3.3. The VC distribution for 0500 is typical of the rural interstate facilities evaluated, with VC 9 trucks dominating the truck traffic stream.

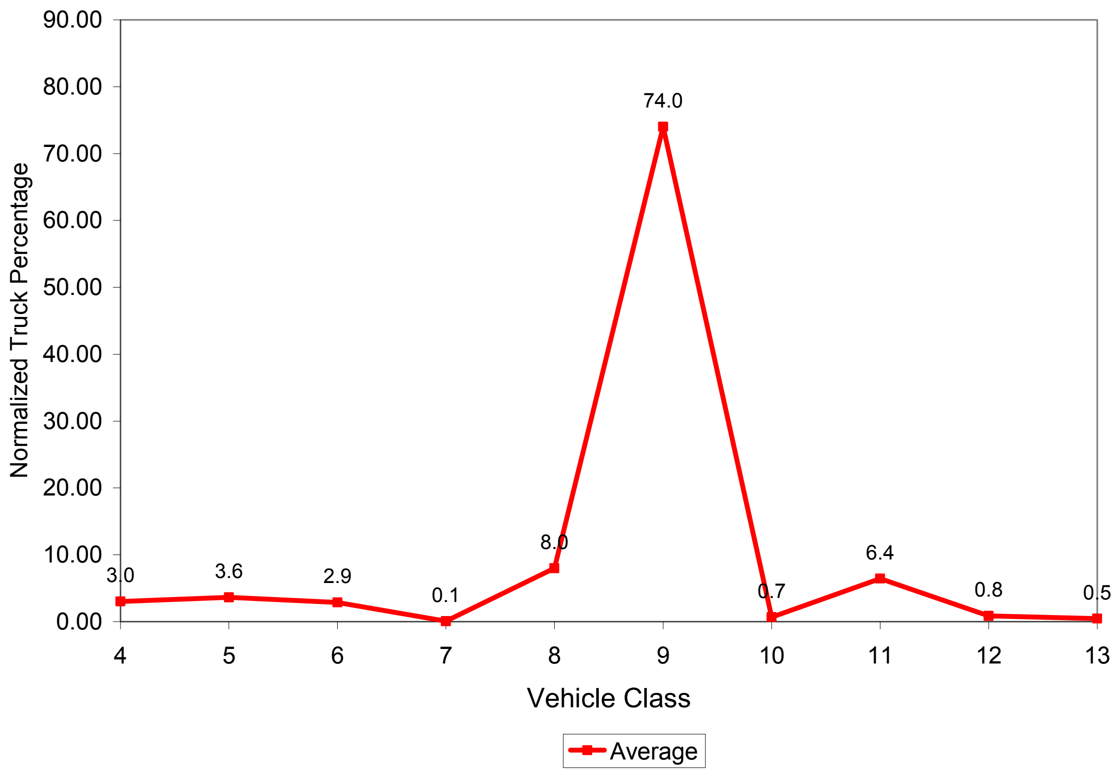

Figure 3.2 Vehicle Class Distribution for 0500

Table 3.3 Truck Percentage and Normalized Truck Class Distribution

Section	Route	Truck Percent, %	Normalized Truck Class Distribution, %									
			4	5	6	7	8	9	10	11	12	13
0500	I 55	25.3	3.02	3.64	2.86	0.05	7.99	74.04	0.67	6.43	0.84	0.46
0900	I 55	18.5	0.94	12.37	2.76	0.09	5.15	71.73	0.47	5.60	0.80	0.10
1001	US 45	7.1	2.29	16.24	6.69	0.47	16.28	47.38	3.73	2.05	0.33	4.52
1016	MS 35	14.8	7.38	18.61	8.06	0.15	11.46	49.61	0.79	3.39	0.25	0.29
1802	US 84	21.3	0.50	22.15	4.67	0.11	6.59	62.24	1.96	0.95	0.34	0.50
2807	MS 6	10.6	3.32	24.45	5.74	0.19	11.27	53.19	0.72	0.57	0.29	0.28
3018	US 72	20.2	3.63	2.08	4.33	0.80	14.08	69.42	1.56	1.44	0.50	2.15
3081	US 78	20.9	0.79	1.16	3.10	0.23	11.92	74.44	0.39	6.92	0.98	0.08
3082	US 82	19.8	1.36	10.31	4.75	0.02	6.10	75.13	0.74	1.18	0.33	0.08
3083	MS 310	9.1	2.81	50.10	6.93	1.48	8.62	24.39	3.86	1.16	0.00	0.66
3087	MS 7	9.3	1.42	22.68	4.15	0.16	11.62	56.67	1.16	0.67	0.60	0.88
3090	MS 315	15.1	3.70	39.17	28.55	1.15	9.12	14.19	1.38	2.13	0.00	0.60
3091	US 45	14.6	1.07	3.46	5.47	1.12	17.16	67.84	1.48	0.95	0.59	0.84
3093	I 10	18.3	1.86	11.30	5.36	0.04	7.64	70.30	0.59	2.05	0.61	0.25
3097	I 55	14.9	0.81	9.93	2.93	0.05	10.92	68.35	0.40	5.88	0.61	0.12
3099	I 20	38.6	0.57	6.22	1.81	0.02	5.57	77.42	0.45	6.79	0.97	0.18
4024	MS 1	3.7	6.86	58.26	6.59	0.07	3.96	22.81	0.37	1.05	0.01	0.02
5006	US 78	21.1	1.10	2.42	3.15	0.19	12.90	71.72	0.37	7.03	1.06	0.06
5025	US 84	10.9	0.39	0.44	19.37	0.78	15.72	58.99	1.79	1.26	0.00	1.25
5803	US 78	23.0	1.39	2.56	2.75	0.09	8.93	75.29	0.35	6.98	1.10	0.55
5805	I 10	16.3	0.98	1.04	11.84	0.16	16.40	66.12	0.72	2.15	0.50	0.09
9030	I 20	28.7	2.17	7.56	5.60	0.07	5.64	73.12	0.40	4.56	0.80	0.09

3.2.1.2 Section 0900, Interstate 55, Tate County

Average annual vehicle class distribution calculated for years 1995, 1996, and 1997 for 0900 is provided in Figure 3.3. This site is classified as a rural principal interstate (FC 1) and is a four-lane interstate highway located in northwest Mississippi. Truck account for approximately 19 percent of total traffic with VC 9 trucks dominating (almost 72 percent) the traffic, as was the case with the 0500 site. However, for this site there appears to be slightly more VC 5 vehicles.

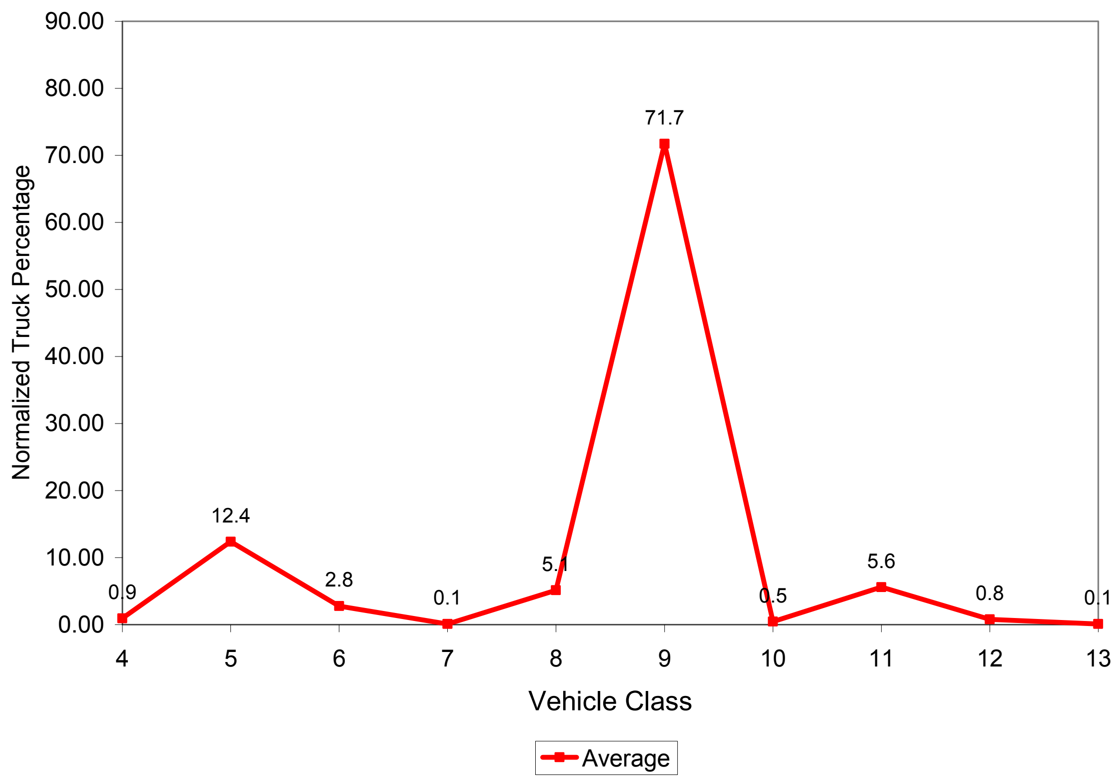

Figure 3.3 Vehicle Class Distribution for 0900

3.2.1.3 Section 1001, U.S. 45, Verona, Lee County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 1001 is provided in Figure 3.4. This site is classified as a rural principal arterial (FC 2) and is a four-lane highway located in northeast Mississippi with 7 percent truck traffic. As with the previous rural principal interstate sites, VC 9 trucks are the primary truck type, but there are substantial VC 5 and VC 8 trucks and an increased number of VC 13 trucks on the facility.

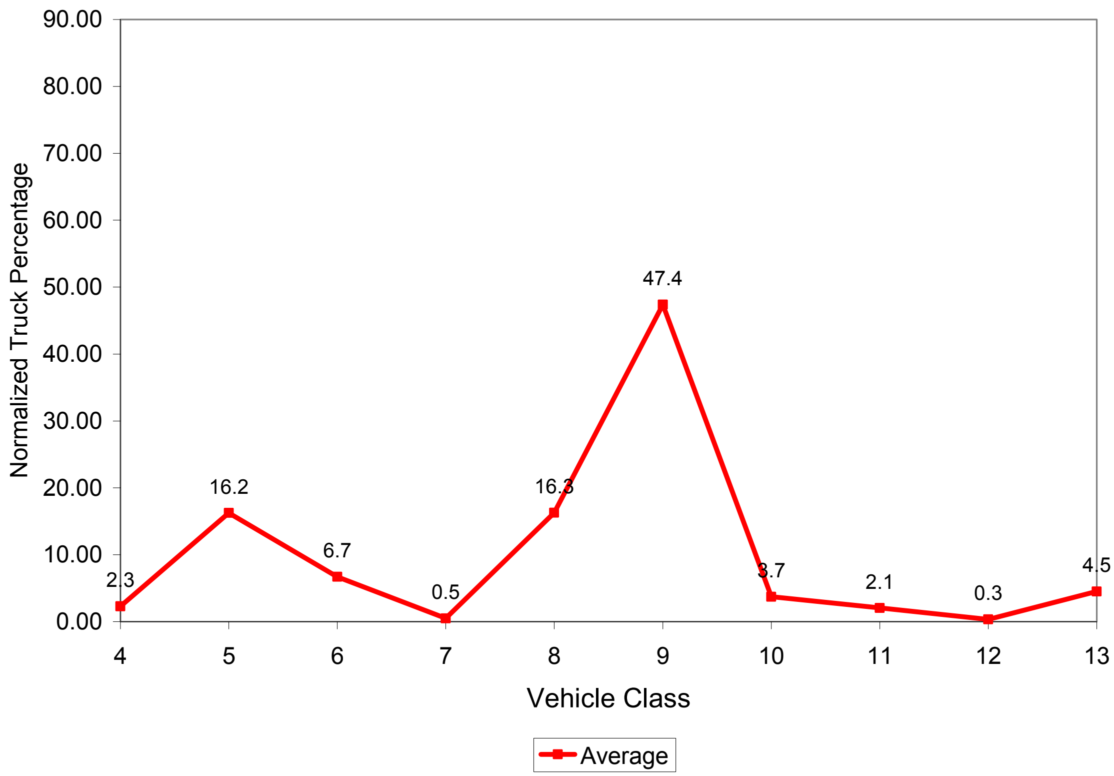

Figure 3.4 Vehicle Class Distribution for 1001

3.2.1.4 Section 1016, MS. 35, Kosciusko, Attala County

Average annual vehicle class distribution calculated for years 1992 through 1995 for 1016 is provided in Figure 3.5. This site is classified as an urban principal arterial (FC 14) with approximately 15 percent truck traffic. As with the previous rural principal interstate sites, VC 9 trucks are the primary truck type, however, there are substantial VC 5 and VC 8 trucks on the facility.

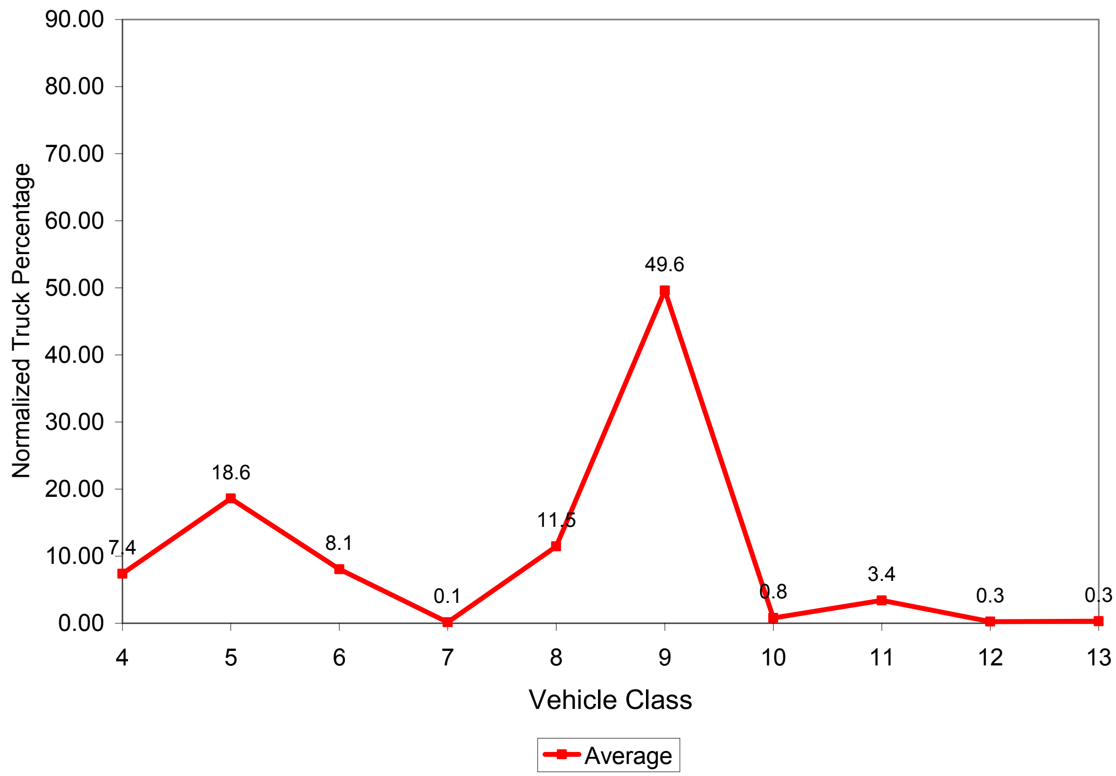

Figure 3.5 Vehicle Class Distribution for 1016

3.2.1.5 Section 1802, U.S. 84, Collins, Covington County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 1802 is provided in Figure 3.6. This site is classified as a rural principal arterial (FC 2) and is a four-lane highway located in south central Mississippi. Trucks comprise 21 percent of the traffic with VC 5 and VC 9 trucks comprising approximately 84 percent of truck traffic.

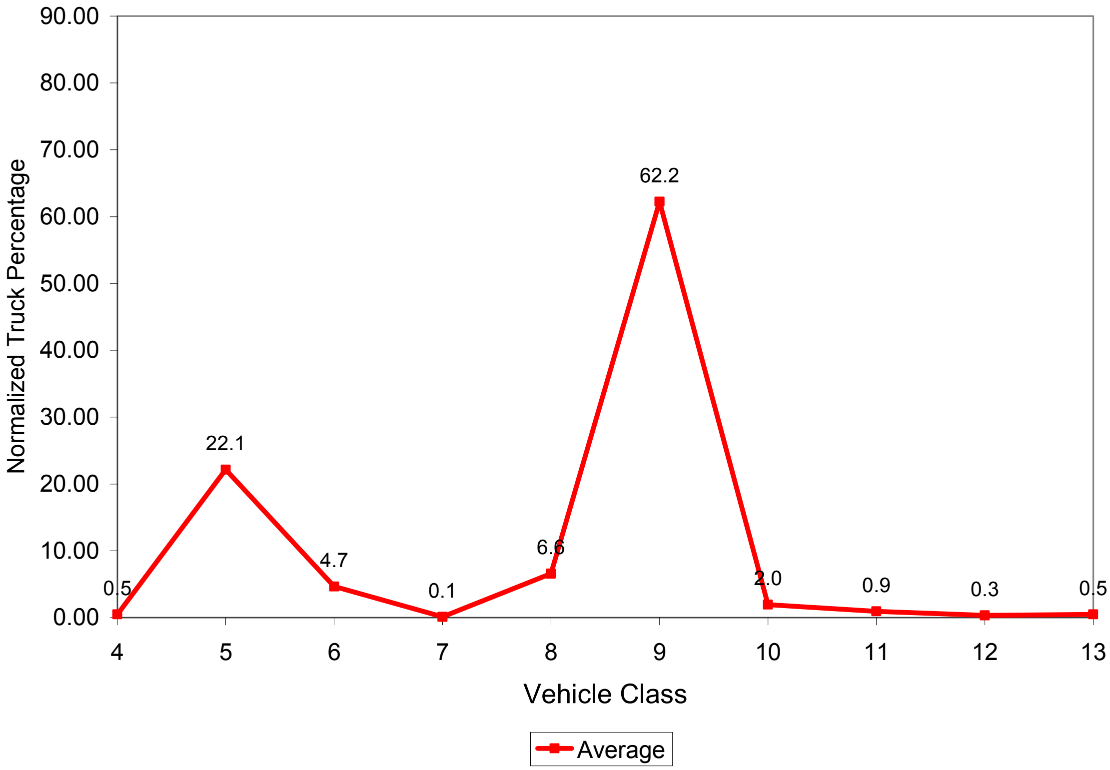

Figure 3.6 Vehicle Class Distribution for 1802

3.2.1.6 Section 2807, MS 6, Oxford, Lafayette County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 2807 is provided in Figure 3.7. This site is classified as a rural principal arterial (FC 2) and is located in northwest Mississippi with approximately 11 percent truck traffic. Similar to the site 1802, VC 5 and VC 9 trucks dominate, with 78 percent of the truck traffic.

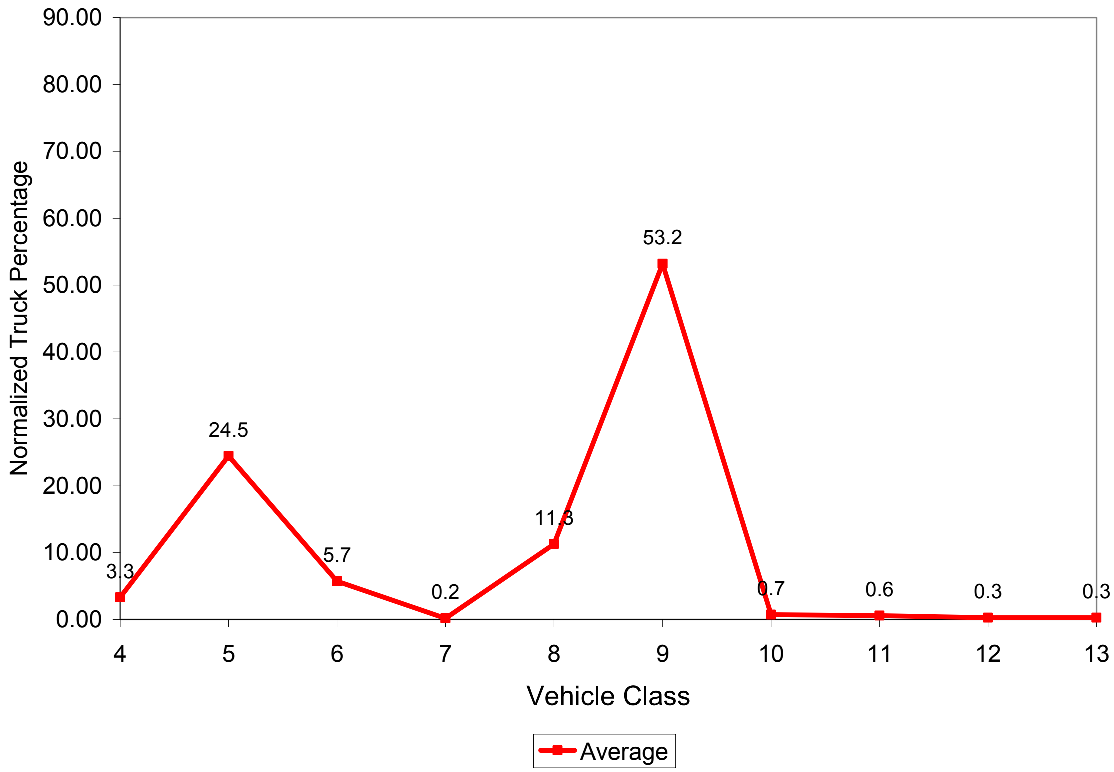

Figure 3.7 Vehicle Class Distribution for 2807

3.2.1.7 Section 3018, U.S. 72, Iuka, Tishomingo County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 3018 is provided in Figure 3.8. This site is classified as a rural principal arterial (FC 2) and is a four-lane highway located in northeast Mississippi. Truck comprise 20 percent of the total traffic with VC data resembling that of the rural interstate sites previously mentioned, with almost 70 percent of truck traffic being VC 9 trucks.

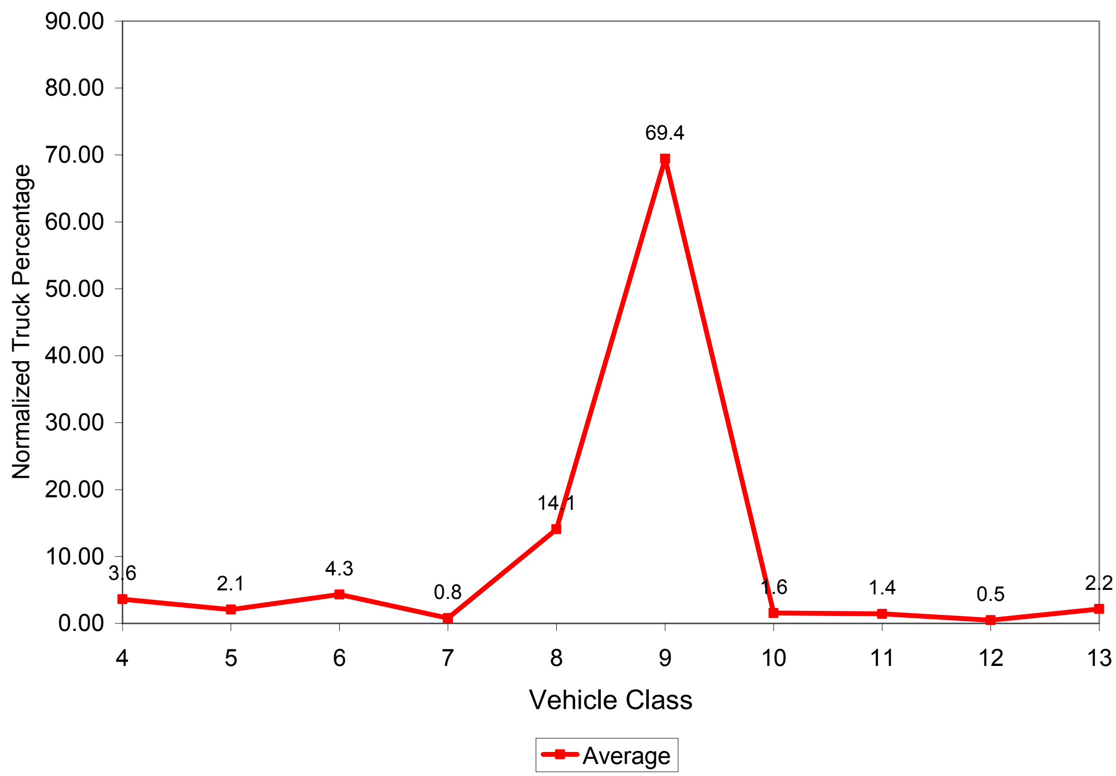

Figure 3.8 Vehicle Class Distribution for 3018

3.2.1.8 Section 3081, U.S. 78, Fulton, Itawamba County

Average annual vehicle class distribution calculated for years 1992 through 1996 for 3081 is provided in Figure 3.9. This, four-lane controlled access highway is a rural principal arterial (FC 2) and a major connector highway from Atlanta, Georgia, to Memphis, Tennessee. Truck traffic for the site was approximately 21 percent. Due to the nature of the highway, it should be expected to have VC distribution similar to rural interstate sites. This is the case, with 74 percent VC 9 trucks dominating the truck traffic.

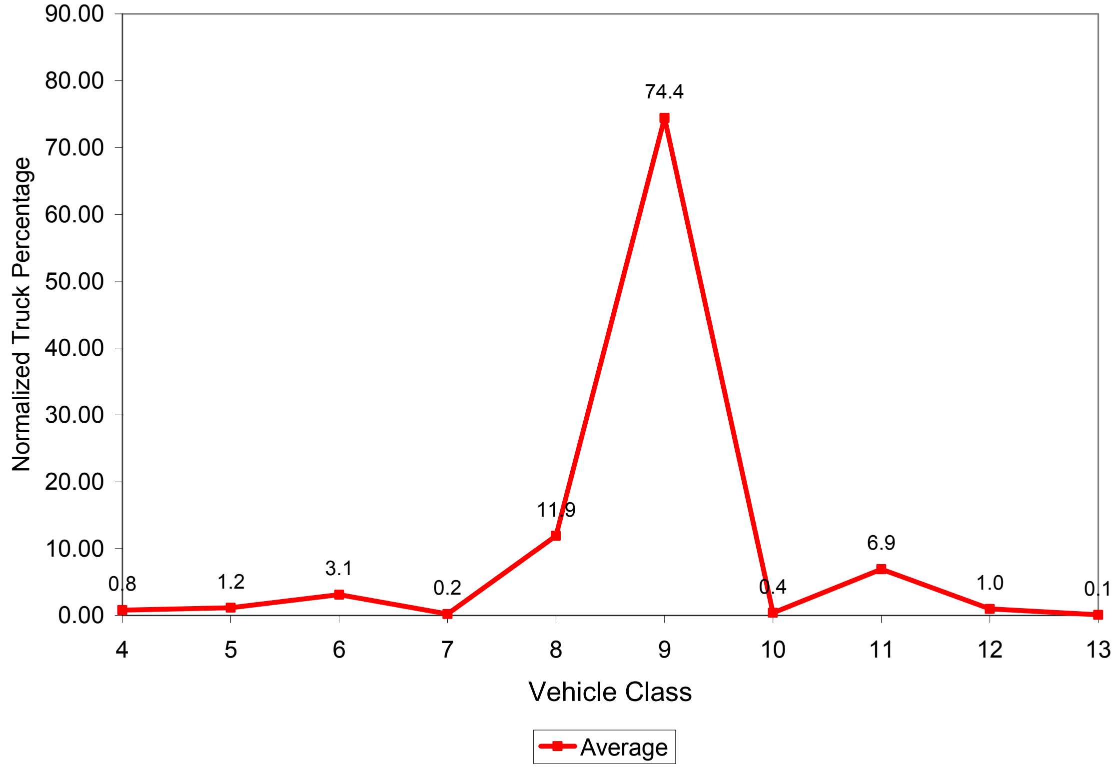

Figure 3.9 Vehicle Class Distribution for 3081

3.2.1.9 Section 3082, U.S. 82, Winona, Montgomery County

Average annual vehicle class distribution calculated for years 1992 through 1997 for 3082 is provided in Figure 3.10. This site is classified as a rural principal arterial (FC 2) and is a four-lane highway located in north central Mississippi carrying approximately 20 percent truck traffic. Again, VC 9 trucks are the dominate truck class, with VC 5 trucks being the next highest.

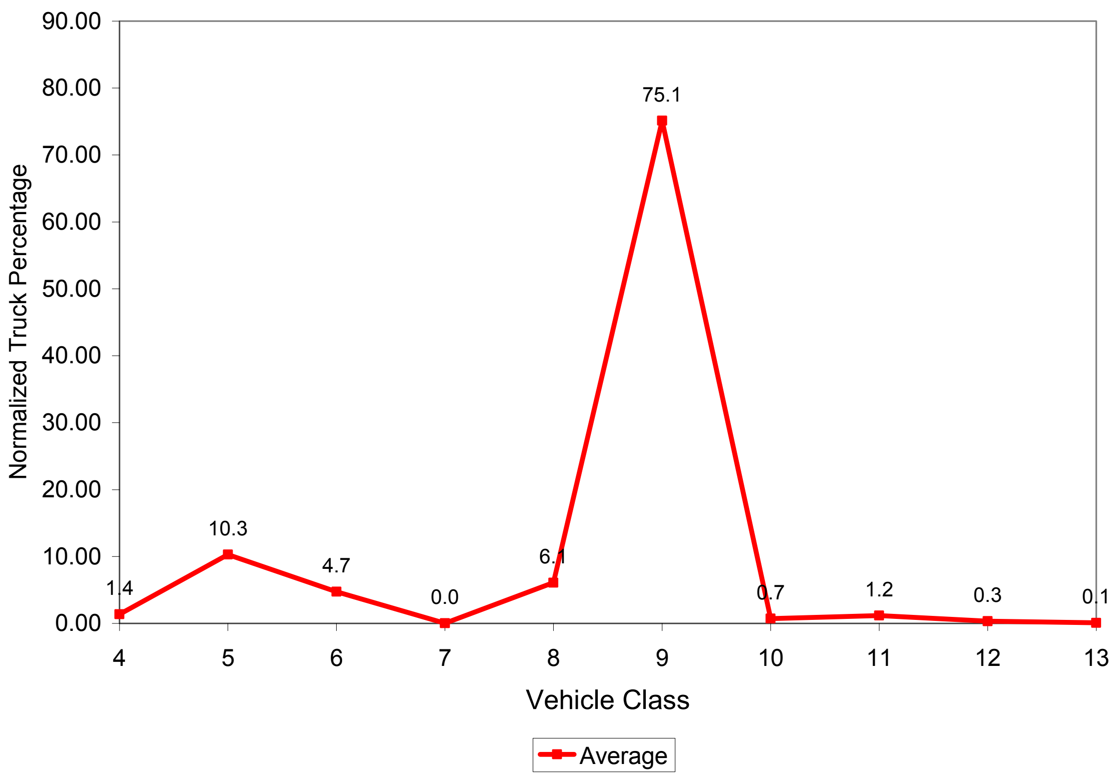

Figure 3.10 Vehicle Class Distribution for 3082

3.2.1.10 Section 3083, MS 310, Holly Springs, Marshall County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 3083 is provided in Figure 3.11. This site is classified as a rural principal arterial (FC 2) and is a low volume two-lane highway located in north Mississippi. Approximately 9 percent truck traffic is carried by this roadway with the VC distribution being distinctly different from previous sites with VC 5 trucks accounting for 50 percent of the truck traffic, followed by 24 percent VC 9 trucks. This is expected since the highway is not considered to be a "thru truck traffic" facility, but more of a "business" facility.

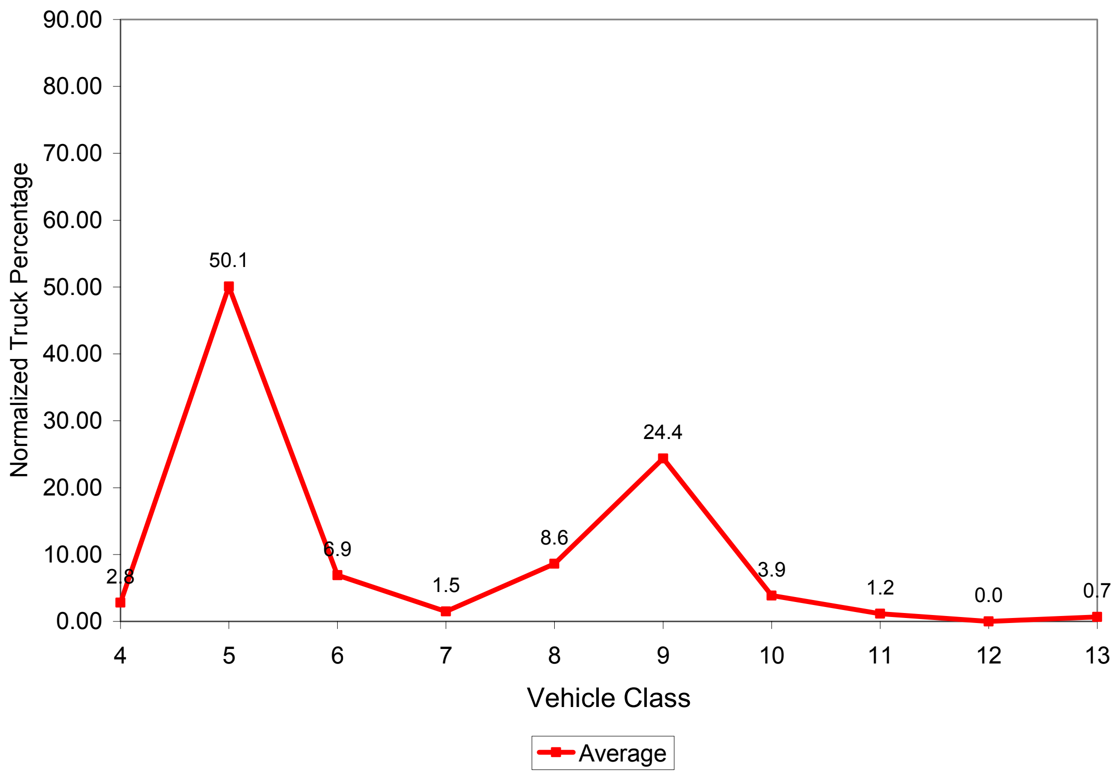

Figure 3.11 Vehicle Class Distribution for 3083

3.2.1.11 Section 3087, MS 7 Oxford, Lafayette County

Average annual vehicle class distribution calculated for years 1992 through 1996 for 3087 is provided in Figure 3.12. This site is classified as a rural principal arterial (FC 2) and is a four-lane highway located in northwest Mississippi with 9 percent truck traffic. Similar to other FC 2 locations, truck traffic is primarily composed of VC 9 and VC 5 trucks, followed by VC 8 trucks.

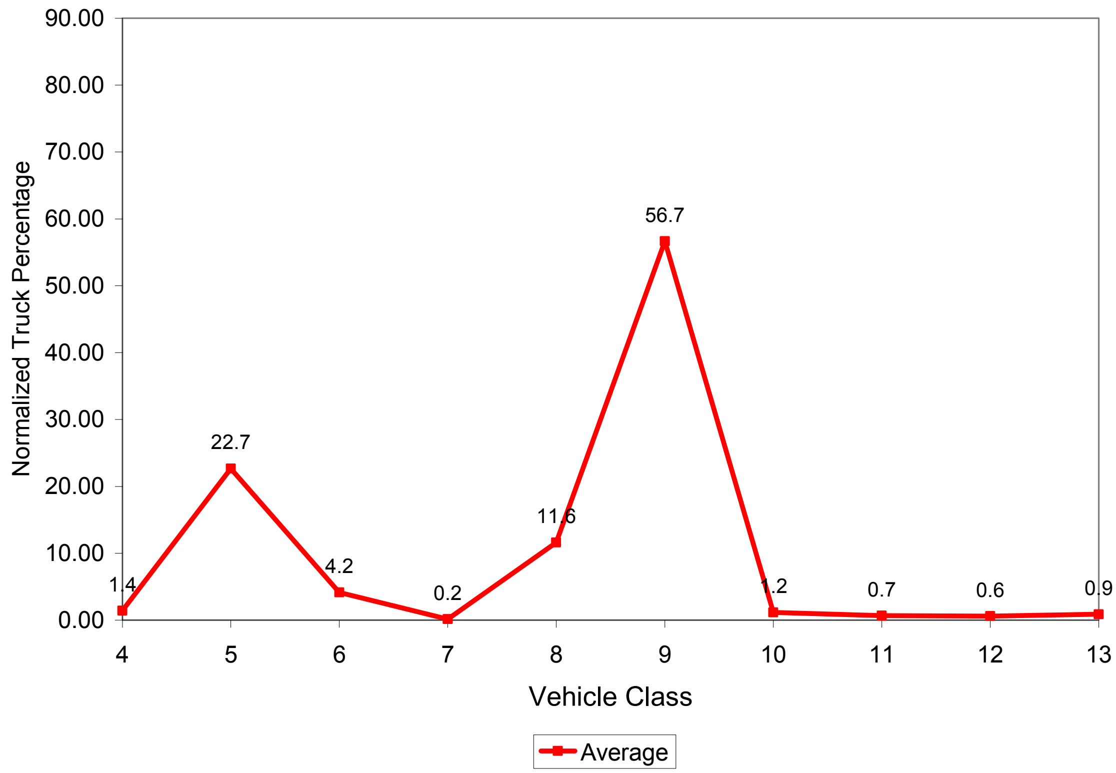

Figure 3.12 Vehicle Class Distribution for 3087

3.2.1.12 Section 3090, MS 315, Sardis, Panola County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 3090 is provided in Figure 3.13. This site is classified as a rural principal arterial (FC 2) and is a low volume two-lane highway located in northwest Mississippi. Trucks comprise 10 percent of traffic with the VC distribution for this site being similar to the 3083 site (MS Hwy 310), with VC 5 trucks accounting for the highest truck traffic. However, for this facility there is more VC 6 traffic (29 percent) than VC 9 traffic (14 percent). As with MS Hwy 310, this can be explained by recognizing this facility is more of a "business" or "day time" use facility

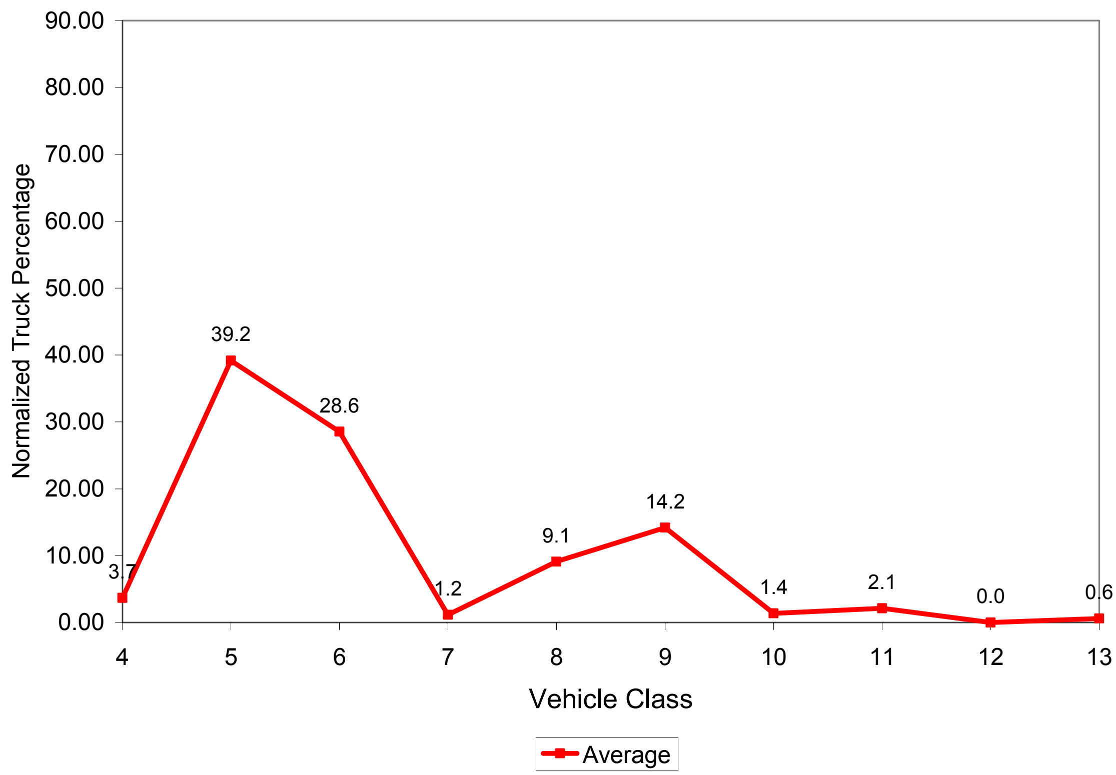

Figure 3.13 Vehicle Class Distribution for 3090

3.2.1.13 Section 3091, U.S. 45, Lauderdale, Lauderdale County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 3091 is provided in Figure 3.14. This site is classified as a rural principal arterial (FC 2) and is a four-lane highway located in east central Mississippi. The truck percentage is approximately 15 percent with the VC distribution agreeing well with previous FC 2 facilities with the VC 9 trucks accounting for 68 percent of the truck traffic.

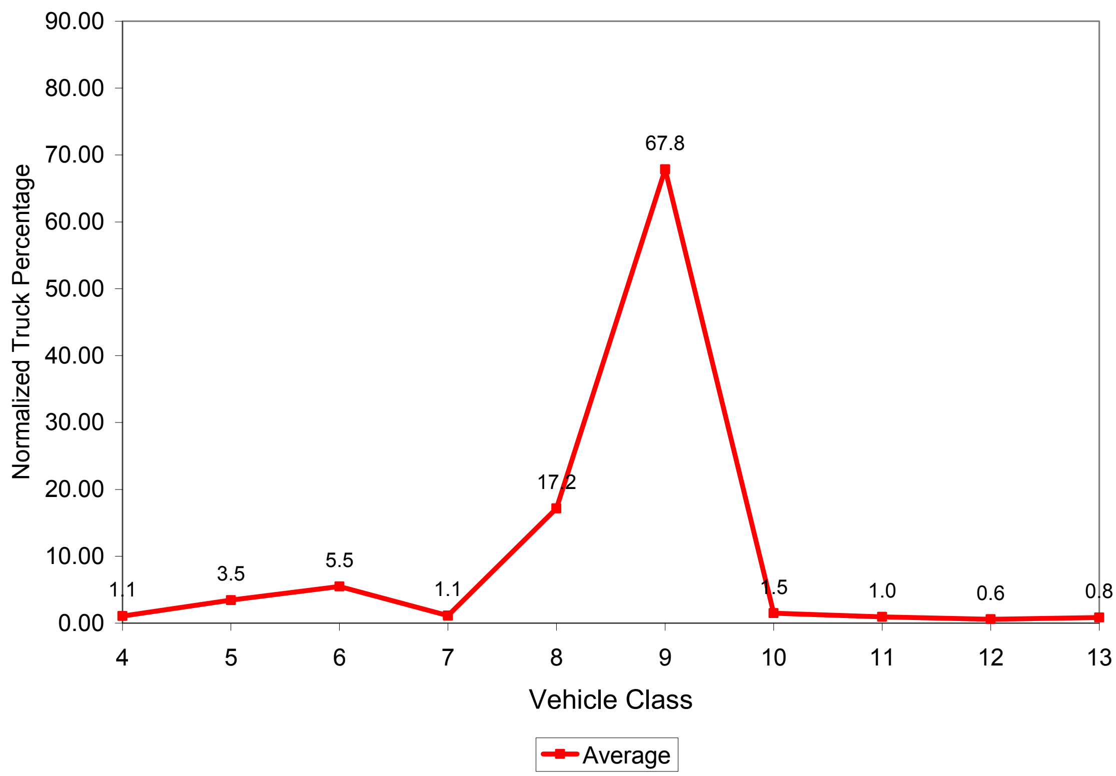

Figure 3.14 Vehicle Class Distribution for 3091

3.2.1.14 Section 3093, Interstate 10, Gautier, Jackson County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 3093 is provided in Figure 3.15. This site, with approximately 18 percent truck traffic, is classified as a rural principal interstate (FC 1) and is a four-lane facility located in coastal Mississippi. Much like the distribution of other FC 1 facilities, VC 9 trucks account for 70 percent of the truck traffic with VC 5 trucks being the next highest percentage at 11 percent.

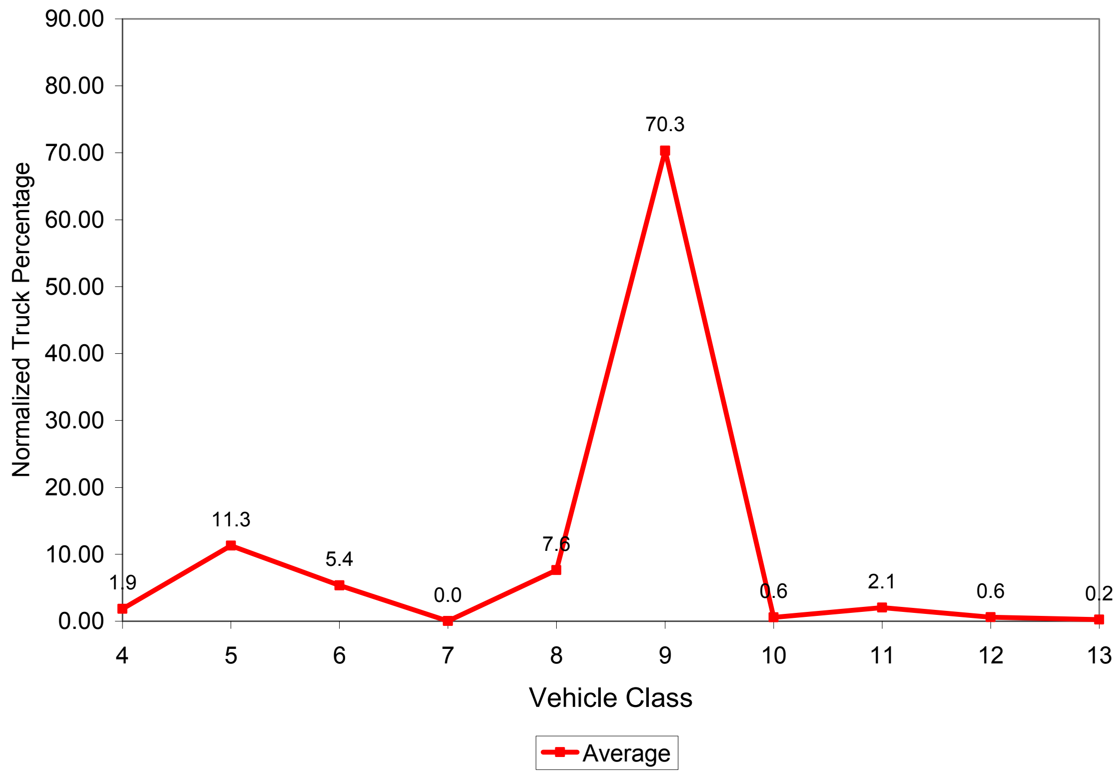

Figure 3.15 Vehicle Class Distribution for 3093

3.2.1.15 Section 3097, Interstate 55, Southaven, DeSoto County

Average annual vehicle class distribution calculated for years 1992 through 1994 for 3097 is provided in Figure 3.16. This site, with 15 percent truck traffic, is classified as a rural principal interstate (FC 1) and is a four-lane facility located in northwest Mississippi. This site is located close to site 0900 so it is expected that the VC distribution would be similar. The distribution is indeed similar with a high amount (68 percent) of VC 9 trucks, followed by approximately the same amount (10 percent) of VC 5 and VC 8 trucks.

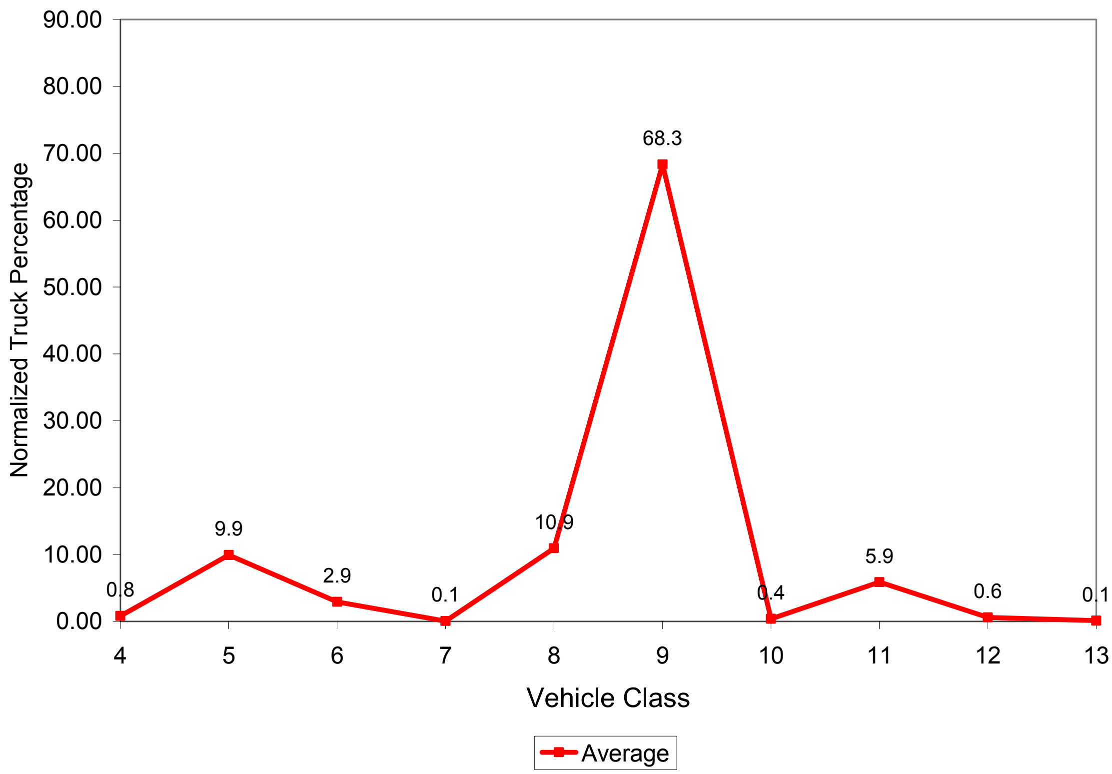

Figure 3.16 Vehicle Class Distribution for 3097

3.2.1.16 Section 3099, Interstate 20, Forest, Scott County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 3099 is provided in Figure 3.17. This site is classified as a rural principal interstate (FC 1) and is a four-lane interstate highway located in central Mississippi. Trucks account for almost 40 percent of the traffic with the distribution having the highest percentage (77) of VC 9 trucks of any site. Small percentages (approximately 6 percent) of VC 5, 8, and 11 are also present.

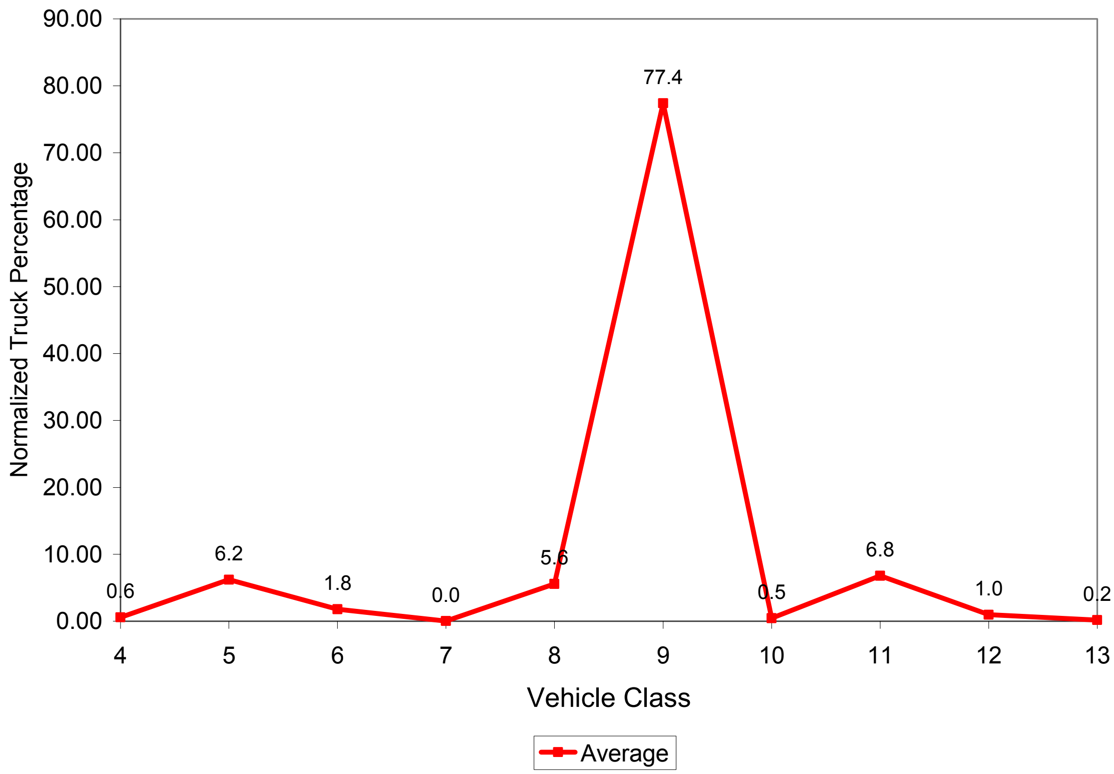

Figure 3.17 Vehicle Class Distribution for 3099

3.2.1.17 Section 4024, MS 1, Greenville, Washington County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 4024 is provided in Figure 3.18. This site, with only 4 percent truck traffic, is classified as an urban principal arterial (FC 14) and located in west central Mississippi. Although being in a different functional classification, the VC distribution appears similar to that shown for the 3083 site (MS Hwy 310) with a VC 5 trucks comprising 58 percent of the traffic, followed by VC 9 trucks. The distribution does not agree with site 1016 (MS Hwy 35), even though the two sites are the same functional classification.

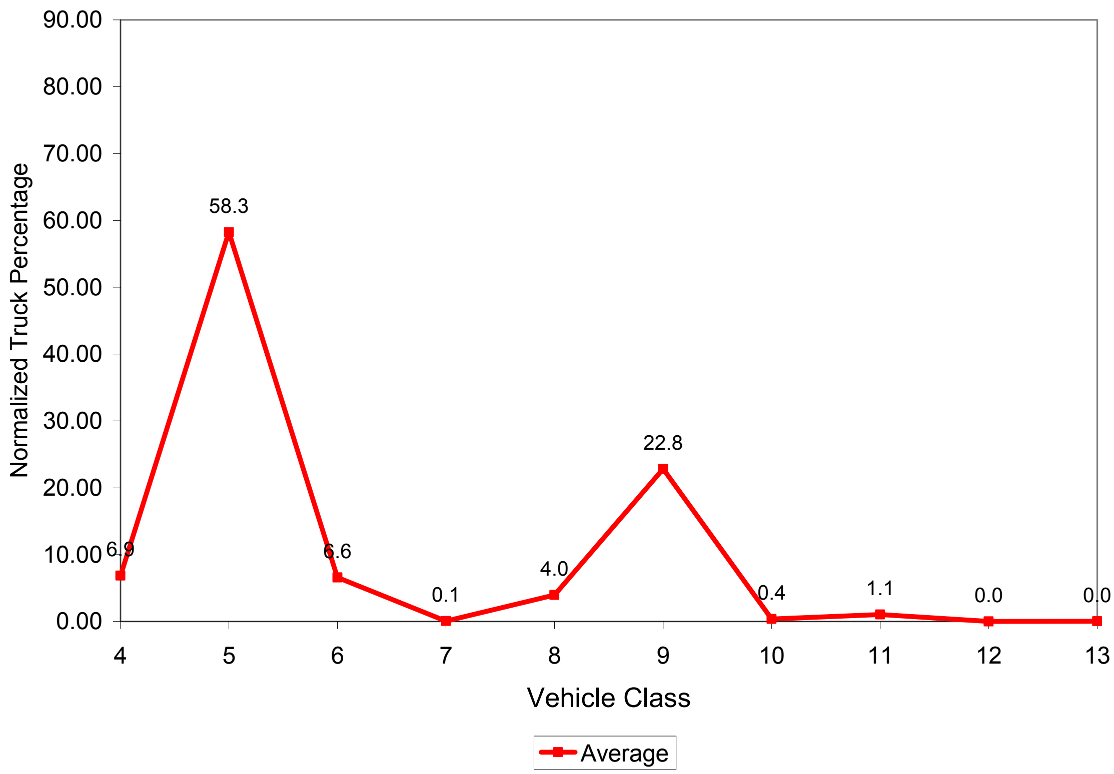

Figure 3.18 Vehicle Class Distribution for 4024

3.2.1.18 Section 5006, U.S. 78, Sherman, Pontotoc County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 5006 is provided in Figure 3.19. Approximately 21 percent truck traffic is recorded for this site. The site is classified as a rural principal arterial (FC 2) and is a four-lane controlled access highway located in northeast Mississippi. This site is located close to site 3081 so the VC distribution should be similar; however U.S. 45 intersects U.S. 78 between the two sites and may change the distribution somewhat. The distribution does agree with site 3081 with approximately 72 percent VC 9 trucks, followed by 13 percent VC 8 trucks.

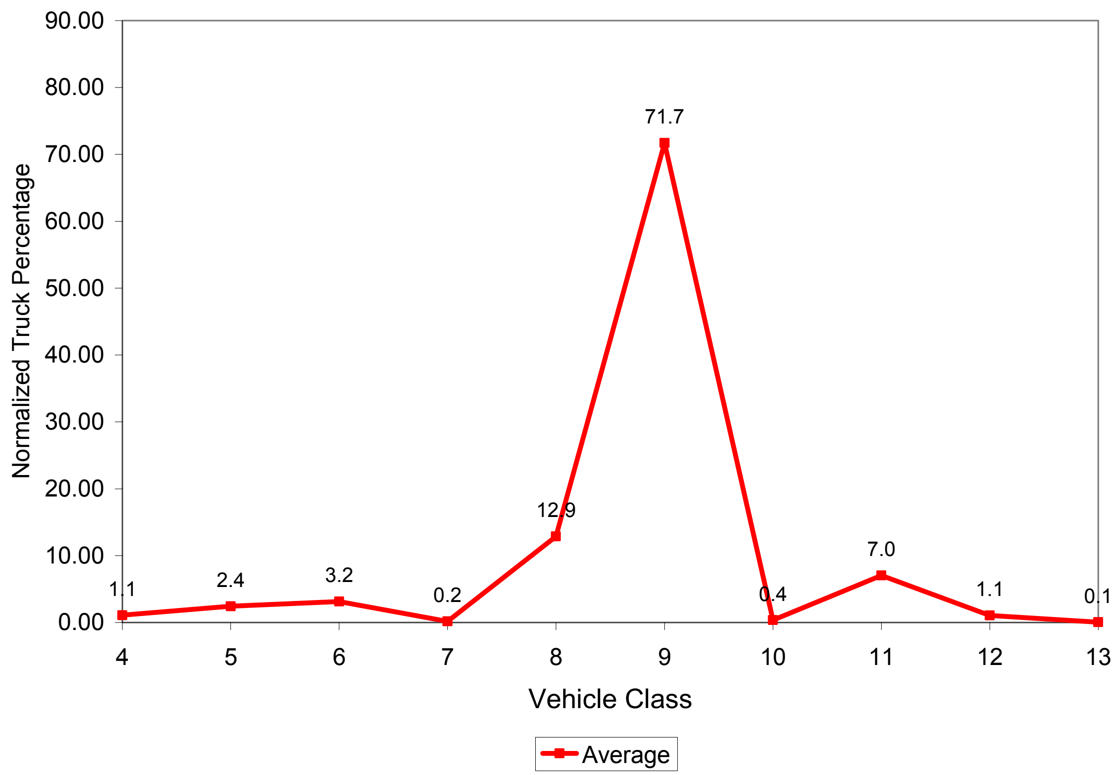

Figure 3.19 Vehicle Class Distribution for 5006

3.2.1.19 Section 5025, U.S. 84, Brookhaven, Lincoln County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 5025 is provided in Figure 3.20. This site is classified as a rural principal arterial (FC 1) and is a four-lane highway located in southwest Mississippi. Trucks account for 11 percent of the traffic volume with VC 9 trucks accounting for 59 percent of the truck traffic, followed by VC 6 and VC 8 trucks at 19 and 16 percent, respectively.

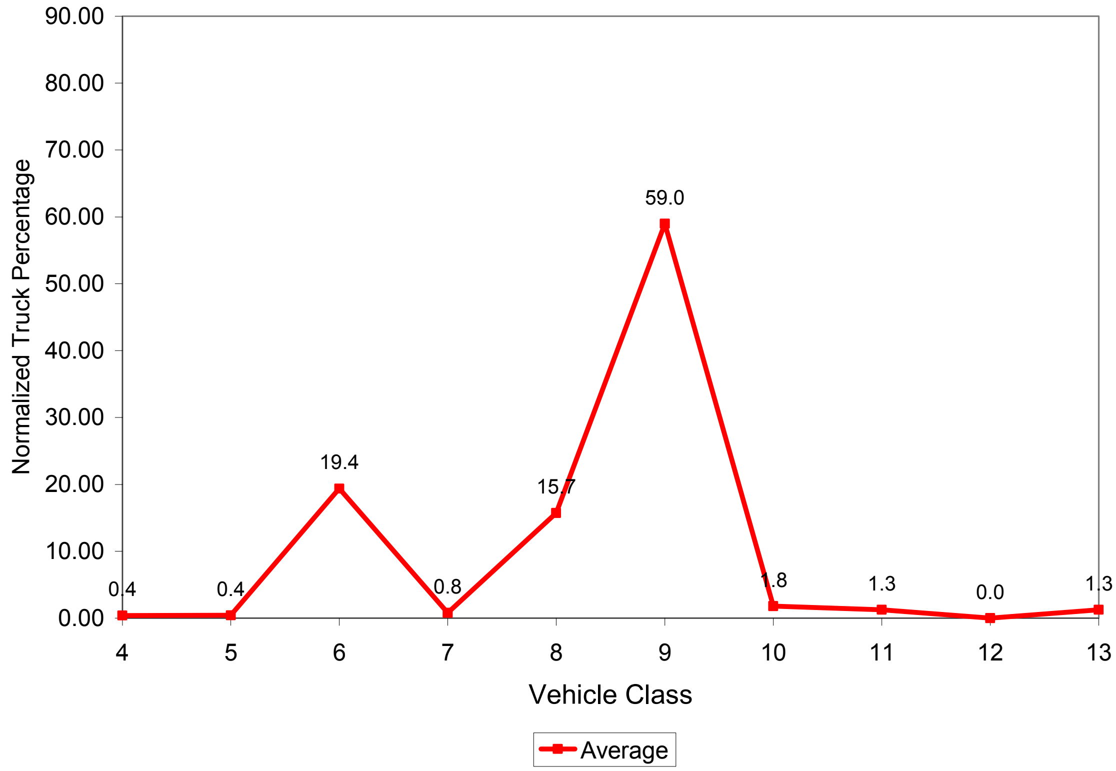

Figure 3.20 Vehicle Class Distribution for 5025

3.2.1.20 Section 5803, U.S. 78, Holly Springs, Marshall County

Average annual vehicle class distribution calculated for years 1992, 1994, and 1996 through 1998 for 5803 is provided in Figure 3.21. Trucks account for 23 percent of the total traffic volume. This site is classified as a rural principal arterial (FC 2) and is a four-lane controlled access highway located in north Mississippi. This site is located close to site 5006 and has a similar distribution with 75 percent VC 9 trucks, followed by 9 percent VC 8 trucks.

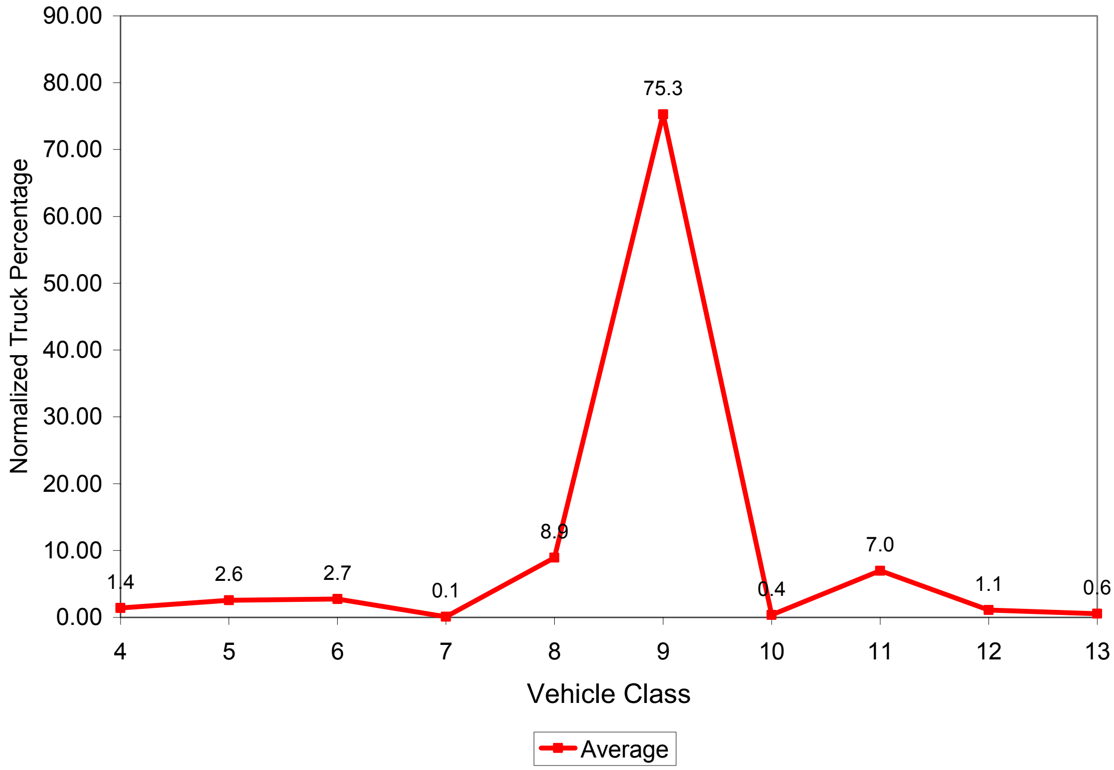

Figure 3.21 Vehicle Class Distribution for 5803

3.2.1.21 Section 5805, Interstate 10, Gulfport, Harrison County

Average annual vehicle class distribution calculated for years 1992 through 1996 for 5805 is provided in Figure 3.22. This site, with 16 percent truck traffic, is classified as an urban principal interstate (FC 11) and is a four-lane facility located in coastal Mississippi. This site, located near site 3093, has a similar distribution with a high percentage of VC 9 trucks, but also substantial amount of VC 6 and 8 trucks.

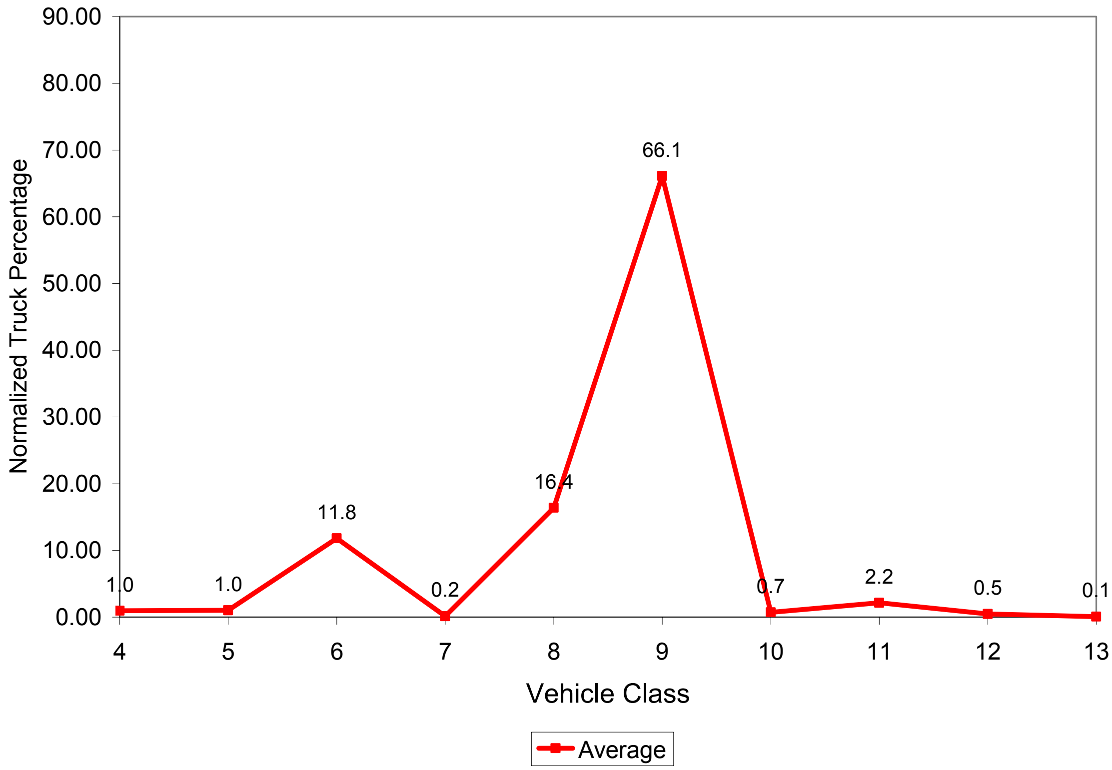

Figure 3.22 Vehicle Class Distribution for 5805

3.2.1.22 Section 9030, Interstate 20, Vicksburg, Warren County

Average annual vehicle class distribution calculated for years 1992 through 1998 for 9030 is provided in Figure 3.23. This site is classified as a rural principal interstate (FC 1) and is a four-lane facility located in west central Mississippi. Trucks comprise almost 30 percent of the traffic volume with a high percentage of VC 9 trucks (73 percent) followed by VC 5, 6, and 8 trucks, each with approximately 6 to 8 percent of the truck traffic.

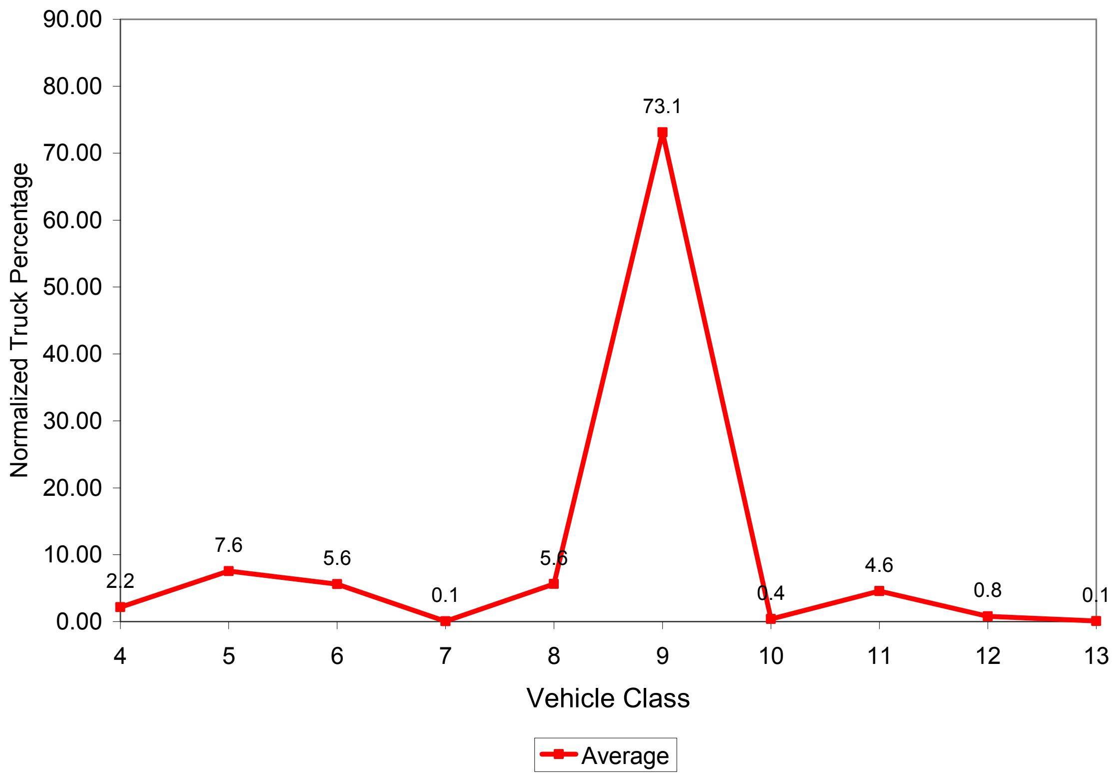

Figure 3.23 Vehicle Class Distribution for 9030

3.2.2 Vehicle Class Distribution for Functional Classifications

Vehicle class distribution for roadways within the same functional class (FC) is important and requires analysis. From an observation of VC distribution, it is evident that facilities within the same FC may or may not have similar distributions. Figure 3.24 illustrates the VC distribution for the six FC 1 (rural arterial – interstate) sites. In general, VC distribution is relatively consistent between the six sites, with VC 9 trucks being the foremost VC for all six. Vehicle class 5 (single unit trucks) and VC 11 (5 axle multi-trailers) exhibited the most variability.

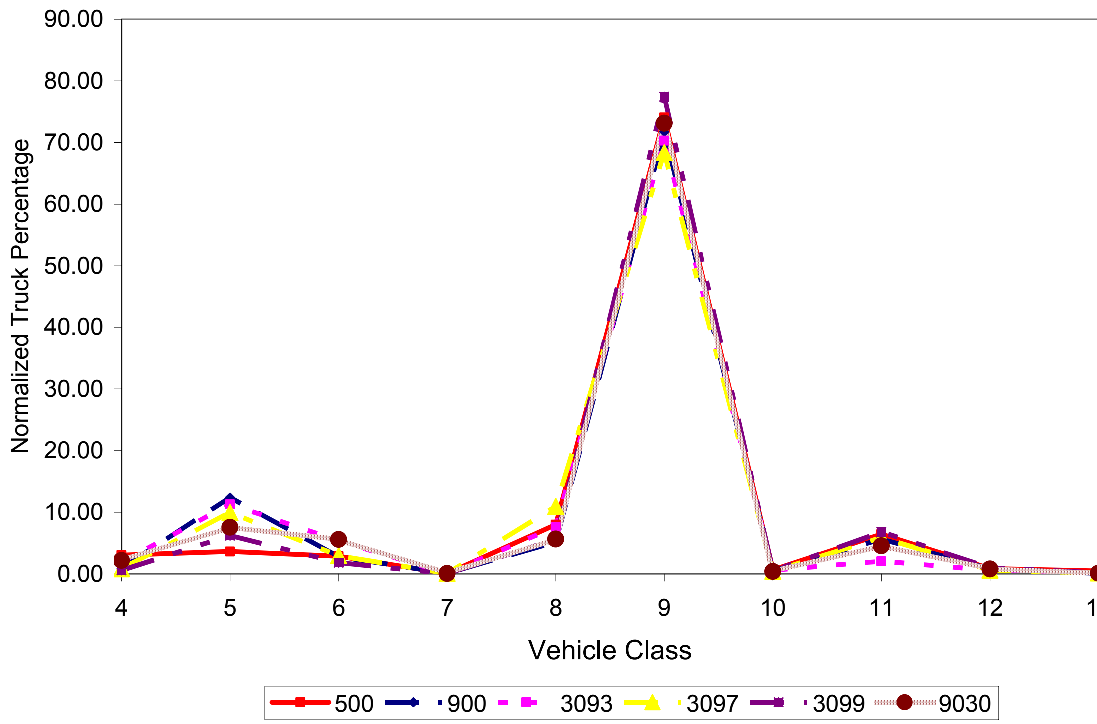

Figure 3.24 Vehicle Class Distribution for Functional Class 1

Vehicle class distribution for the 13 FC 2 sites is provided in Figure 3.25. Unlike, those for FC 1, significant variability exist between the various sites for most of the VC. This is likely due to the broad range of sites classified as FC 2. Two sites, 3083 (MS 310) and 3090 (MS 315), are low volume highways that are very different from the other 11 sites, as evident from higher VC 5 percentage and lower VC 9 percentage.

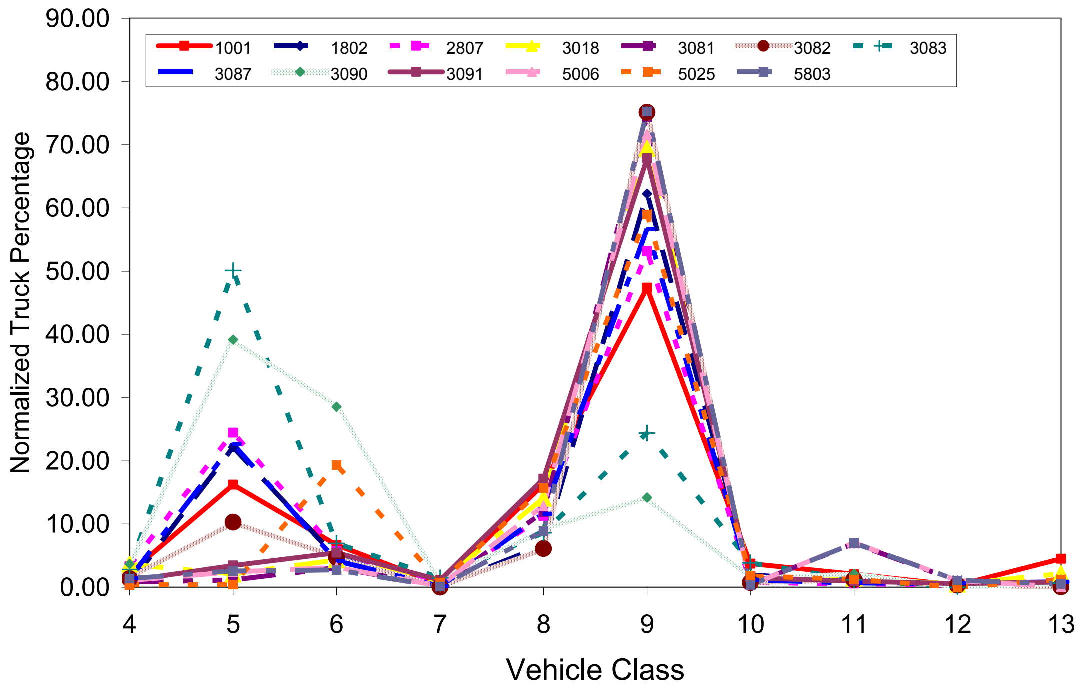

Figure 3.25 Vehicle Class Distribution for Functional Class 2

Figure 3.26 illustrates the VC distribution for the two FC 14 sites. Although only two FC 14 sites are represented, it is clear that there is significant variability, especially for VC 5 and VC 9 trucks. Only one FC 11 site (5805) is represented in the data with its VC data provided earlier in Figure 3.22.

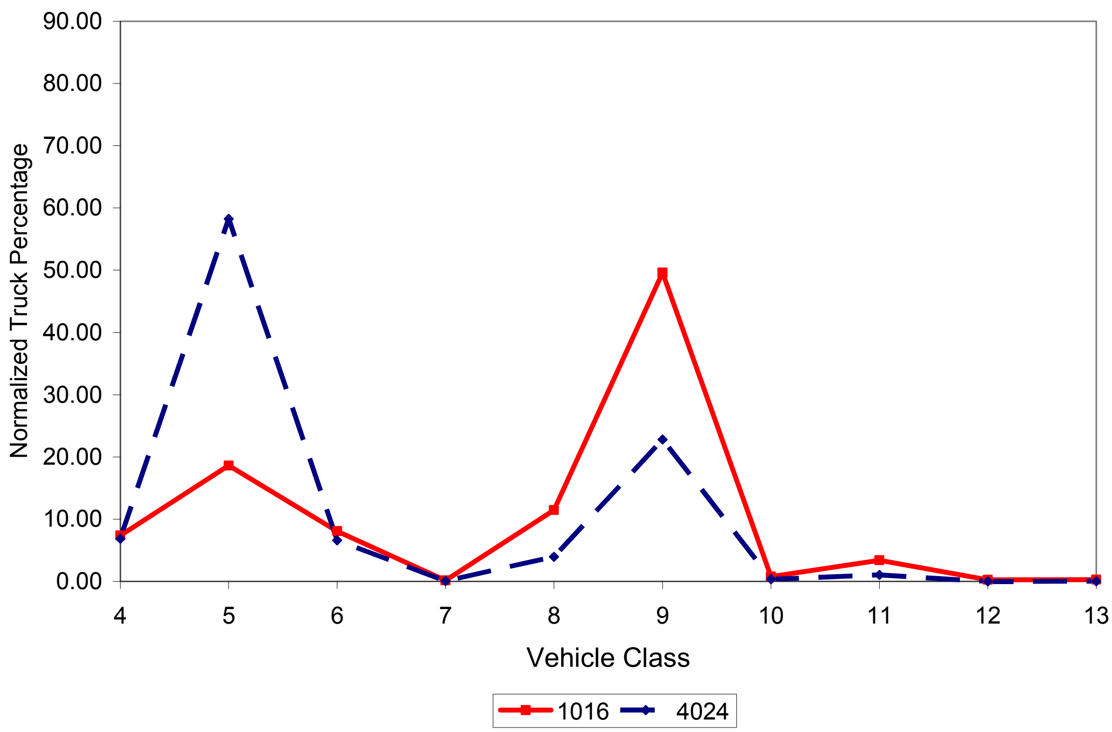

Figure 3.26 Vehicle Class Distribution for Functional Class 14

3.2.3 Truck Traffic Classification Groups

Past research (4) has shown extensive variation in truck distribution for highways within the same functional classification. This fact was also illustrated in the previous section with the Mississippi LTPP sites. Therefore, it is not recommended to group highways for traffic analysis based on their functional classification. The selected method to be used in the new design guide is based on a truck traffic classification (TTC) group system, which is a function of the normalized VC distribution for FHWA classes 4 through 13.

The process of assigning a given roadway to a TTC group is straightforward. First, VC distribution for a given time period (e.g., day, week, month, or year) is determined for the roadway in terms of the 13 FHWA classifications. This can be obtained from either AVC or WIM sites. Since TTC group development is based only on VC 4 to 13, classes 1 through 3 are not considered. Second, a normalized truck distribution is determined by dividing the total trucks in each vehicle class by the total trucks on the roadway (i.e., truck classes 4 through 13).

In the new design guide, seventeen TTC groups have been developed and are based on the distribution of buses, single-unit trucks, single-trailer trucks, and multi-trailer trucks. TTC descriptions are provided in Table 3.4 with typical TTC grouping for functional classification provided in Table 3.5. Table 3.6 provides general guidelines for TTC grouping based on percentages of buses, single-unit trucks, single-trailer trucks, and multiple-trailer trucks. Selection of a TTC group for a given roadway is somewhat subjective based on the guidelines provided in Table 3.6. However, TTC grouping can likely be narrowed down to 1 or 2 possible groups.

Using developed TTC descriptions, Mississippi LTPP sites were classified accordingly and are illustrated in Table 3.7. The majority of LTPP sites are classified as TTC 3, which are major single and multi-trailer truck routes. These sites include interstates and 4-lane highways which are generally recognized as being “thru” truck routes. Five of the sites were classified as TTC 7, which is a major mixed truck route. These sites are very close to TTC 3 sites, but with a slightly smaller percentage of single trailer trucks and a greater percentage of single-unit trucks. Two sites, 3083 (MS 310) and 3090 (MS 315) were classified as TTC 15, which is a major light truck route. One site, 1016 (MS 35) was classified as TTC 6, which is an intermediate light and single-trailer route. Future discussions of the LTPP sites will be in terms of TTC in lieu of functional classification.

Table 3.4 General Truck Traffic Classification Descriptions (3)

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

Table 3.5 Functional Classification and TTC Relationship (3)

Functional Classification	Applicable TTC Group
Principal Arterials - Interstate and Defense Routes	1,2,3,4,5,8,11,13
Principal Arterials - Intrastate Routes, Including Freeways and Expressways	1,2,3,4,6,7,8,9,10,11,12,14,16
Minor Arterials	4,6,8,9,10,11,12,15,16,17
Major Collectors	6,9,12,14,15,17
Minor Collectors	9,12,14,17
Local Routes and Streets	9,12,14,17

Table 3.6 Truck Traffic Classification Group Criteria (*3*)

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

Table 3.7 Truck Traffic Classification Grouping

SHRP ID	ROUTE	Buses	Single-Unit	Single Trailer	Single Unit + Single Trailer	Multiple-Trailers	TTC
		VC 4	VC 5 - 7	VC 8 - 10	VC 5 - 10	VC 11 - 12	
0500	I 55	3.02	6.55	82.70	89.25	7.73	3
0900	I 55	0.94	15.22	77.34	92.56	6.50	3
3018	US 72	3.63	7.21	85.06	92.27	4.09	3
3081	US 78	0.79	4.48	86.75	91.24	7.97	3
3082	US 82	1.36	15.07	81.98	97.05	1.59	3
3091	US 45	1.07	10.05	86.49	96.54	2.38	3
3093	I 10	1.86	16.70	78.53	95.23	2.91	3
3097	I 55	0.81	12.92	79.67	92.59	6.60	3
3099	I 20	0.57	8.04	83.44	91.49	7.94	3
5006	US 78	1.10	5.76	84.98	90.75	8.16	3
5025	US 84	0.39	20.59	76.51	97.10	2.51	3
5803	US 78	1.39	5.40	84.58	89.98	8.63	3
5805	I 10	0.98	13.03	83.24	96.27	2.75	3
9030	I 20	2.17	13.23	79.15	92.38	5.45	3
1016	MS 35	7.38	26.82	61.86	88.68	3.94	6
1001	US 45	2.29	23.40	67.40	90.80	6.90	7
1802	US 84	0.50	26.93	70.79	97.72	1.78	7
2807	MS 6	3.32	30.38	65.17	95.55	1.13	7
3087	MS 7	1.42	26.99	69.45	96.44	2.14	7
4024	MS 1	6.86	64.92	27.14	92.06	1.08	12
3083	MS 310	2.81	58.51	36.86	95.37	1.82	15
3090	MS 315	3.70	68.87	24.69	93.57	2.73	15

With TTC grouping established for the LTPP sites, it is now desirable to review the VC distribution for each developed TTC group. Figure 3.27 illustrates the VC distribution for TTC 3 sites and indicates very good VC distribution agreement within the sites. Two sites, 5025 and 5805, appear to have slightly elevated percentages of VC 6 vehicles, but otherwise agree.

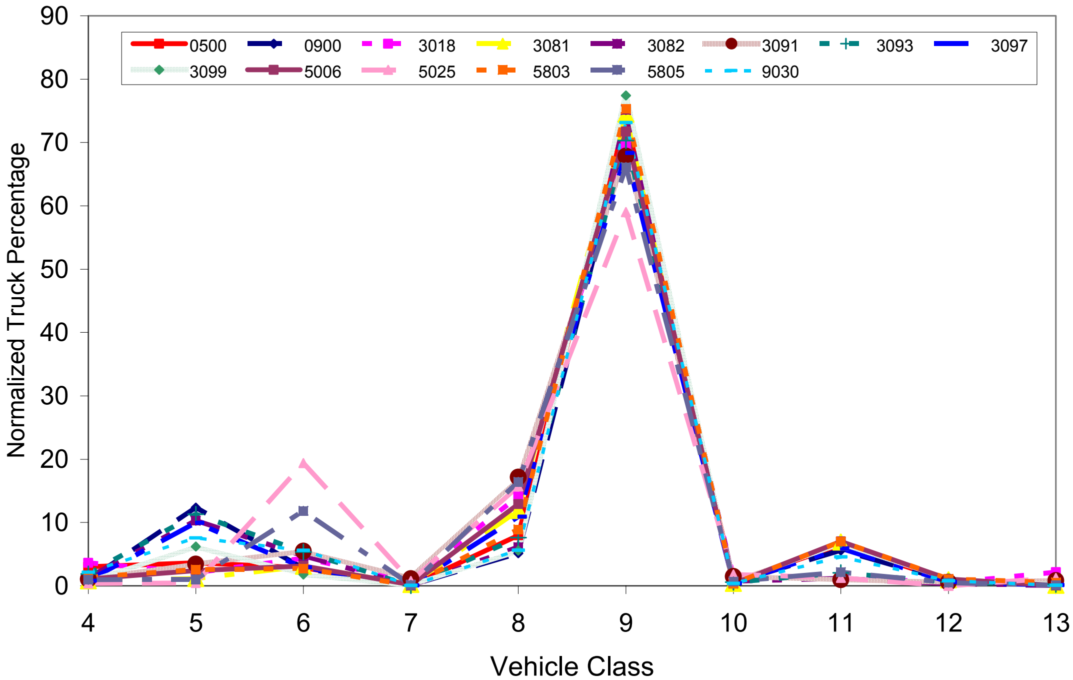

Figure 3.27 Vehicle Class Distribution for TTC 3

Vehicle class distribution for the single TTC 6 site is shown previously in Figure 3.5. Distributions for TTC 7 are provided in Figure 3.28 and once more indicate good agreement among the four sites. The fact that the sites have good VC distribution agreement again appears to offer validity to the TTC group methodology.

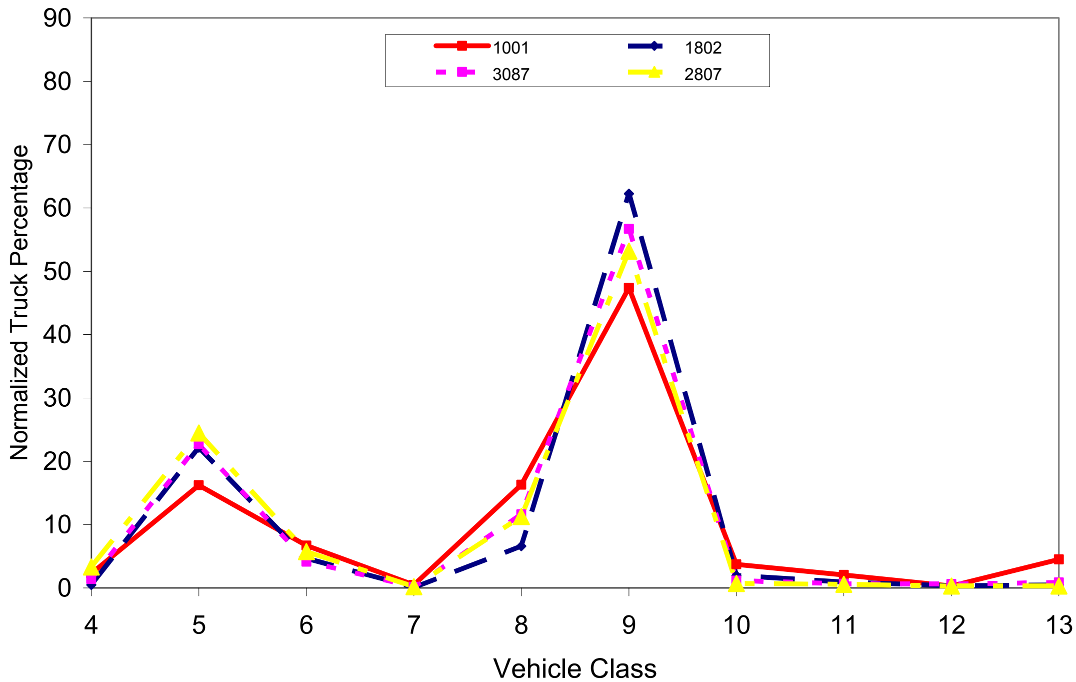

Figure 3.28 Vehicle Class Distribution for TTC 7

Vehicle class distribution for the single TTC 12 site was presented previously in Figure 3.18. The VC distributions for two TTC 15 sites are presented in Figure 3.29. There is some variability between the two sites for VC 6 and 9, but otherwise appear in good agreement.

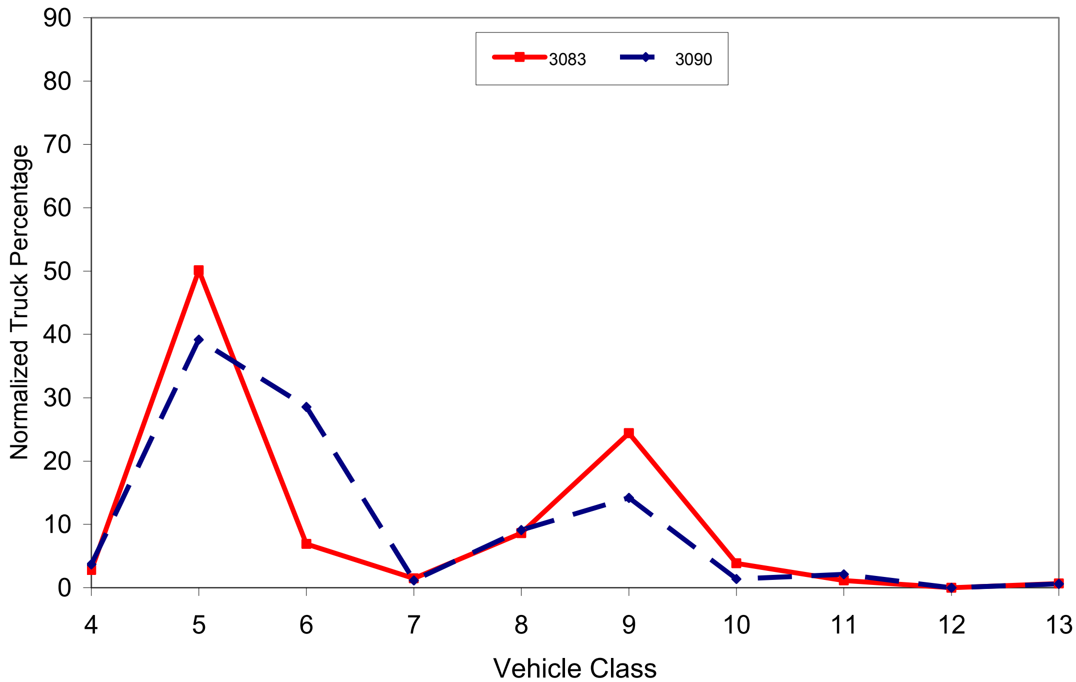

Figure 3.29 Vehicle Class Distribution for TTC 15

3.2.4 Monthly Truck Distribution Adjustment

It is important to review monthly truck class and volume distribution. Monthly truck class distribution adjustment is based on a given month's normalized truck class distribution relative to the yearly average. Monthly truck class distribution is important because even though overall truck volume may be consistent throughout the year, truck class distribution may change somewhat due to seasonal operations (e.g., more VC 9 trucks during harvesting season).

3.2.4.1 Monthly Truck Class Distribution

Data generally showed monthly truck class distribution to be consistent for the LTPP sites. More monthly variation was observed for lower volume facilities, which was expected. An example of monthly truck class distribution for one site from each TTC group is provided in Figures 3.30 through 3.33. Monthly truck distribution LTPP data was incomplete for the TTC 12 site 4024; therefore monthly truck class variation could not be determined.

Figure 3.30 illustrates monthly truck distribution for TTC 3 site 3099 (Interstate 20). It is readily apparent that little variability exists in truck class distribution throughout the year, which was expected since this is a "thru" truck facility. This site is typical of other TTC 3 facilities. Based on this data, it does not appear that any adjustment should be made to truck class distribution within the year.

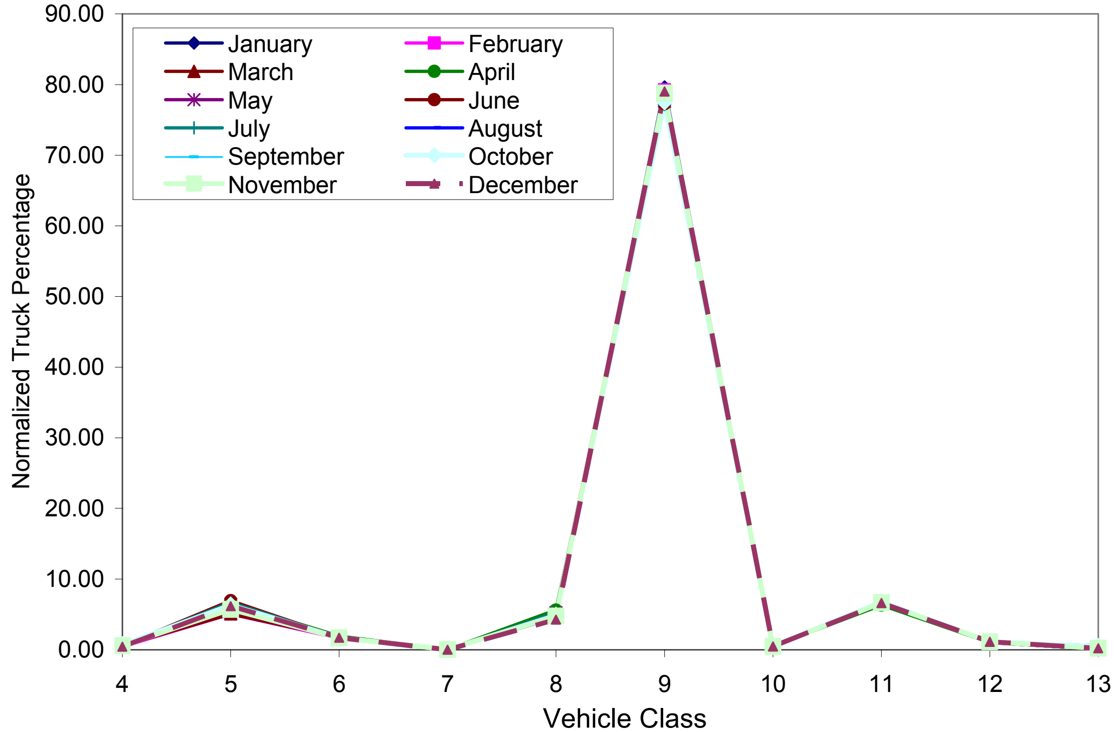

Figure 3.30 Monthly Truck Class Distribution for Site 3099

Figure 3.31 illustrates monthly truck class distribution for TTC 6 site 1016 (Hwy 35). As with site 3099, variation in truck class distribution within the year is very low. Again, it does not appear any monthly truck class distribution adjustments should be developed for this site.

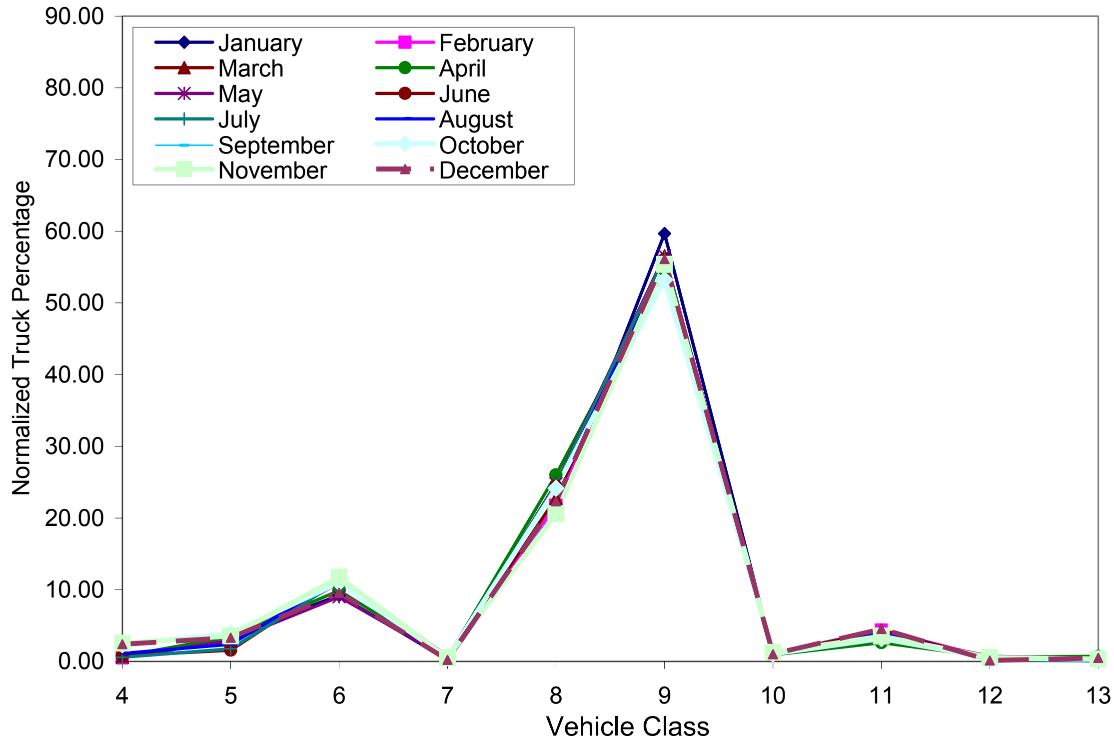

Figure 3.31 Monthly Truck Class Distribution for Site 1016

Figure 3.32 illustrates monthly truck distribution for TTC 7 site 3087 (Hwy 7). Truck distribution is consistent with VC 5 and 9 trucks showing the most variation. Even with the variation, the use of truck class adjustment factors is not recommended due to the relatively limited available site data. Perhaps, with more data, truck class adjustments could be made to VC 5 and 9 classes, or possibly other classes.

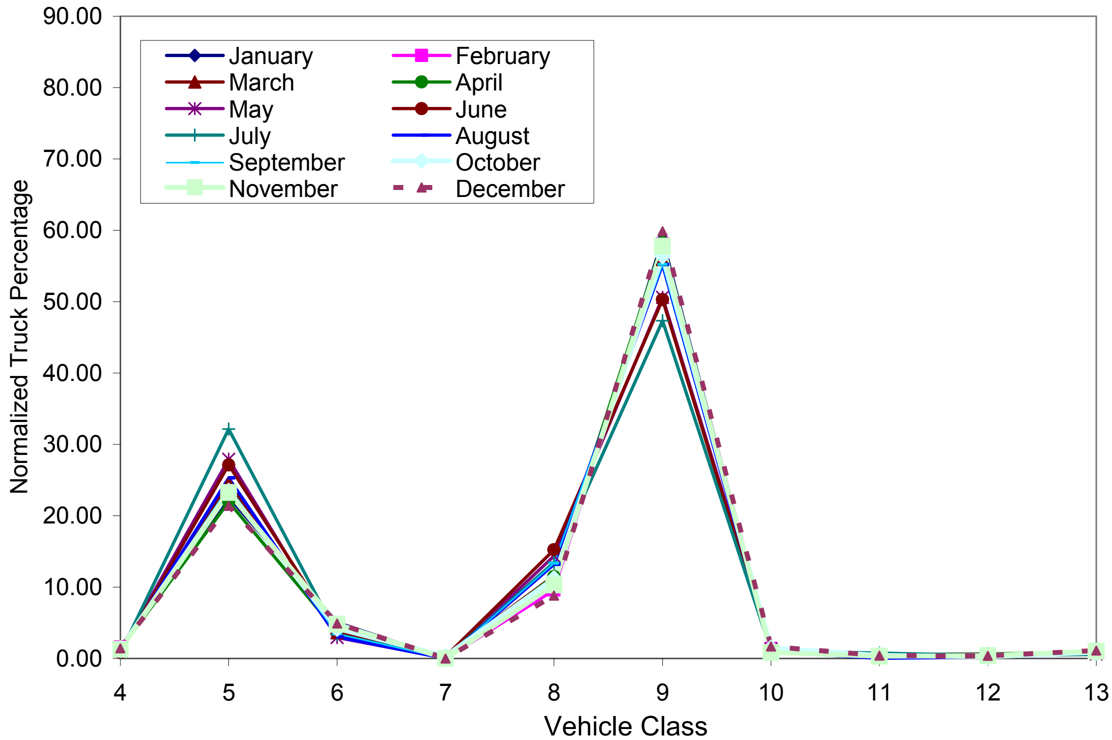

Figure 3.32 Monthly Truck Class Distribution for Site 3087

Figure 3.33 illustrates monthly truck distribution for TTC 15 site 3083 (Hwy 310). Truck distribution has considerable variability throughout the year, especially for VC 5 and 9 trucks. This was also evident with site 3090 (MS 315), the other TTC 15 site. Monthly truck class distribution factors could be developed for this group, however, due to limited site data, it is not recommended. More sites should be evaluated prior to developing appropriate monthly distribution factors for various truck classes. Additionally, TTC 15 sites are low volume facilities where a Level 1 design is not likely to be conducted.

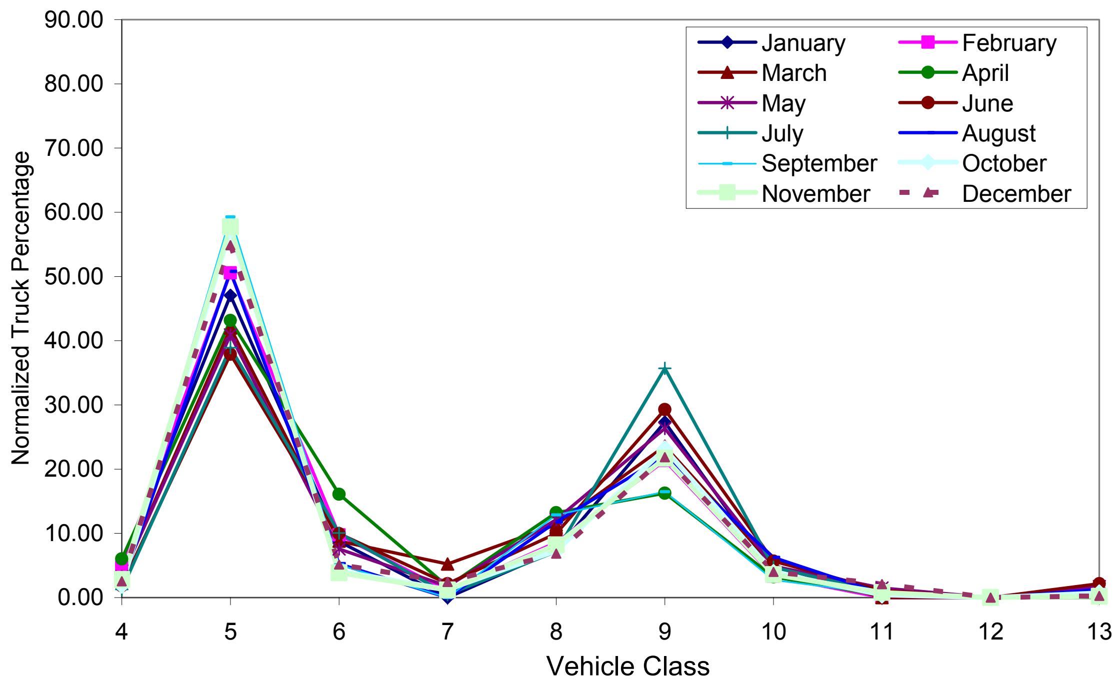

Figure 3.33 Monthly Truck Class Distribution for Site 3083

3.2.4.2 Monthly Distribution Factors

Monthly distribution factors (MDF) are used to account for truck volume variability within the year. These factors are the ratio of average monthly daily truck traffic (AMDTT) to average annual daily truck traffic (AADTT). Monthly distribution factors would be applicable where traffic distributions are significantly influenced by seasonal operations (e.g., agricultural planting and harvesting operations). If there is not sufficient data to suggest the use of monthly adjustment factors, national level default values of 1.0 should be used for all months.

Extensive data were analyzed for each Mississippi LTPP site to determine appropriate MDF. Overall average MDF for each TTC is provided in Table 3.8. Figures 3.34 through 3.38 illustrates average MDF for TTC 3, 6, 7, 12, and 15 sites, respectively. From Figure 3.34, the TTC 3 sites, which are comprised of interstate and high volume, four-lane highways generally appear to have uniform truck traffic throughout the year (i.e., MDF = 1.0). As discussed previously, this is logical since loading on these facilities is not significantly influenced by local traffic with the facilities being "thru" truck traffic routes.

Table 3.8 Average Monthly Distribution Factor for TTC Classification

Month	Average Monthly Distribution Factor (MDF)				
	TTC 3	TTC 6	TTC 7	TTC 12	TTC 15
January	0.90	0.80	0.82	0.96	0.69
February	0.96	0.97	0.91	1.06	0.70
March	1.01	1.02	0.97	0.99	0.79
April	1.00	0.97	1.00	0.89	0.93
May	0.99	0.96	1.04	1.05	0.84
June	1.01	1.09	1.04	1.05	0.90
July	0.98	0.96	0.98	1.11	0.86
August	1.06	1.07	1.03	1.07	1.15
September	1.04	1.08	1.05	1.28	1.21
October	1.08	1.12	1.11	1.03	1.46
November	1.00	1.08	1.06	0.80	1.23
December	0.96	0.88	0.99	0.70	1.25

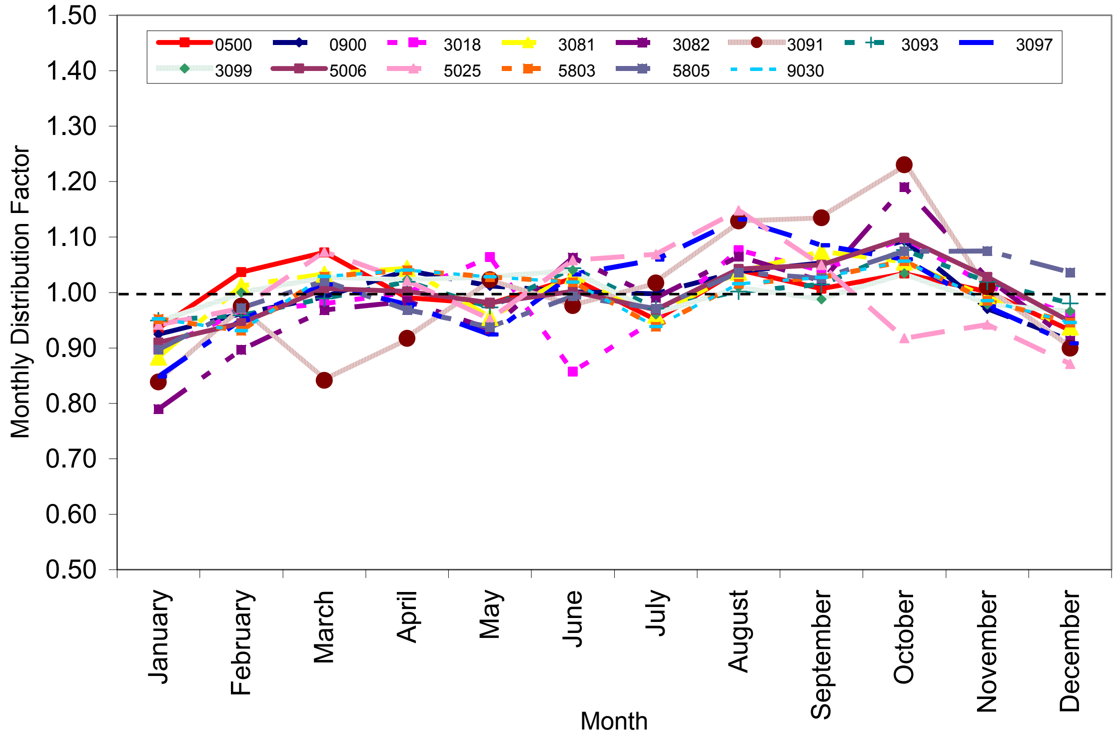

Figure 3.34 Monthly Distribution Factors for TTC 3

Figure 3.35 illustrates MDF for the single TTC 6 site. While there is only one site present, it does provide a contrast to that of TTC 3. Monthly truck traffic variations are much more evident at this site, with a general increase in truck traffic during fall months and less traffic during winter months. This is a situation where seasonal harvesting operations may have influenced the data.

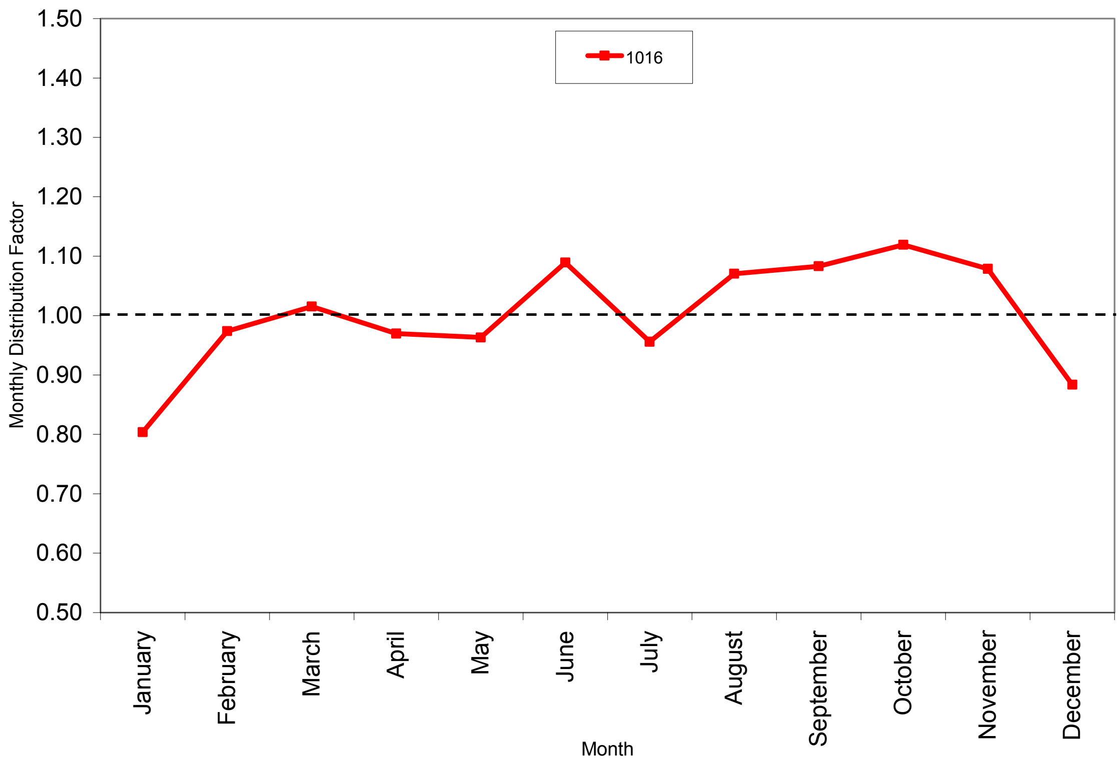

Figure 3.35 Monthly Distribution Factors for TTC 6

The MDF for TTC 7 sites is provided in Figure 3.36. As anticipated, there appears to be more variability in truck traffic than for TTC 3 sites. Considerable differences among sites are evident with two sites, 1802 and 2807, having greater truck traffic during fall months than winter and spring months. Site 3087 shows greater traffic during summer months than for the remainder of the year. Site 1001 has higher truck traffic during spring and lower truck traffic during the summer. There does not appear to be an evident reason as to why the sites demonstrate such different truck traffic patterns. This clearly emphasizes the need for in-depth analysis of a given site to determine what loading influences occur and how to account for them during the design process.

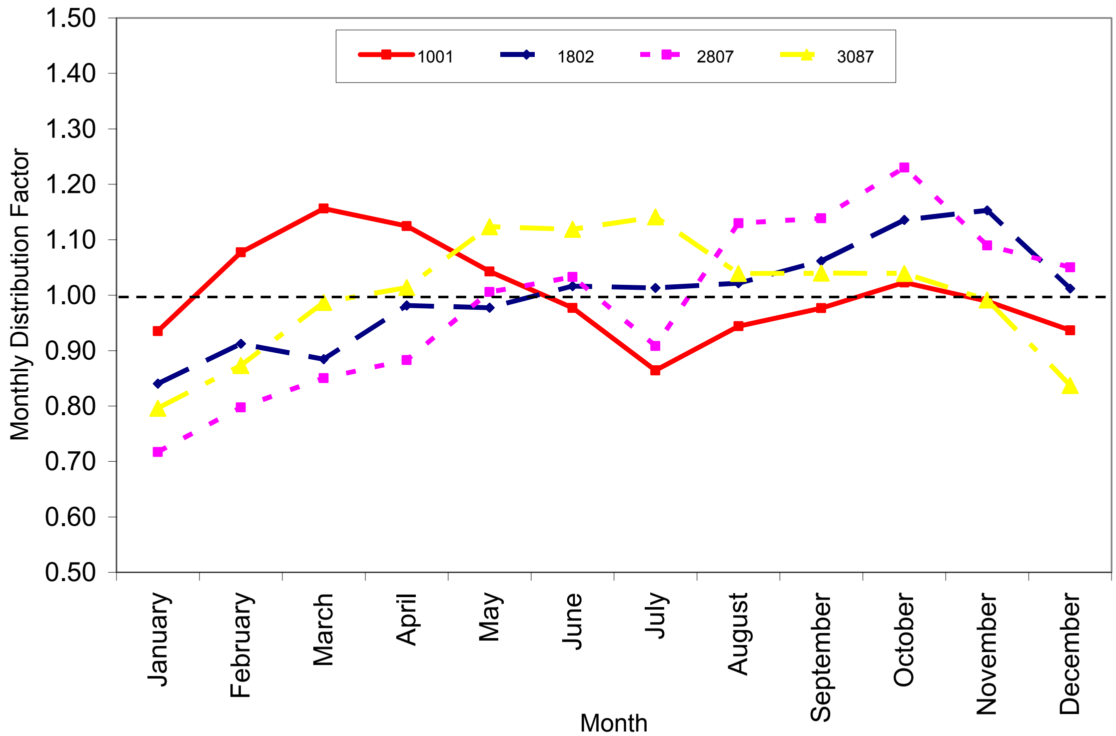

Figure 3.36 Monthly Distribution Factors for TTC 7

Figure 3.37 illustrates the MDF for the single TTC 12 site. Again, the MDF are substantially higher during the summer and fall months with a substantial decrease in truck traffic during the late fall and early winter months.

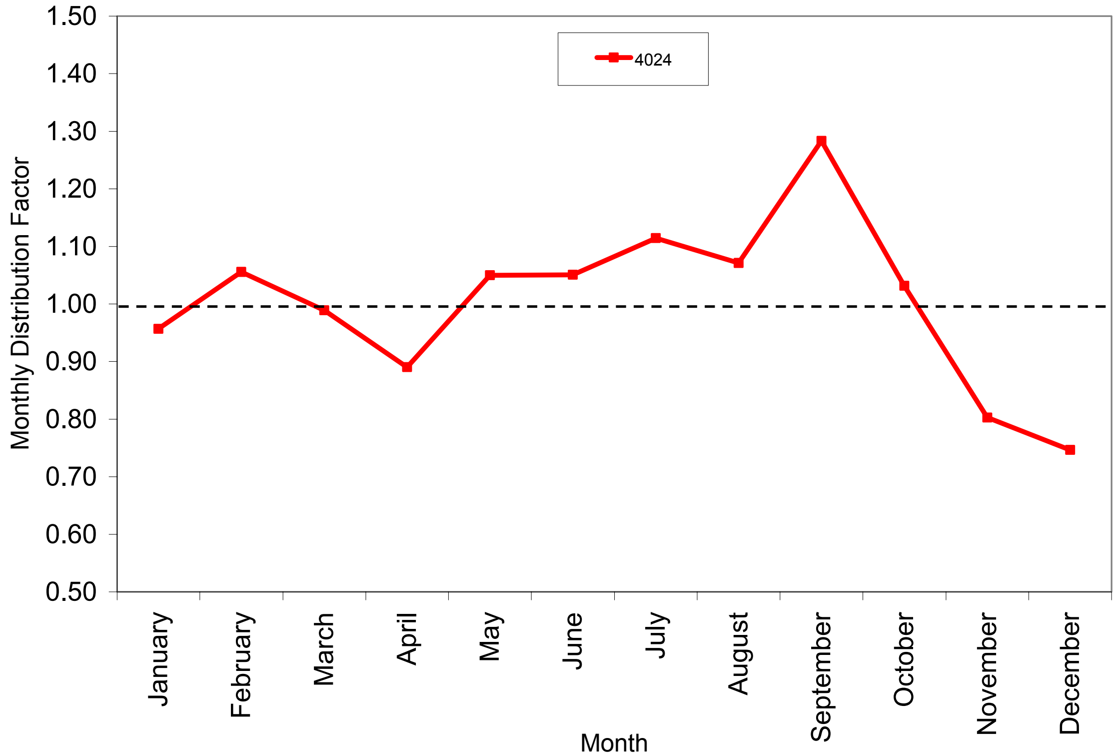

Figure 3.37 Monthly Distribution Factors for TTC 12

Figure 3.38 illustrates MDF for the two TTC 15 sites. Variation of MDF is greatest for these sites with variation being generally the same for each site. Truck traffic is split between the first and second part of the year, with much lower truck traffic during the first half and much higher during the second half, especially during the fall months. These two sites are both two-lane connector facilities whose traffic is primarily influenced by local activities. It is possible that local farming operations contributed to the peaked truck traffic during the fall months.

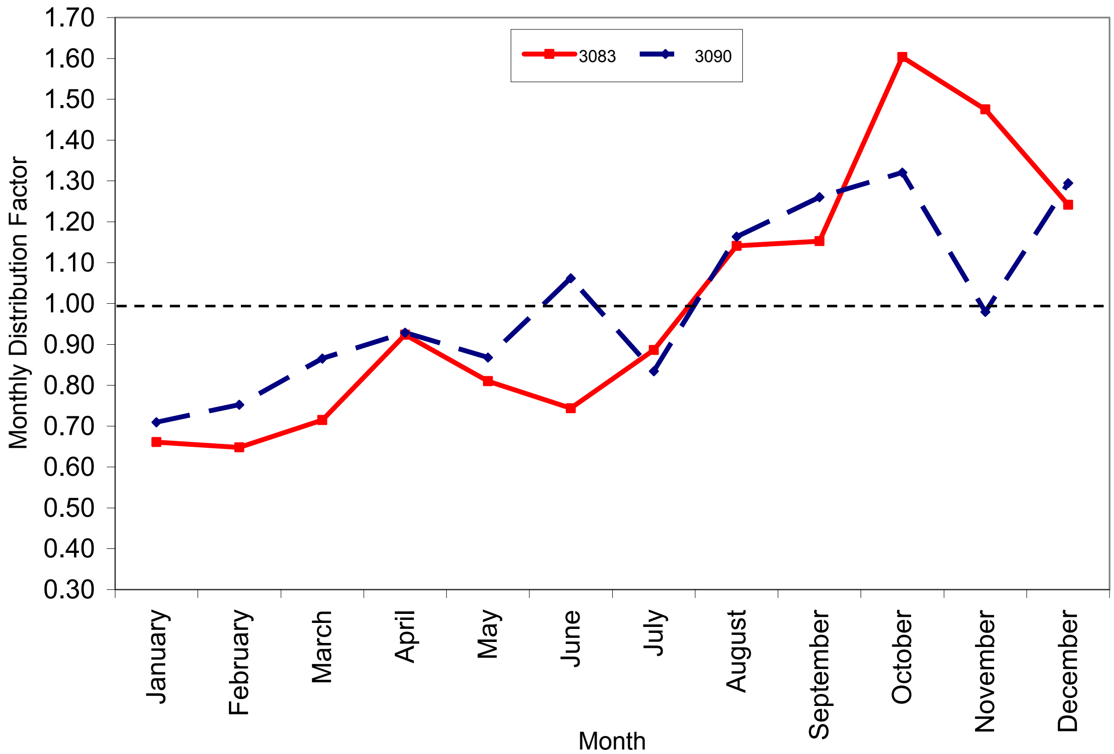

Figure 3.38 Monthly Distribution Factors for TTC 15

3.2.5 Hourly Distribution Factors

Hourly distribution factors (HDF) are needed to adjust truck volume throughout the day. Highway facilities can have varying truck volume distributions, based on their functional classification or location within the state. For example, interstate facilities typically experience more uniform truck hourly distributions compared to low volume, two-lane facilities. Hourly truck volume distribution is critical to pavement response. Temperature variations induce curling in concrete pavements and influence stiffness of hot mix asphalt pavements. Increased truck traffic during these periods can influence concrete slab cracking and rutting and/or cracking of asphalt pavements.

Development of HDF requires hourly truck volume data for a given site. It is desirable to have weekday and weekend data so that a composite HDF can be established. In cases where there is no such data, HDF can be determined through a default hourly traffic distribution which is provided in Table 3.9.

Table 3.9 Default Truck Traffic Hourly Distribution (3)

Time of Day	Default Percent of Truck Traffic
Midnight to 6 a.m.	14.0
6 a.m. to 10 a.m.	19.8
10 a.m. to 4 p.m.	35.1
4 p.m. to 8 p.m.	18.5
8 p.m. to Midnight	12.6

For each Mississippi LTPP section, truck volume distribution was analyzed for weekday and weekend days for each year of available data. Weekday analysis was restricted to mid-week days of Tuesday, Wednesday, or Thursday to more accurately evaluate average weekday distribution. For the majority of the sections, Saturday was selected for weekend evaluation. An overall hourly truck traffic distribution was developed for each site based on a weighted average of five weekdays and two weekend days.

In the following section of the report, hourly truck volume distribution will be presented for each TTC group. The hourly distribution will then be compared to national level default values. Average hourly truck distribution for each TTC group is provided in Table 3.10, and provided graphically in Figure 3.39 through 3.44 for each TTC group.

Table 3.10 Average Hourly Distribution for TTC Groups

Time	Hourly Distribution of Truck Traffic, %				
	TTC 3	TTC 6	TTC 7	TTC 12	TTC 15
Midnight - 1 a.m.	2.85	0.96	1.79	0.93	0.62
1 to 2 a.m.	2.55	0.89	1.53	0.92	0.42
2 to 3 a.m.	2.49	1.29	1.58	0.77	0.40
3 to 4 a.m.	2.65	2.68	1.32	1.04	0.28
4 to 5 a.m.	2.94	3.24	2.07	0.87	1.69
5 to 6 a.m.	3.42	3.86	3.21	2.77	2.69
6 to 7 a.m.	4.25	4.49	4.77	3.79	8.55
7 to 8 a.m.	4.64	6.74	5.36	6.25	8.93
8 to 9 a.m.	4.81	6.79	6.22	6.78	6.00
9 to 10 a.m.	5.16	8.05	6.01	7.01	9.58
10 to 11 a.m.	5.55	8.11	7.24	7.07	7.44
11 to 12 noon	5.51	7.46	7.37	7.09	5.46
12 noon to 1 p.m.	5.55	6.78	5.82	6.67	6.19
1 to 2 p.m.	5.66	6.74	6.74	6.74	5.93
2 to 3 p.m.	5.63	5.94	6.35	7.62	4.78
3 to 4 p.m.	5.24	5.44	6.48	6.92	6.72
4 to 5 p.m.	5.23	5.60	5.87	5.59	8.50
5 to 6 p.m.	4.80	3.72	5.40	5.15	4.67
6 to 7 p.m.	4.31	2.95	4.21	5.37	3.87
7 to 8 p.m.	3.93	1.93	2.79	2.72	3.04
8 to 9 p.m.	3.49	2.47	2.34	3.62	1.75
9 to 10 p.m.	3.42	1.47	2.28	1.48	1.64
10 to 11 p.m.	3.15	1.05	1.50	1.28	0.23
11 p.m. to Midnight.	2.77	1.32	1.76	1.55	0.63

Hourly truck distribution for TTC 3 sites is shown in Figure 3.39 and 3.40 (7 sites per figure). It is evident that truck volume distribution peaks during mid-day with significant truck traffic occurring throughout the night. This should be expected since these TTC 3 facilities, especially interstates, are generally used by truck drivers during night time hours for more efficient trucking operations. General agreement was evident among the various sites with site 3081 having a slightly higher percentage of truck traffic during mid-day and site 5025 having somewhat of a bi-modal hourly distribution, peaking from 5 a.m. to 7 a.m. and from 1 p.m. to 4 p.m.

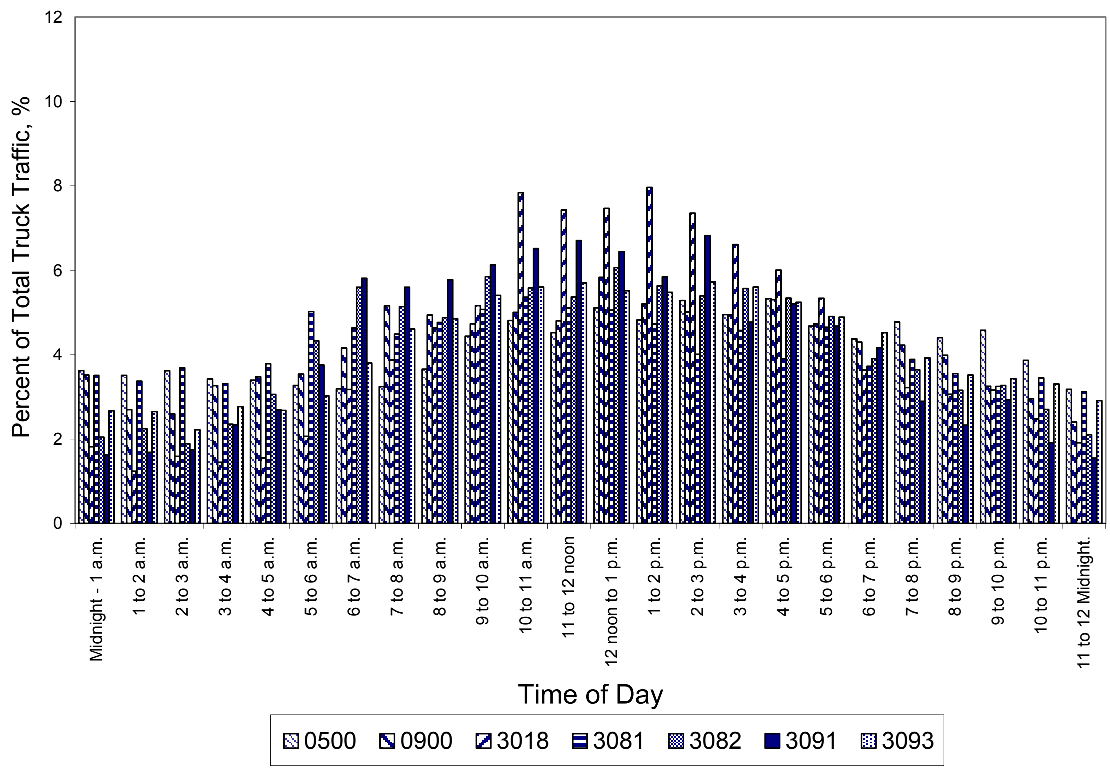

Figure 3.39 Hourly Truck Distribution for TTC 3 (1st seven sites)

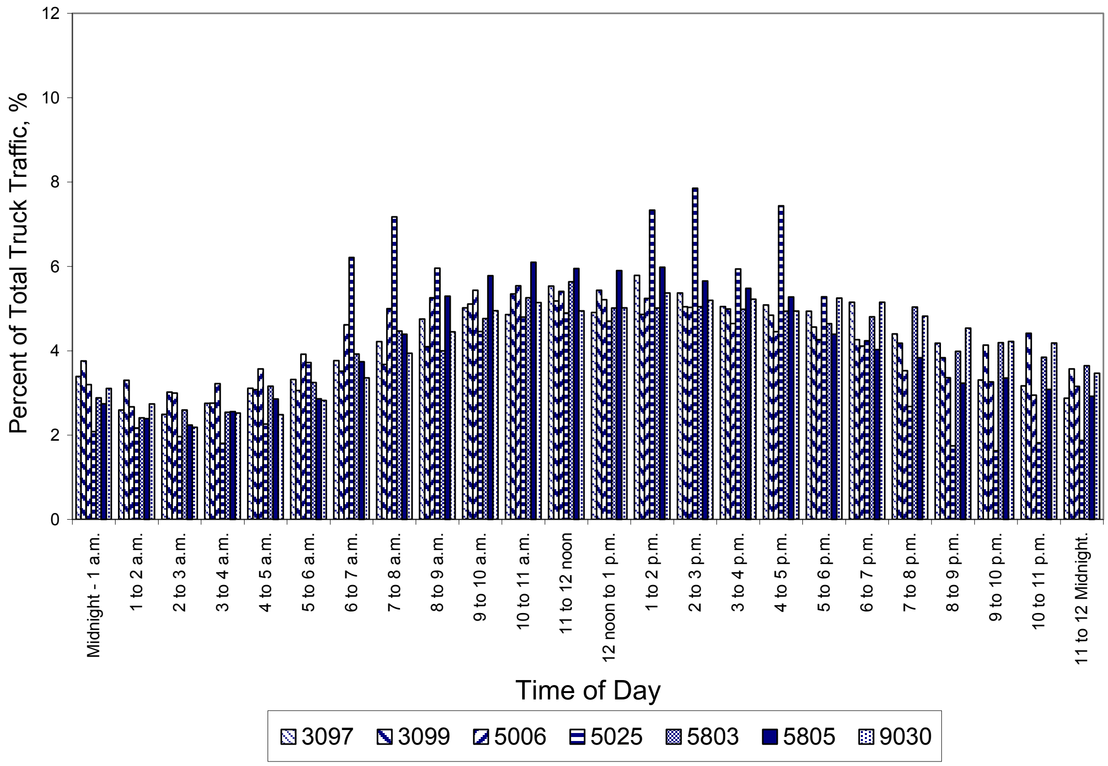

Figure 3.40 Hourly Truck Distribution for TTC 3 (2nd seven sites)

Hourly truck volume distribution for the TTC 6 site is shown in Figure 3.41. Immediately evident is the concentration of truck traffic within the hours of 7 a.m. to 5 p.m. Very little of the design truck traffic occurred during late evening and early morning hours, in contrast to the TTC 3 and 7 sites.

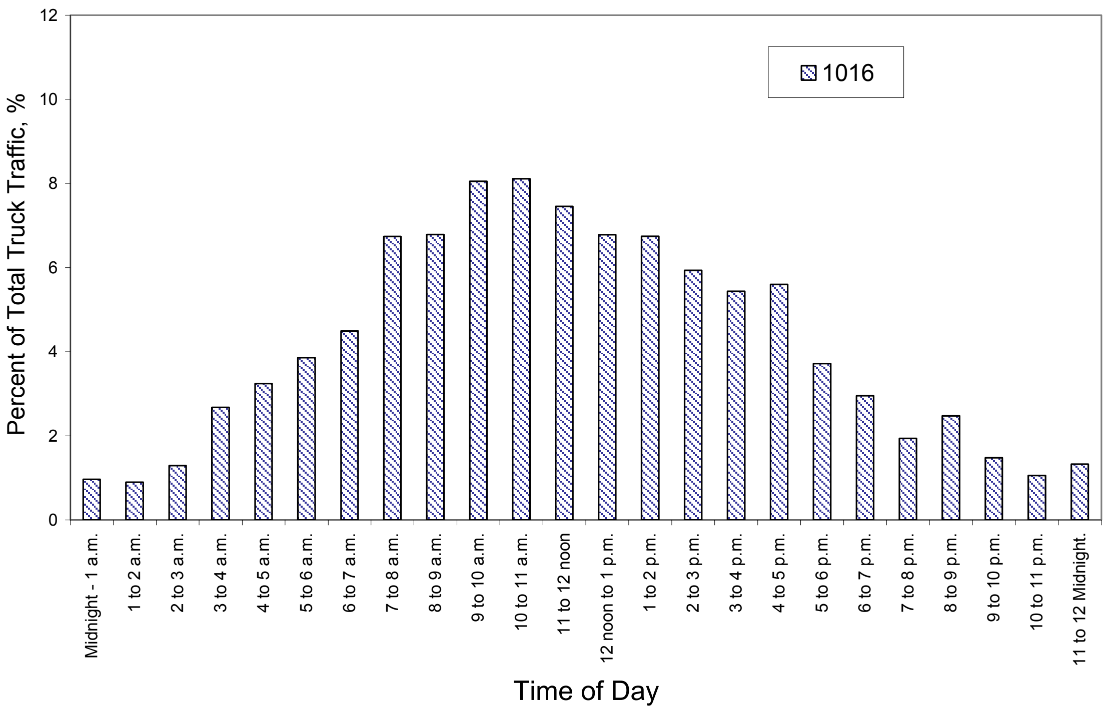

Figure 3.41 Hourly Truck Distribution for TTC 6

Hourly truck distribution for the TTC 7 sites is shown in Figure 3.42. In comparison to the TTC data, the hourly truck volume is more concentrated from the hours of 5 a.m. to 7 p.m. The amount of truck traffic during evening and early morning hours was considerably more than for the TTC 6 site, which was anticipated due to the nature of the TTC 7 facilities.

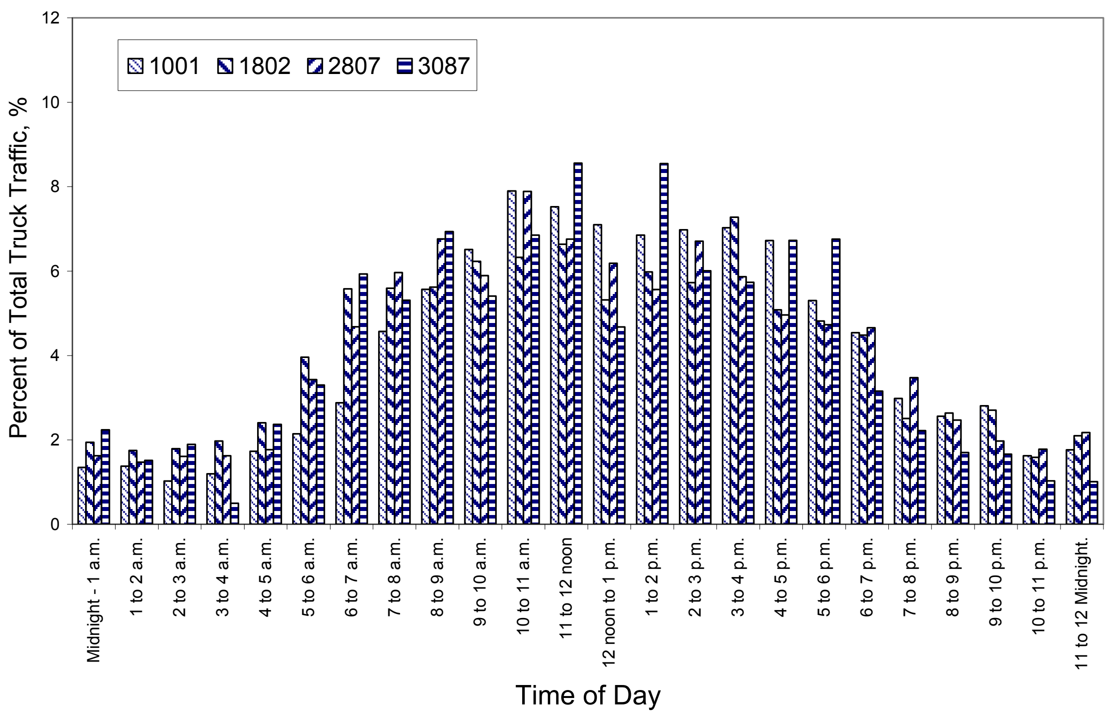

Figure 3.42 Hourly Truck Distribution for TTC 7

Hourly truck distribution for the TTC 12 site is shown in Figure 3.43. The data are very similar to the TTC 6 site with a heavy concentration of truck traffic occurring during hours of 5 a.m. to 9 p.m. with very little truck traffic during night time hours. This again was anticipated due to the facility being more of a business truck traffic route.

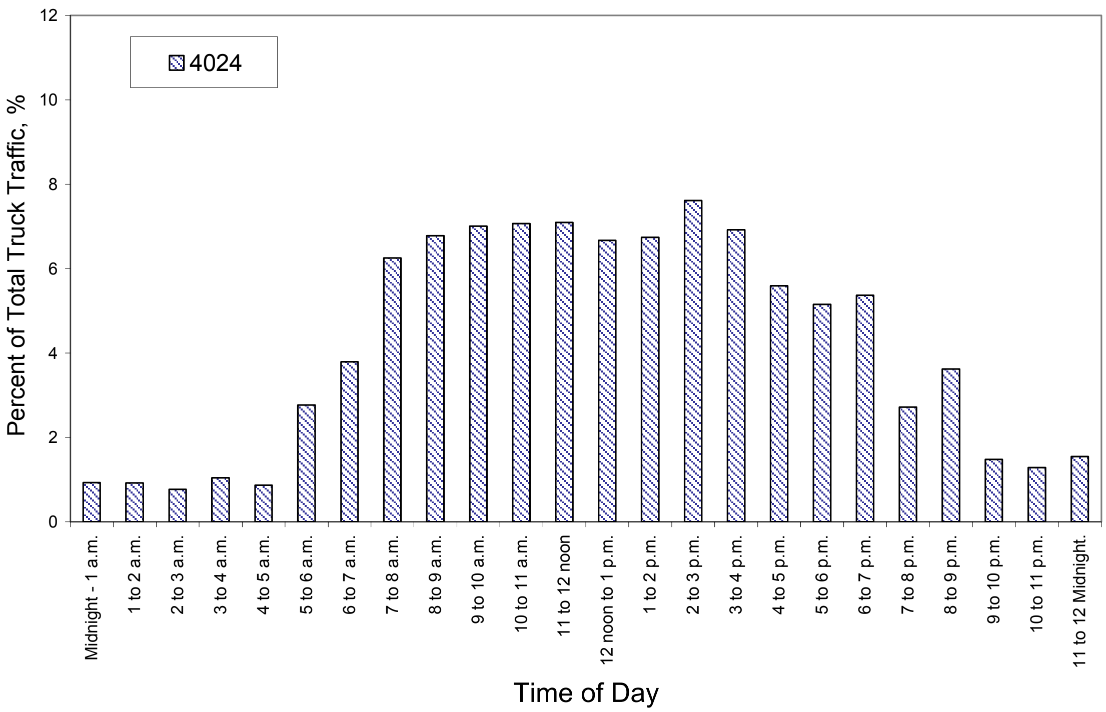

Figure 3.43 Hourly Truck Distribution for TTC 12

Hourly truck distribution for the TTC 15 sites is shown in Figure 3.44. The dominance of day time truck traffic is more evident with these sites than for any other TTC group. Very little truck traffic occurred during the hours of 10 p.m. to 4 a.m. As with the TTC 6 and 12 sites, this can be attributed to the facilities being business truck traffic routes.

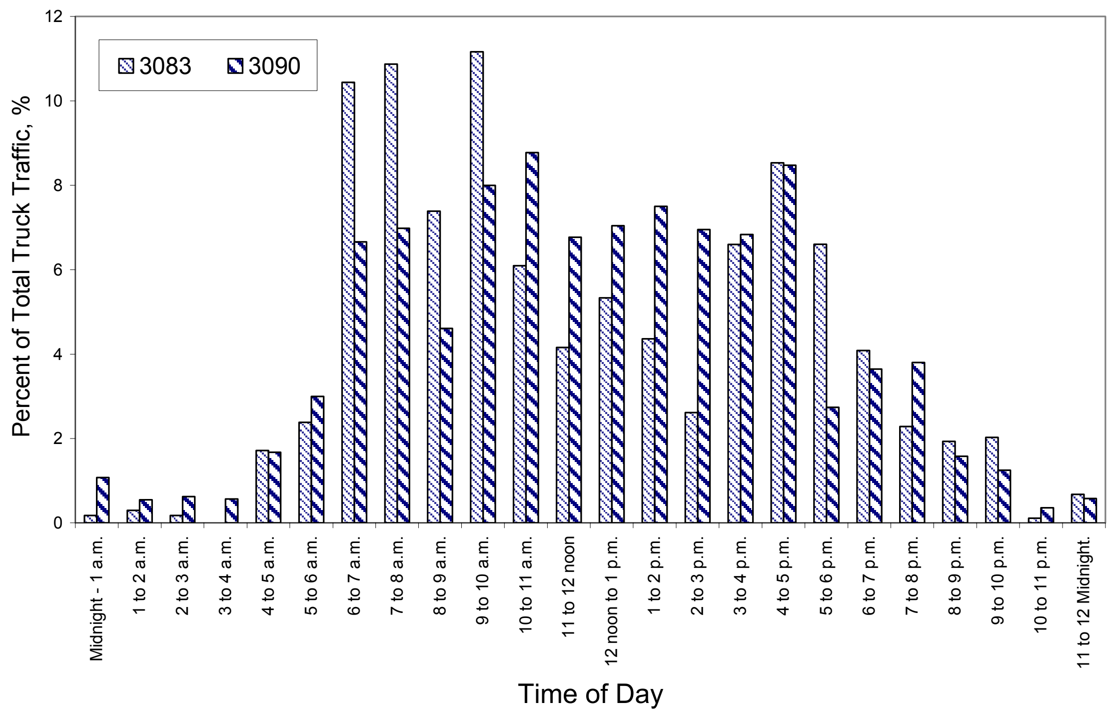

Figure 3.44 Hourly Truck Distribution for TTC 15

National level hourly distribution defaults, previously presented in Table 3.9, were determined through an analysis of approximately 500 LTPP sites (4), so they represent an overall average from a range of highway types throughout the country. While this distribution should be used if no data is available, potential significant differences may exist between default and actual values, as illustrated in Table 3.11. Default values are very similar to those recorded for TTC 3, however, there are substantial differences between default values and distributions for other TTC groups. Among the largest differences are late night and early morning distributions for TTC 12 and 15, which as previously mentioned are "business" type facilities. These facilities have a much greater truck traffic percentage during hours of 6 a.m. to 8 p.m.

Table 3.11 Comparison of TTC Group Average Hourly Distribution and Default Values

Time of Day	Hourly Distribution of Truck Traffic, %						
	Default	TTC 3	TTC 6	TTC 7	TTC 12	TTC 15	Average TTC
Midnight to 6 a.m.	14.0	16.90	12.93	11.49	7.29	6.10	10.94
6 a.m. to 10 a.m.	19.8	18.86	26.07	22.35	23.83	33.05	24.83
10 a.m. to 4 p.m.	35.1	33.14	40.47	39.99	42.11	36.51	38.44
4 p.m. to 8 p.m.	18.5	18.27	14.21	18.28	18.83	20.08	17.93
8 p.m. to Midnight	12.6	12.83	6.33	7.89	7.93	4.25	7.84

3.2.6 Directional and Lane Distribution Factors

Percentage (in decimal form) of truck volume in the design direction is referred to as the directional distribution factor (DDF). For a highway with equal traffic in both directions, DDF is equal to 0.5. In reality, the DDF factor is a function of many parameters, but research conducted on highways within the LTPP database showed DDF to vary between 0.5 and 0.6 (*4*). Furthermore, it was shown that the DDF for VC 9, the most common truck class, was 0.55. National level defaults are provided for various truck classes as follows: VC 4 = 0.50, VC 5 through 7 = 0.62, VC 8 through 10 = 0.55, and VC 11 through 13 = 0.50. If specific truck data is not available for a given site, the DDF for the predominate truck class should be used for all truck traffic.

In addition to DDF, the percentage (in decimal form) of truck traffic in the design lane is important and is referred to as the lane distribution factor (LDF). The LDF will vary depending primarily on the number of travel lanes per direction. It is recommended that a LDF of 0.9, 0.6, and 0.45 be used for four, six, and eight-lane highways. By default, LDF is equal to 1.0 for two-lane roadways (*4*).

3.2.7 Traffic Growth Factors

It is important to understand truck traffic growth rate for a given roadway so traffic volumes and loading can be accurately forecasted. Traffic growth is dependent upon many parameters and is often best-estimated or assumed. Accurate growth rate determination requires extensive data collection over a number of years to establish appropriate truck volume trends. The new design guide allows traffic growth rate to be no growth, linear growth, or compound growth. Traffic growth of all truck classes can be input as a single value or individual growth rates of each VC can be input. Very accurate and specific growth data will need to be obtained prior to inputting individual VC growth rates.

3.3 AXLE LOAD SPECTRA

Axle load spectra for each year of available monitoring data was analyzed and averaged to determine base annual axle load spectra for single, tandem, tridem axles for each vehicle class for the Mississippi LTPP sites. Single axle load spectra for TTC groups are provided in Tables 3.12, 3.13, 3.14, 3.15, and 3.16. Similarly, Tables 3.17 through 3.21 and Tables 3.22 through 3.26 provide tandem and tridem axle load spectra, respectively, for the TTC groups.

Developing axle load spectra for a given roadway requires WIM data consisting of axle distribution and weight data. In this study, each site had a minimum of several years of WIM data available for analysis. For each vehicle class, WIM data are reviewed to determine the number of single, tandem, tridem, and quadem axles. Furthermore, axle weights of each axle type are analyzed and sorted into weight classes of varying size. For example, the weight class range is 4.45, 8.9, 13.3, and 17.8 kN (1,000, 2,000, 3,000 and 4,000 lbs) for single, tandem, tridem, and quadem axles, respectively. Normalized axle load spectra are determined in much the same manner as previously discussed for normalized vehicle class distribution. For a given vehicle class, the number of single axles within each weight class is divided by the total number of recorded single axles to determine the normalized axle spectra. The process is repeated for tandem, tridem, and quadem.

For each table, the shown values represent the percentages of the various axle types having weights bounded by the corresponding weight and the next lowest weight. For example, referring to Table 3.12, for VC 9, 19.37 percent of the single axles weighed between 44 and 49 kN (10,000 and 11,000 lbs)

Obviously, not all vehicle classes have tandem and tridem axles (e.g.., tandem axle on VC 5), therefore axle load spectra is not available (shown as 0.0) for these cases. Very few quad axles were found in the LTPP data; therefore, axle load spectra could not be developed. Default quad axle load spectra should therefore be used, if required.

Table 3.12 Normalized Single Axle Load Spectra for TTC 3

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
13	3,000	0.28	5.40	1.08	3.89	7.62	0.35	0.00	0.04	0.00	55.64
18	4,000	1.06	9.42	0.47	0.56	2.88	0.61	0.00	0.53	0.58	6.88
22	5,000	1.11	24.48	1.07	4.33	8.31	1.14	0.63	2.52	3.29	0.00
27	6,000	1.56	12.74	2.99	2.22	6.81	1.75	0.84	4.86	7.16	0.00
31	7,000	3.86	10.32	6.29	9.33	8.83	3.84	4.00	6.31	10.74	4.79
36	8,000	6.93	9.33	11.76	10.91	11.77	8.22	11.59	8.01	11.97	1.67
40	9,000	11.08	7.82	18.52	15.37	13.27	13.87	19.09	10.49	15.21	15.02
44	10,000	14.42	6.09	20.12	7.94	11.57	18.15	25.33	12.18	15.56	1.70
49	11,000	17.83	4.51	17.23	19.89	8.44	19.37	22.04	11.18	11.85	7.57
53	12,000	13.60	3.06	10.32	4.07	5.62	14.83	11.24	9.31	9.80	2.30
58	13,000	11.16	2.06	5.74	2.96	3.95	7.30	4.35	7.93	5.71	0.99
62	14,000	8.73	1.45	2.53	1.11	2.95	3.18	0.71	6.88	3.70	0.33
67	15,000	4.12	1.12	0.81	1.85	2.32	1.75	0.18	5.69	2.26	1.04
71	16,000	2.41	0.87	0.44	5.00	1.79	1.33	0.00	4.66	1.51	0.00
76	17,000	1.12	0.46	0.33	1.39	1.45	1.22	0.00	3.43	0.37	0.00
80	18,000	0.43	0.33	0.11	1.39	0.98	1.07	0.00	2.50	0.19	0.00
85	19,000	0.15	0.21	0.09	5.00	0.63	0.81	0.00	1.72	0.05	2.08
89	20,000	0.09	0.14	0.10	0.00	0.37	0.54	0.00	0.94	0.05	0.00
93	21,000	0.02	0.07	0.00	0.00	0.23	0.31	0.00	0.40	0.00	0.00
98	22,000	0.02	0.04	0.00	1.39	0.09	0.17	0.00	0.25	0.00	0.00
102	23,000	0.02	0.02	0.00	0.00	0.09	0.09	0.00	0.11	0.00	0.00
107	24,000	0.00	0.02	0.00	0.00	0.01	0.05	0.00	0.04	0.00	0.00
111	25,000	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
116	26,000	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
120	27,000	0.00	0.01	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	29,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
138	31,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
142	32,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
156	35,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
165	37,000	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.13 Normalized Single Axle Load Spectra for TTC 6

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
13	3,000	11.69	6.70	0.00	12.50	1.25	0.00	0.00	0.00	3.57	35.83
18	4,000	27.92	6.93	0.00	0.00	0.00	0.00	0.00	1.92	0.00	0.00
22	5,000	44.15	33.78	0.00	20.83	9.83	0.85	0.00	5.79	6.25	5.00
27	6,000	16.23	13.02	6.25	20.83	11.08	1.65	0.00	7.72	10.27	5.00
31	7,000	0.00	9.11	9.82	0.00	13.66	5.31	0.00	7.72	13.39	5.00
36	8,000	0.00	7.24	17.11	0.00	14.75	9.04	0.00	7.72	13.39	5.00
40	9,000	0.00	5.91	20.24	25.00	14.75	14.45	0.00	7.72	12.95	8.33
44	10,000	0.00	4.53	17.11	0.00	12.11	16.83	0.00	7.72	9.82	13.33
49	11,000	0.00	3.20	13.99	8.33	7.19	15.61	0.00	7.72	17.41	0.00
53	12,000	0.00	2.65	7.74	0.00	6.00	12.74	0.00	7.72	6.70	10.00
58	13,000	0.00	1.56	7.74	0.00	4.92	9.75	0.00	7.72	6.25	0.00
62	14,000	0.00	1.33	0.00	0.00	2.28	6.76	0.00	7.72	0.00	0.00
67	15,000	0.00	1.33	0.00	12.50	1.09	3.72	0.00	7.72	0.00	12.50
71	16,000	0.00	1.33	0.00	0.00	0.00	1.80	0.00	7.72	0.00	0.00
76	17,000	0.00	0.55	0.00	0.00	1.09	1.17	0.00	3.71	0.00	0.00
80	18,000	0.00	0.60	0.00	0.00	0.00	0.31	0.00	3.71	0.00	0.00
85	19,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	20,000	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	21,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	22,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	23,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	25,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	27,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	29,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
138	31,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
142	32,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
156	35,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
165	37,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.14 Normalized Single Axle Load Spectra for TTC 7

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
13	3,000	0.00	9.00	0.00	0.00	3.49	0.98	6.22	0.71	1.19	34.30
18	4,000	0.00	9.97	0.00	0.00	1.92	1.21	3.48	5.38	3.38	4.41
22	5,000	67.11	31.52	0.76	9.17	11.24	2.69	5.53	14.51	8.37	6.19
27	6,000	2.00	15.16	4.10	4.43	10.93	4.63	13.72	14.32	14.63	3.11
31	7,000	2.89	9.54	7.89	5.40	13.28	7.90	18.03	12.75	16.22	2.34
36	8,000	7.70	6.96	18.77	14.03	13.60	11.71	18.20	8.39	6.79	4.41
40	9,000	4.44	5.31	12.59	11.07	12.13	14.70	8.34	7.15	9.50	8.48
44	10,000	2.44	3.75	20.37	22.34	9.61	15.16	8.34	9.27	11.44	15.71
49	11,000	5.70	2.69	12.47	4.05	7.73	13.36	8.34	6.28	10.88	3.90
53	12,000	1.56	1.90	9.81	10.22	5.39	10.44	3.34	5.11	5.21	4.71
58	13,000	5.26	1.37	5.71	0.82	4.12	6.93	3.34	5.51	2.49	7.05
62	14,000	0.44	0.95	3.65	0.00	3.07	4.00	1.95	2.77	1.16	0.00
67	15,000	0.44	0.74	2.26	5.33	1.82	2.14	0.60	1.50	3.31	0.00
71	16,000	0.00	0.41	1.05	2.00	0.95	1.36	0.60	1.41	1.95	0.83
76	17,000	0.00	0.27	0.44	0.00	0.48	0.94	0.00	1.26	0.00	2.17
80	18,000	0.00	0.22	0.06	0.00	0.19	0.67	0.00	1.73	0.00	2.38
85	19,000	0.00	0.11	0.06	1.43	0.04	0.48	0.00	0.63	1.34	0.00
89	20,000	0.00	0.11	0.00	5.71	0.01	0.31	0.00	1.29	1.21	0.00
93	21,000	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00
98	22,000	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.03	0.00	0.00
102	23,000	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.75	0.00
107	24,000	0.00	0.00	0.00	4.00	0.00	0.02	0.00	0.00	0.00	0.00
111	25,000	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00
120	27,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	29,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
138	31,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
142	32,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
156	35,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
165	37,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.15 Normalized Single Axle Load Spectra for TTC 12

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
13	3,000	35.23	10.46	0.00	0.00	6.23	0.46	0.00	0.00	0.00	19.18
18	4,000	13.18	12.57	0.00	0.00	1.43	0.51	0.00	0.00	4.17	2.86
22	5,000	44.47	42.55	0.00	0.72	19.20	1.43	0.00	0.00	6.25	6.86
27	6,000	6.59	13.16	2.38	9.90	12.78	3.39	0.00	6.68	8.33	12.86
31	7,000	0.53	6.39	9.52	1.42	12.78	8.52	0.00	5.87	6.53	15.19
36	8,000	0.00	4.09	15.48	18.47	12.78	14.54	75.00	6.21	10.69	15.00
40	9,000	0.00	2.57	16.67	8.57	12.78	17.38	25.00	13.49	5.44	10.19
44	10,000	0.00	2.00	26.67	15.71	12.78	17.13	0.00	12.52	12.38	7.86
49	11,000	0.00	1.32	17.14	17.62	6.23	15.23	0.00	13.96	7.92	0.00
53	12,000	0.00	1.22	6.43	3.47	3.02	10.20	0.00	8.25	2.38	0.00
58	13,000	0.00	1.10	2.86	2.04	0.00	6.07	0.00	11.11	8.61	0.00
62	14,000	0.00	1.06	2.86	7.65	0.00	3.29	0.00	14.30	8.21	10.00
67	15,000	0.00	0.74	0.00	9.66	0.00	1.34	0.00	2.86	3.77	0.00
71	16,000	0.00	0.72	0.00	0.00	0.00	0.51	0.00	0.00	5.16	0.00
76	17,000	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00
80	18,000	0.00	0.00	0.00	4.76	0.00	0.00	0.00	2.38	0.00	0.00
85	19,000	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00
89	20,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00	0.00
93	21,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	22,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.78	0.00
102	23,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	25,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	27,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	29,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
138	31,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
142	32,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
156	35,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
165	37,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.16 Normalized Single Axle Load Spectra for TTC 15

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
13	3,000	8.33	27.65	0.00	6.25	35.37	0.00	0.00	23.99	0.32	8.40
18	4,000	4.17	20.28	0.00	0.00	10.29	0.00	0.00	7.35	1.04	10.49
22	5,000	0.00	24.32	3.46	0.00	30.78	3.33	9.72	9.27	13.86	4.58
27	6,000	0.00	11.91	5.42	8.93	12.59	16.67	0.00	9.48	15.32	7.71
31	7,000	12.50	5.28	4.88	8.63	6.04	26.67	52.08	7.87	2.50	6.25
36	8,000	16.67	3.41	55.19	14.88	3.91	23.33	11.81	11.11	2.01	10.83
40	9,000	8.33	2.39	3.83	4.17	0.34	23.33	0.00	6.43	0.32	8.33
44	10,000	3.13	1.41	4.14	1.43	0.34	6.67	4.17	3.83	17.11	0.00
49	11,000	3.13	1.57	3.30	4.17	0.34	0.00	5.56	1.79	3.15	4.86
53	12,000	3.13	0.57	3.61	7.98	0.00	0.00	0.00	6.67	13.47	5.21
58	13,000	3.13	0.50	10.75	3.81	0.00	0.00	0.00	1.30	0.97	0.00
62	14,000	10.42	0.25	1.76	3.81	0.00	0.00	0.00	1.16	1.04	0.00
67	15,000	3.13	0.25	1.38	1.43	0.00	0.00	0.00	1.81	1.04	0.00
71	16,000	15.63	0.06	0.73	0.00	0.00	0.00	0.00	1.16	0.71	4.17
76	17,000	0.00	0.06	0.31	0.00	0.00	0.00	0.00	1.16	0.00	16.67
80	18,000	4.17	0.06	0.31	14.88	0.00	0.00	0.00	1.11	0.00	0.00
85	19,000	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.51	0.00	0.00
89	20,000	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.65	12.82	0.00
93	21,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	22,000	0.00	0.00	0.31	0.00	0.00	0.00	0.00	1.43	14.29	0.00
102	23,000	0.00	0.00	0.00	9.82	0.00	0.00	0.00	0.51	0.00	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00
111	25,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00
120	27,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	6.25
129	29,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
138	31,000	4.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
142	32,000	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25
156	35,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
165	37,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.17 Normalized Tandem Axle Load Spectra for TTC 3

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
27	6,000	0.00	0.00	2.95	19.56	8.81	0.60	0.00	0.00	0.00	2.38
36	8,000	0.13	84.63	15.27	8.07	7.88	3.48	0.71	0.00	0.00	0.00
44	10,000	0.26	8.70	27.21	19.04	14.65	6.65	1.55	0.00	0.48	0.00
53	12,000	0.18	2.22	12.50	12.89	17.83	7.75	0.71	15.56	4.92	2.38
62	14,000	0.54	2.22	7.01	1.84	15.92	7.57	36.05	15.56	14.93	2.38
71	16,000	3.05	2.22	9.29	1.50	11.76	6.45	16.05	15.56	18.33	35.71
80	18,000	6.58	0.00	6.49	8.64	7.00	5.66	7.71	21.11	26.90	2.38
89	20,000	11.84	0.00	4.05	6.36	4.52	5.28	29.38	21.11	20.75	2.38
98	22,000	19.16	0.00	2.92	0.56	3.69	5.27	4.50	11.11	13.21	2.38
107	24,000	26.19	0.00	2.34	2.49	2.57	5.53	1.67	0.00	0.24	0.00
116	26,000	17.33	0.00	2.26	4.22	1.15	5.99	1.67	0.00	0.24	19.05
125	28,000	8.19	0.00	2.71	0.00	0.99	6.55	0.00	0.00	0.00	2.38
133	30,000	3.71	0.00	1.53	0.00	0.91	7.12	0.00	0.00	0.00	2.38
142	32,000	1.70	0.00	1.27	0.00	0.82	7.68	0.00	0.00	0.00	2.38
151	34,000	0.61	0.00	1.00	3.70	0.59	7.26	0.00	0.00	0.00	10.71
160	36,000	0.24	0.00	0.42	0.00	0.37	4.95	0.00	0.00	0.00	10.71
169	38,000	0.18	0.00	0.22	11.11	0.25	2.77	0.00	0.00	0.00	2.38
178	40,000	0.05	0.00	0.14	0.00	0.15	1.56	0.00	0.00	0.00	0.00
187	42,000	0.05	0.00	0.11	0.00	0.07	0.89	0.00	0.00	0.00	0.00
196	44,000	0.00	0.00	0.11	0.00	0.04	0.47	0.00	0.00	0.00	0.00
205	46,000	0.00	0.00	0.09	0.00	0.02	0.26	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.04	0.00	0.01	0.13	0.00	0.00	0.00	0.00
222	50,000	0.00	0.00	0.04	0.00	0.00	0.06	0.00	0.00	0.00	0.00
231	52,000	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
249	56,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
258	58,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
276	62,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
285	64,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	68,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
311	70,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
329	74,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
338	76,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
356	80,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.18 Normalized Tandem Axle Load Spectra for TTC 6

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
27	6,000	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.00	0.00	0.00
36	8,000	0.00	100.00	33.33	50.00	0.00	5.90	0.00	0.00	0.00	0.00
44	10,000	0.00	0.00	33.33	50.00	0.00	9.40	0.00	0.00	33.33	0.00
53	12,000	0.00	0.00	33.33	0.00	0.00	9.86	0.00	0.00	0.00	0.00
62	14,000	0.00	0.00	0.00	0.00	0.00	8.83	0.00	0.00	50.00	16.67
71	16,000	0.00	0.00	0.00	0.00	0.00	6.74	100.00	0.00	0.00	0.00
80	18,000	0.00	0.00	0.00	0.00	0.00	4.28	0.00	0.00	0.00	0.00
89	20,000	0.00	0.00	0.00	0.00	0.00	3.57	0.00	0.00	0.00	16.67
98	22,000	0.00	0.00	0.00	0.00	0.00	2.85	0.00	0.00	16.67	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	2.78	0.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	0.00	0.00	2.78	0.00	0.00	0.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	3.81	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	4.55	0.00	0.00	0.00	50.00
142	32,000	0.00	0.00	0.00	0.00	0.00	4.55	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	4.62	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	4.30	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	3.95	0.00	0.00	0.00	16.67
178	40,000	0.00	0.00	0.00	0.00	0.00	4.01	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	0.00	2.92	0.00	0.00	0.00	0.00
196	44,000	0.00	0.00	0.00	0.00	0.00	2.58	0.00	0.00	0.00	0.00
205	46,000	0.00	0.00	0.00	0.00	0.00	2.22	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00
222	50,000	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00
231	52,000	0.00	0.00	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00
249	56,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
258	58,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
276	62,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
285	64,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	68,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
311	70,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
329	74,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
338	76,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
356	80,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.19 Normalized Tandem Axle Load Spectra for TTC 7

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
27	6,000	0.00	0.00	1.17	0.00	55.15	2.68	0.00	0.00	0.00	0.00
36	8,000	0.00	75.00	17.54	11.11	9.74	6.09	1.79	12.50	0.00	0.00
44	10,000	0.00	25.00	26.25	11.11	12.07	8.62	3.87	16.67	25.00	5.00
53	12,000	0.00	0.00	12.50	0.00	11.39	9.09	1.79	0.00	29.17	6.25
62	14,000	0.00	0.00	9.17	0.00	6.62	8.03	8.04	12.50	12.50	0.00
71	16,000	0.00	0.00	4.56	16.67	3.18	6.45	58.04	0.00	12.50	5.00
80	18,000	0.00	0.00	3.35	33.33	1.50	5.08	8.04	0.00	12.50	12.50
89	20,000	100.00	0.00	6.17	0.00	0.35	4.38	3.87	0.00	0.00	5.00
98	22,000	0.00	0.00	5.49	0.00	0.00	4.38	6.25	0.00	0.00	2.50
107	24,000	0.00	0.00	4.54	11.11	0.00	4.78	4.17	0.00	0.00	11.25
116	26,000	0.00	0.00	3.35	0.00	0.00	5.08	4.17	0.00	0.00	25.00
125	28,000	0.00	0.00	3.35	0.00	0.00	5.15	0.00	0.00	8.33	0.00
133	30,000	0.00	0.00	1.28	0.00	0.00	5.13	0.00	12.50	0.00	12.50
142	32,000	0.00	0.00	1.28	0.00	0.00	4.74	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	4.38	0.00	33.33	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	3.75	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	16.67	0.00	3.25	0.00	12.50	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	2.55	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
196	44,000	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.00	0.00	0.00
205	46,000	0.00	0.00	0.00	0.00	0.00	1.04	0.00	0.00	0.00	6.25
214	48,000	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00
222	50,000	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00
231	52,000	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	2.50
249	56,000	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
258	58,000	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	6.25
267	60,000	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
276	62,000	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
285	64,000	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	68,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
311	70,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
329	74,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
338	76,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
356	80,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.20 Normalized Tandem Axle Load Spectra for TTC 12

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
27	6,000	0.00	0.00	0.00	0.00	0.00	2.38	0.00	0.00	0.00	26.67
36	8,000	0.00	66.67	50.00	0.00	0.00	7.92	0.00	0.00	0.00	0.00
44	10,000	0.00	33.33	50.00	0.00	0.00	10.03	0.00	0.00	0.00	0.00
53	12,000	0.00	0.00	0.00	0.00	0.00	11.99	0.00	0.00	0.00	20.00
62	14,000	0.00	0.00	0.00	0.00	0.00	10.07	0.00	33.33	0.00	40.00
71	16,000	0.00	0.00	0.00	0.00	0.00	7.22	0.00	0.00	50.00	0.00
80	18,000	0.00	0.00	0.00	0.00	0.00	4.81	0.00	33.33	0.00	0.00
89	20,000	0.00	0.00	0.00	100.00	0.00	3.77	0.00	0.00	25.00	0.00
98	22,000	0.00	0.00	0.00	0.00	0.00	2.85	0.00	0.00	0.00	6.67
107	24,000	0.00	0.00	0.00	0.00	0.00	2.76	100.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	25.00	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	6.67
142	32,000	0.00	0.00	0.00	0.00	0.00	4.04	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	4.04	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	3.45	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	3.91	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	2.83	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	0.00	1.64	0.00	16.67	0.00	0.00
196	44,000	0.00	0.00	0.00	0.00	0.00	1.64	0.00	16.67	0.00	0.00
205	46,000	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.00	0.00	0.00
222	50,000	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00
231	52,000	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
249	56,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
258	58,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
276	62,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
285	64,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	68,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
311	70,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
329	74,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
338	76,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
356	80,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.21 Normalized Tandem Axle Load Spectra for TTC 15

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
27	6,000	0.00	0.00	0.00	0.00	100.00	2.26	0.00	0.00	0.00	13.33
36	8,000	0.00	45.83	50.00	0.00	0.00	6.58	50.00	0.00	0.00	0.00
44	10,000	0.00	54.17	50.00	0.00	0.00	8.86	0.00	0.00	0.00	0.00
53	12,000	0.00	0.00	0.00	0.00	0.00	10.58	0.00	0.00	8.33	22.50
62	14,000	0.00	0.00	0.00	0.00	0.00	9.15	0.00	33.33	0.00	20.00
71	16,000	0.00	0.00	0.00	0.00	0.00	7.25	0.00	0.00	50.00	0.00
80	18,000	0.00	0.00	0.00	0.00	0.00	5.19	0.00	33.33	0.00	12.50
89	20,000	0.00	0.00	0.00	100.00	0.00	3.95	0.00	0.00	12.50	0.00
98	22,000	0.00	0.00	0.00	0.00	0.00	3.35	0.00	0.00	0.00	3.33
107	24,000	0.00	0.00	0.00	0.00	0.00	3.30	50.00	0.00	0.00	0.00
116	26,000	0.00	0.00	0.00	0.00	0.00	3.82	0.00	0.00	12.50	0.00
125	28,000	0.00	0.00	0.00	0.00	0.00	3.71	0.00	0.00	16.67	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	3.82	0.00	0.00	0.00	28.33
142	32,000	0.00	0.00	0.00	0.00	0.00	3.95	0.00	0.00	0.00	0.00
151	34,000	0.00	0.00	0.00	0.00	0.00	4.08	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	3.67	0.00	0.00	0.00	0.00
169	38,000	0.00	0.00	0.00	0.00	0.00	3.90	0.00	0.00	0.00	0.00
178	40,000	0.00	0.00	0.00	0.00	0.00	3.12	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	0.00	2.52	0.00	16.67	0.00	0.00
196	44,000	0.00	0.00	0.00	0.00	0.00	2.40	0.00	16.67	0.00	0.00
205	46,000	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00
222	50,000	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00
231	52,000	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
249	56,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
258	58,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
276	62,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
285	64,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
302	68,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
311	70,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
329	74,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
338	76,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
356	80,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.22 Normalized Tridem Axle Load Spectra for TTC 3

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
53	12,000	0.00	0.00	0.00	25.83	56.48	87.50	61.67	44.44	27.50	33.33
67	15,000	0.00	0.00	0.00	19.38	2.78	0.00	28.33	0.00	6.25	11.11
80	18,000	0.00	0.00	0.00	6.25	0.00	0.00	10.00	11.11	18.13	0.00
93	21,000	0.00	0.00	0.00	9.38	0.00	0.00	0.00	11.11	15.63	0.00
107	24,000	0.00	0.00	0.00	0.00	5.56	0.00	0.00	0.00	15.00	0.00
120	27,000	0.00	0.00	0.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	5.63	5.56	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	5.00	3.70	0.00	0.00	16.67	6.25	16.67
173	39,000	0.00	0.00	0.00	2.50	5.56	0.00	0.00	0.00	2.50	16.67
187	42,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200	45,000	0.00	0.00	0.00	3.75	3.70	0.00	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	0.00	5.56	12.50	0.00	0.00	0.00	0.00
227	51,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00
254	57,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25	0.00
267	60,000	0.00	0.00	0.00	3.13	0.00	0.00	0.00	0.00	0.00	11.11
280	63,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.11
294	66,000	0.00	0.00	0.00	2.50	0.00	0.00	0.00	0.00	2.50	0.00
307	69,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00
334	75,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	81,000	0.00	0.00	0.00	0.00	11.11	0.00	0.00	0.00	0.00	0.00
374	84,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
387	87,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	90,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
414	93,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
427	96,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
440	99,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
454	102,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.23 Normalized Tridem Axle Load Spectra for TTC 6

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
53	12,000	0.00	0.00	0.00	33.33	50.00	0.00	0.00	0.00	0.00	0.00
67	15,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	18,000	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	50.00	33.33
93	21,000	0.00	0.00	0.00	0.00	0.00	66.67	0.00	0.00	0.00	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00
120	27,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200	45,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33
214	48,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
227	51,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
254	57,000	0.00	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33
280	63,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
307	69,000	0.00	0.00	0.00	0.00	0.00	33.33	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
334	75,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	81,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
374	84,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
387	87,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	90,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
414	93,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
427	96,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
440	99,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
454	102,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.24 Normalized Tridem Axle Load Spectra for TTC 7

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
53	12,000	0.00	0.00	0.00	25.00	66.67	33.33	66.67	0.00	58.33	25.00
67	15,000	0.00	0.00	0.00	0.00	0.00	16.67	33.33	0.00	0.00	0.00
80	18,000	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	16.67	20.83
93	21,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	25.00	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	27,000	0.00	0.00	0.00	3.13	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	8.33
147	33,000	0.00	0.00	0.00	0.00	33.33	0.00	0.00	12.50	0.00	0.00
160	36,000	0.00	0.00	0.00	9.38	0.00	0.00	0.00	0.00	0.00	8.33
173	39,000	0.00	0.00	0.00	18.75	0.00	0.00	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00
200	45,000	0.00	0.00	0.00	10.42	0.00	33.33	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	6.25	0.00	0.00	0.00	12.50	0.00	12.50
227	51,000	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00
254	57,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	12.50
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
280	63,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
307	69,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
334	75,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.50
360	81,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
374	84,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
387	87,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	90,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
414	93,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
427	96,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
440	99,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
454	102,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.25 Normalized Tridem Axle Load Spectra for TTC 12

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
53	12,000	0.00	0.00	0.00	0.00	16.67	100.00	100.00	0.00	0.00	28.57
67	15,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	18,000	0.00	0.00	0.00	50.00	16.67	0.00	0.00	0.00	0.00	0.00
93	21,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.29
120	27,000	0.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	14.29
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	16.67	0.00	0.00	100.00	100.00	0.00
160	36,000	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00
173	39,000	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	5.89	0.00	0.00	0.00	0.00	0.00
200	45,000	0.00	0.00	0.00	0.00	12.55	0.00	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	0.00	7.18	0.00	0.00	0.00	0.00	14.29
227	51,000	0.00	0.00	0.00	0.00	19.22	0.00	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	14.29
254	57,000	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
280	63,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
307	69,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
334	75,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	81,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
374	84,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
387	87,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	90,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
414	93,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
427	96,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
440	99,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
454	102,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.26 Normalized Tridem Axle Load Spectra for TTC 15

Axle Load		Vehicle / Truck Class									
kN	lbs.	4	5	6	7	8	9	10	11	12	13
53	12,000	0.00	0.00	0.00	100.00	100.00	0.00	0.00	0.00	0.00	50.00
67	15,000	0.00	0.00	0.00	0.00	0.00	0.00	66.67	0.00	0.00	0.00
80	18,000	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.00	0.00	0.00
93	21,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
107	24,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	27,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133	30,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
147	33,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	36,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00
173	39,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
187	42,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200	45,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
214	48,000	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
227	51,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
240	54,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
254	57,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
267	60,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
280	63,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
294	66,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
307	69,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320	72,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00
334	75,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
347	78,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	81,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
374	84,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
387	87,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	90,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
414	93,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
427	96,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
440	99,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
454	102,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For example illustration purposes, several graphs will be presented for single, tandem, and tridem axles for primary vehicles in the traffic stream. Figure 3.45 shows VC 5 single axle load spectra for each TTC group, along with single axle default load spectra for VC 5. This default spectra is not unique to one TTC group, but an overall average from the LTPP database. Load spectra for TTC groups are similar with the major exception of TTC 15 (low volume, two-lane highways). Axle load distribution is slightly better distributed for TTC 3 facilities than for other TTC groups. For all TTC group and default spectra, single axle load exhibited a peak around 27 kN (6,000 lbs), with the TTC 15 group also having another slightly higher peak at 18 kN (4,000 lbs). Default spectra showed less of a peak value and appeared to follow TTC 3 spectra at higher single axle loads.

Figure 3.46 illustrates VC 9 single axle load spectra. Much like VC 5 distribution, there appears to be general agreement between TTC groups, with the exception of TTC 15, which had a substantially lower peak axle load. Peak axle load for TTC 3 was 53 kN (12,000 lbs), which agrees with commonly accepted axle weights for loaded VC 9 trucks. Peak axle load for TTC 6, 7, and 12 groups was 44.5 kN (10,000 lbs), slightly lower than that for TTC 3. Default spectra closely followed TTC 3 spectra with the default spectra distribution peaking at a slightly lower load.

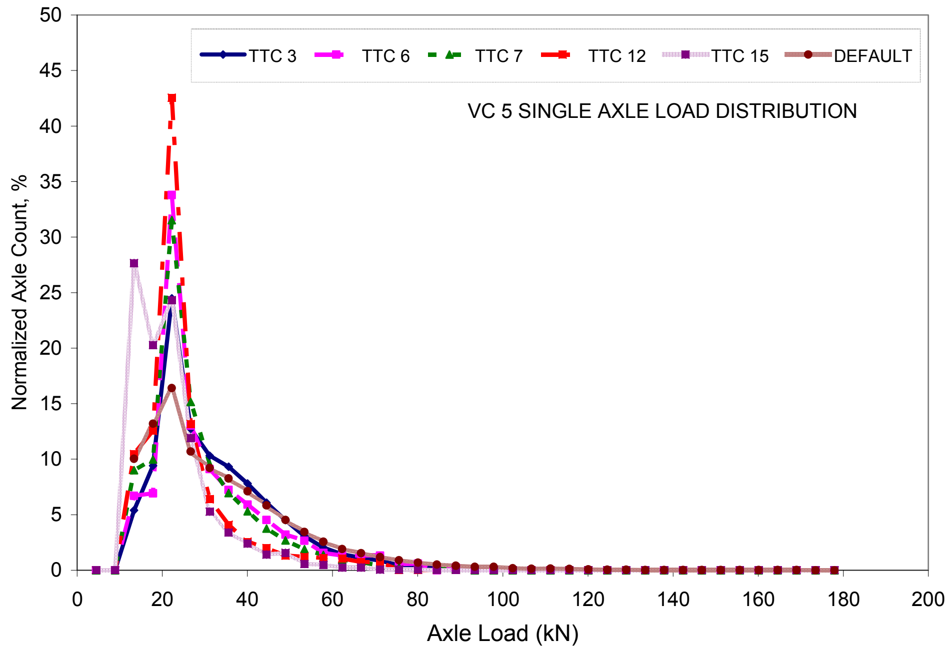

Figure 3.45 VC 5 Single Axle Load Spectra for TTC Groups

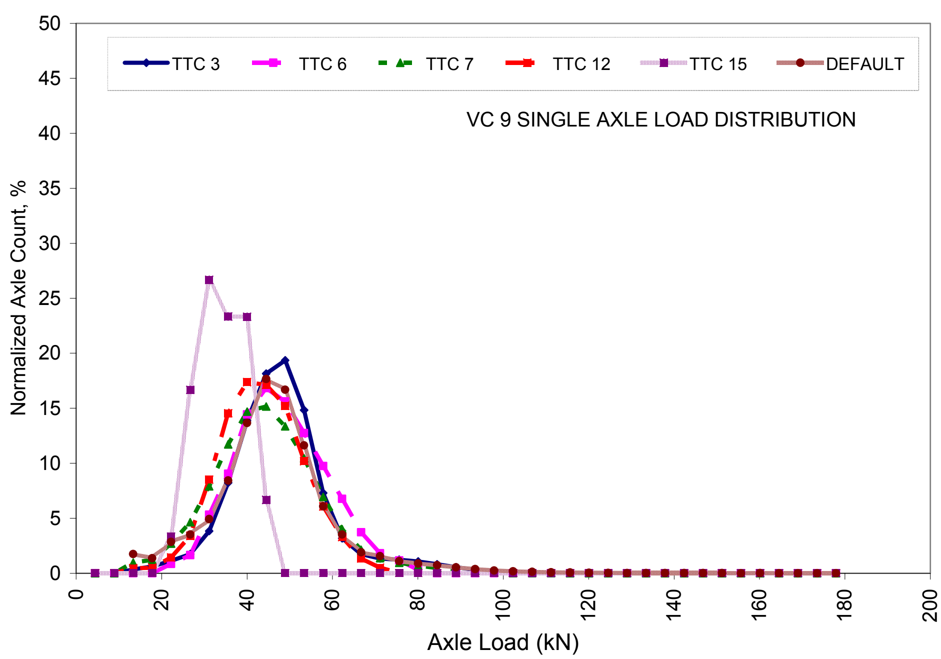

Figure 3.46 VC 9 Single Axle Load Spectra for TTC Groups

Tandem axle load spectra for VC 6 are illustrated in Figure 3.47. The highest concentration of axle load for the TTC groups averages approximately 44.5 kN (10,000 lbs), with the TTC 3 group having the widest range of axle loads. TTC 7 had about 50 percent of tandem axles recorded at weights from 35.5 to 44.5 kN (8,000 to 10,000 lbs). Default spectra were again closest to TTC 3 spectra, but exhibited a broader distribution with a less prominent peak value and increased axle loads.

Figure 3.48 shows VC 9 tandem axle load spectra. It is evident that a bi-modal distribution exists for each TTC group with peaks at 53 kN (12,000 lbs), (unloaded truck) and near 142 kN (32,000 lbs), (loaded truck). The two peaks for the TTC 3 group are approximately equal, which would indicate fewer unloaded trucks trafficking those facilities. Default spectra also showed a bi-modal distribution and agreed well with the TTC groups, especially with the TTC 3.

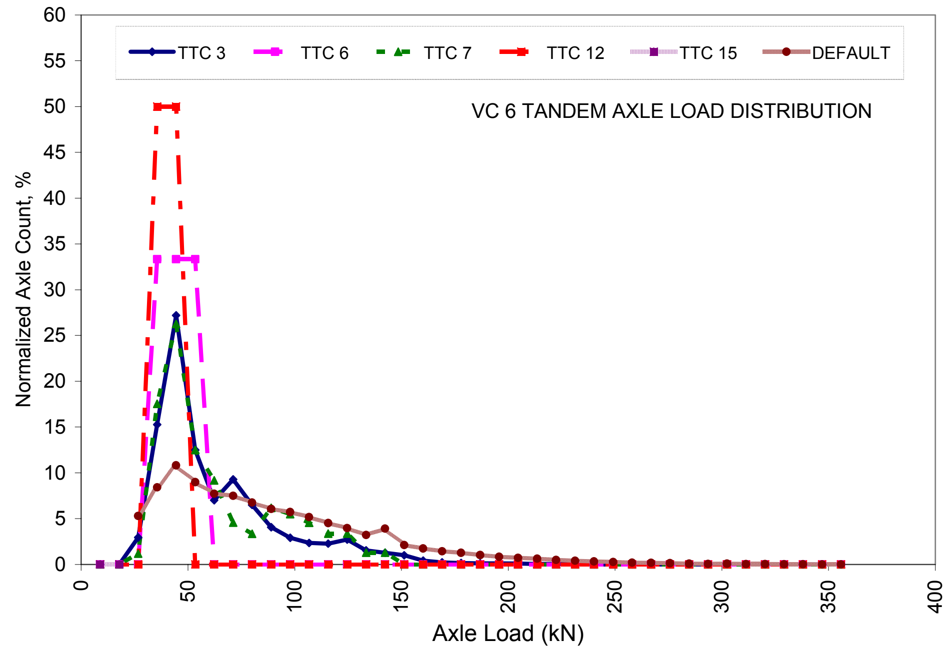

Figure 3.47 VC 6 Tandem Axle Load Spectra for TTC Groups

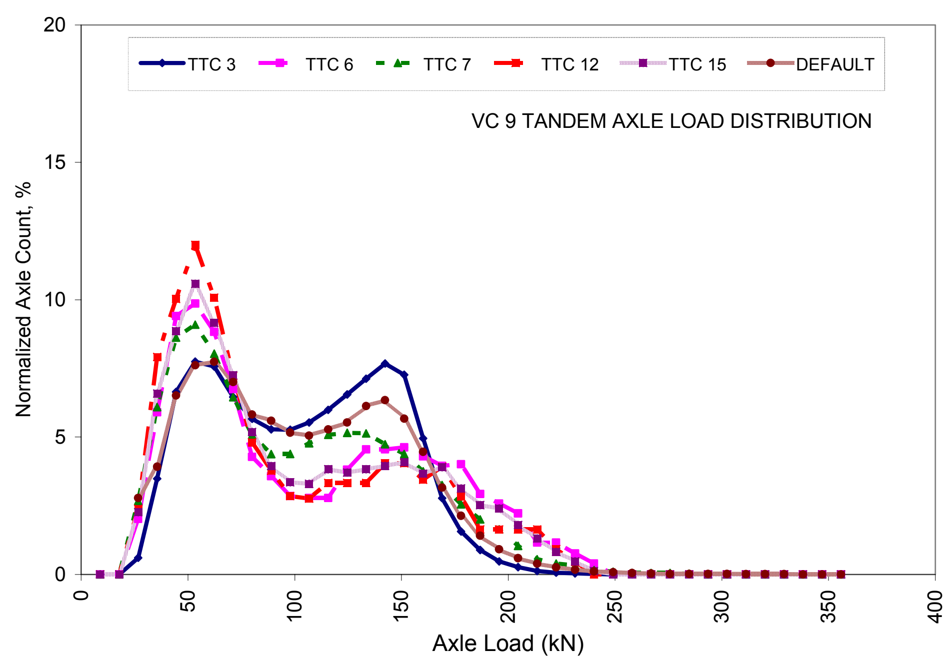

Figure 3.48 VC 9 Tandem Axle Load Spectra for TTC Groups

Tridem axle load spectra for VC 7 is illustrated in Figure 3.49 and is highly variable, most likely due to the small number of tridem axles recorded. For the TTC 3 group, it appears the peak tridem load is around 50 kN (11,000 lbs), with the highest recorded tridem axle loads being approximately 300 kN (67,500 lbs). For the TTC 7 group, there appear two primary peaks at 50 and 175 kN (11,000 and 39,500 lbs).

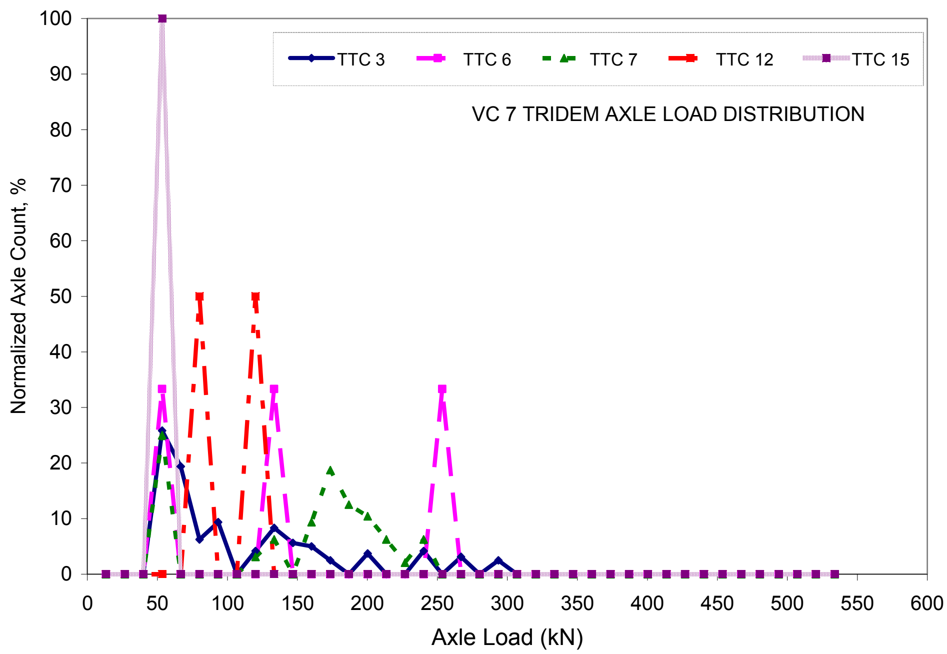

Figure 3.49 VC 7 Tridem Axle Load Distribution

3.4 GENERAL TRAFFIC INPUTS

The new design guide requires several general traffic inputs to characterize truck traffic. Among these are axles per vehicle, tire pressure, axle and tire spacing, and traffic wander. Each of these items will be discussed below and values presented for use in the new design guide.

3.4.1 Axles Per Vehicle

It is important to accurately know the number of axles per each vehicle class. Extensive national level research, consisting of a review of over 700,000 individual truck records, was conducted to develop default axles (single, tandem, tridem and quadem) per vehicle class as shown in Table 3.27 (4). These national level defaults are based on much more extensive data than that available for the Mississippi sites and therefore should be more appropriate. The number of quad axles is given as 0.00 due to very limited quad axles recorded in the LTPP database.

In reviewing the default axle per vehicle class data in Table 3.27 it is obvious that some of the data are slightly different that the expected. For example, with VC 6 (a single-unit truck with a single steering axle and a tandem rear drive axle) there should be exactly 1.0 single axle and 1.0 tandem axle. However, the data indicates an average of 1.02 single axles and 0.99 tandem axles. These errors are slight and are simply a result of vehicle classification errors.

Table 3.27 Default Axle Per Vehicle Class (3)

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

3.4.2 Mean Wheel Location

Mean wheel location refers to the distance from the outside vehicle wheel to the lane marking material. This is important because loads closer to the pavement edge may result in more pavement damage. Mean wheel location is likely to vary with lane width (i.e., wider lane = larger mean wheel location and vice-versa). A default value of 45.7 cm (18 in) can be used as a default value if no other data is available (3).

3.4.3 Traffic Wander

Traffic wander is basically a statistical parameter (i.e., standard deviation) describing the wheel distribution across the wheel path. For a roadway, concrete or asphalt, pure channelized traffic (i.e., no traffic wander) is the worst case for design since all load applications occur over the same location. However, traffic wander exists to varying degrees on every pavement location. Traffic wander of 25.4 cm (10 in) should be assumed unless other data is available (3).

3.4.4 Design Lane Width

Design lane width is the distance between the lane markings of the design traffic lane. It is not the actual paving or slab width, since traffic markings define the travel lane. The value is important since it influences traffic wander and mean wheel location. A value of 3.7 m (12 ft) should be assumed unless otherwise known. Obviously, for lower volume facilities, design lane width may be lower and should be input accordingly (3).

3.4.5 Tire Pressure

Applied vehicle tire contact pressure is important in pavement layered elastic analysis. It is commonly assumed that tire pressure is equal to applied contact pressure. Through the years, tire pressures have continued to increase. For the new design guide a hot tire inflation pressure should be assumed to be 827 kPa (120 psi) and 758 kPa (110 psi) for single and dual tires, respectively (3).

3.4.6 Axle Configuration

Axle configuration is also required for use in pavement layered elastic analysis. Parameters used to define axle configuration are average axle width, dual tire spacing, and axle spacing. Average axle width is the distance between outside edges of an axle and is assumed to be 2.6 m (8.5 ft) for typical trucks (3). Wider dual tire spacing will result in less damage to the pavement due to the loading being spread over a larger area (5). Dual tire spacing is the center to center distance between dual tires and is assumed to be 30.5 cm (12.0 in) in the new guide. This is somewhat conservative since other agencies typically use 34.3 cm (13.5 in) (5). Axle spacing is the distance between consecutive tandem, tridem, or quadem axles and is assumed to be 131.1 cm (51.6 in) for tandem and 125.0 cm (49.2 in) for both tridem and quadem axles (3).

3.4.7 Wheelbase

Wheelbase is the distance between the steering axle and the first drive axle and is defined by two parameters: average axle spacing and percent trucks with given axle spacing. Average axle spacing is described as short, medium, and large with recommended input values of 3.7, 4.6, and 5.5 m (12, 15, and 18 ft), respectively. Percent trucks with short, medium, and large average axle spacing is also important. Without knowledge of the vehicle class distribution, it is recommended to use a uniform distribution of 33, 33, and 34 percent trucks for short, medium, and large axle spacing (3).

CHAPTER 4 TRAFFIC DATA DEVELOPMENT OVERVIEW

The purpose of this chapter is to present general approaches or framework for development of the required traffic data for input into the new design guide. Complete documentation on the background and traffic parameter input development is found in "Part 2 – Design Inputs, Chapter 4 Traffic" of the new design guide software user's guide (*3*).

For a given project, all available traffic data (volume, classification, and axle weight) should be obtained. In addition, historical traffic growth rates should be determined. Development of necessary traffic data will be dictated by the required design level. As mentioned previously, the amount and accuracy of traffic data will be more for level 1 designs compared to level 2 and 3 designs. For a level 1 design, an accurate measure of the previously discussed traffic data must be obtained. Crucial to this design level is an accurate measure of axle load spectra and truck distribution. In the new design guide, for design levels 2 and 3, the use WIM and AVC data from related roadways can be utilized to develop inputs. Additionally, use of a truck traffic classification (TTC) group can be utilized for level 2 and 3 designs.

4.1 TRAFFIC PARAMETERS FOR VARIOUS DESIGN LEVELS

The various traffic data hierarchical requirements for each design level were presented previously in Table 2.2. In conducting the pavement design, the first item which must be addressed is the design level. Will the design require a high level of accuracy and reliability (i.e., level 1) or can reasonable traffic assumptions and estimations be used (i.e., level 2 or 3)?

If a level 1 design is to be conducted, the necessary parameters can be obtained from Table 2.2. Among these parameters is an accurate determination of axle load spectra, vehicle classification, and traffic volume data for the site. Axle load data should be obtained for each truck class and axle type. Additional truck traffic and tire factors are also required, but are common to all design levels, not just level 1. These factors were previously discussed in Chapter 3 and are described in detail in the design guide software documentation (*3*).

For a level 2 design, similar data is required, but not to the extent as that for level 1. The primary difference is the lack of site specific axle load and vehicle classification data. In this case, "regional" WIM and AVC data can be used. This means that data from a similar (i.e., same TTC group) highway in terms of axle load data can be used in lieu of site specific data. However, accurate vehicle classification must be obtained for the site. Truck traffic and tire factors are still required, as with level 1.

For a level 3 design, traffic data accuracy is the lowest. In this case, traffic volume is likely to be the only traffic data available. With only traffic volume known, an estimate of the percent trucks is required. No site specific axle load or vehicle classification data is available; therefore, an estimate of the axle load and vehicle classification data is made from similar roadways (i.e., same TTC group). Again, truck traffic and tire factors are required.

Items that require extensive traffic analysis are development of TTC groups, truck distribution (hourly and monthly), and axle load spectra. The general process of developing each parameter is discussed again in the following section. However, it is again recommended that the new design guide documentation (*3*) be reviewed for further, more detailed information.

4.2 TRUCK TRAFFIC CLASSIFICATION (TTC) GROUPING

As mentioned earlier in Chapter 3, the TTC group system is a function of the normalized vehicle class distribution for FHWA vehicle classes 4 through 13. Assigning a given roadway to a TTC group consists of first, determining the vehicle classification distribution for a given time period (e.g., day, week, month, or year) for the roadway in terms of the 13 FHWA classifications. This can be obtained from either AVC or WIM sites. Since TTC group development is based only on vehicle classes 4 to 13, classes 1 through 3 are not considered. Second, a normalized truck distribution is determined by dividing the total trucks in each vehicle class by the total trucks on the roadway (i.e., truck classes 4 through 13). The protocol for assigning roadways to TTC groups was previously illustrated in Chapter 3.

4.3 AXLE LOAD SPECTRA DEVELOPMENT

The process of developing axle load spectra for a given roadway requires WIM data consisting of axle distribution and axle weight data. If WIM data are available, the process described in Chapter 3 can be used for developing very accurate axle load spectra. However, if a roadway without WIM data is similar to roadways with accurate WIM data, an estimation of the axle load spectra can still be obtained.

4.3.1 Axle Load Spectra Development for Sites with Weigh-in-Motion Data

Axle load spectra can be developed with a high degree of accuracy for sites with WIM data. For each vehicle class, WIM data are obtained, checked for correctness, and analyzed to determine the number of single, tandem, tridem, and quadem axles.

WIM data is in the form of traffic cards formatted in accordance with the FHWA Traffic Monitoring Guide. WIM data from these cards can be imported into a spreadsheet computer program (e.g., Excel™) for analysis. Weights of each axle type are analyzed and sorted into weight classes of varying size as described in Chapter 3.

Furthermore, axle load spectra can be analyzed to determine possible monthly variations within the year. This process consists of developing average axle spectra for each axle type of each vehicle class for the year and then determining the change in axle spectra occurring during a given month. For example, during agricultural harvest seasons, axle weight spectra for trucks in the area may be significantly different than for the remainder of the year.

4.2.1 Axle Load Spectra Development Without WIM Data

For level 2 and 3 designs, similar data is required, but not to the extent as that for level 1. The primary difference is the lack of site specific axle load and vehicle classification data. For sites without WIM data, the axle load spectra can be estimated, but with obvious reduced accuracy. In this case, "regional" WIM and AVC data can be used. This means axle load data from a similar (i.e., same TTC group) highway, preferably in the same geographical location can be used as an estimate of the axle load spectra for the actual site. For example, if a rural interstate highway site has no WIM data, axle load spectra data for a similar rural interstate highway in the same TTC group (based on vehicle class distribution) can be used as an "estimate".

If a given roadway has only traffic volume data, axle load spectra can also be estimated, but again with reduced accuracy. For a site in this case, there is no classification data available for TTC group development. This necessitates the estimation of an appropriate vehicle class distribution based on similar roadways. With the vehicle class distribution established, a TTC group can be established and axle load spectra can then be estimated in a similar manner as discussed above.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The following conclusions are presented based on analyses of Mississippi LTPP traffic data.

- For interstates and four-lane highways the primary truck class is VC 9: single trailer trucks, which comprise approximately 70 percent of truck traffic.
- For low volume "three-digit" routes, the primary truck class is VC 5: single-unit trucks.
- Overall, multiple-trailer trucks (VC 11 through 13) represented a very small percentage of the truck traffic.
- Roadways within the same functional classification exhibited considerable variability in truck distribution.
- Truck traffic classification (TTC) grouping appeared to better define roadway groups than functional classification.
- Monthly truck class distribution variability was very low for TTC 3 followed by TTC 7. Variability was higher for other TTC groups. However, variability was based on very limited site data.
- Interstates and four-lane highways, comprised in TTC groups 3 and 7, exhibited less truck volume variability throughout the year than did the other highways evaluated. This is likely attributable to interstates and four-lane facilities being "thru" truck facilities.
- Low volume, two-lane facilities (MS 310 and 315), TTC 15, exhibited the most variability in truck volume throughout the year.
- Hourly truck volume distributions clearly indicated increased use of interstate and four-lane highways (TTC 3 and 7) during late evening and early morning hours. For other TTC groups, the truck volume distribution was primarily concentrated during day time hours.

- Developed hourly distribution factors for TTC 3 agreed closely with default factors (i.e., nationally recommended default values), but hourly distribution factors for other TTC groups deviated substantially.
- Axle load spectra were developed for each vehicle class within each TTC group and appeared reasonable.
- Default single and tandem axle load spectra appeared to more closely resemble that obtained for TTC 3 (interstates and four-lane highways) than for other TTC groups.
- Tridem axle load spectra are highly variable due to limited number of recorded axles.
- Insufficient data was available for quad axle load spectra development.

5.2 RECOMMENDATIONS

The following recommendations are made regarding traffic inputs for the new design guide.

- Utilize truck traffic classification (TTC) groups, based on truck distribution, to sort Mississippi highways, rather that functional classification.
- Developed axle load spectra for TTC 3 and 7 groups, the high traffic volume facilities, can be used directly in the new design guide.
- Developed hourly truck distribution factors for all TTC groups should be utilized in the new design guide.
- Due to a limited number of LTPP sites, traffic information for other TTC groups, comprising lower volume highways, should be further evaluated to insure more accurate inputs (vehicle distribution, load spectra, etc.). However, the probability of these sites being Level 1 designs in the new design guide is low. Therefore, default values may be sufficient.
- Default monthly truck volume distribution factors of 1.0 should be used for each truck class until more accurate determinations can be made.

- Default values for general traffic inputs such as axle per vehicle, mean wheel location, traffic wander, design lane width, tire pressure, axle configuration, and wheelbase should be used unless specific information is obtained.
- An analysis of the new design guide and software should be conducted to determine the sensitivity of pavement performance with respect to changes in the various traffic inputs. This will provide MDOT with valuable information as to the most crucial traffic inputs, which will yield the most efficient use of the new design guide.
- Use of automated software that processes, checks, analyzes and prepares traffic data in the format required for input into the design guide would greatly reduce time and result in more accurate and efficient use of the guide. Manual processing of the large volume of traffic data can be accomplished, but will be labor intensive and subject to increased mistakes.

CHAPTER 6 REFERENCES

1. Traffic Characterization for the NCHRP 1-37A 2002 Design Guide, http://www.2002designguide.com/traffic.htm, Accessed June 29, 2004.

2. Hallenbeck, Mark and Weinblatt, Herbert, “Equipment for Collecting Traffic Data.” National Cooperative Highway Research Program (NCHRP) Report 509, Transportation Research Board, Washington, D.C., 2004.

3. 2002 Design Guide Software, Version (0.701), NCHRP Sponsor and On-line Version, Developed by ERES Division Applied Research Associates and Arizona State University, July 1, 2004

4. Tam, Weng On, and Von Quintus, Harold, “Use of Long Term Pavement Performance Data to Develop Traffic Defaults in Support of Mechanistic-Empirical Pavement Design Procedures.” Paper Prepared for Presentation and Presentation at the 2003 Transportation Research Record Annual Meeting, TRB, National Research Council, Washington D.C.

5. Timm, David, Birgisson, Bjorn, and Newcomb, David., “Development of Mechanistic-Empirical Pavement Design in Minnesota.” Transportation Research Record 1629, TRB, National Research Council, Washington D.C., (1998), pp. 181–188.

APPENDIX A

NEW DESIGN GUIDE
TRAFFIC INPUT DOCUMENTATION

"Part 2 – Design Inputs, Chapter 4 Traffic"

Note: Appendix Material Taken from the 2002 Design Guide Software, Version (0.701), NCHRP Sponsor and On-line Version, Developed by ERES Division Applied Research Associates and Arizona State University, July 1, 2004

PART 2—DESIGN INPUTS

CHAPTER 4
TRAFFIC

2.4.1 INTRODUCTION

Traffic data is one of the key data elements required for the structural design/analysis of pavement structures. It is required for estimating the loads that are applied to a pavement and the frequency with which those given loads are applied throughout the pavement's design life. For the Design Guide procedure, the traffic data required are the same regardless of pavement type (flexible or rigid) or design type (new or rehabilitated). The following lists typical traffic data required for design:

- Base year truck-traffic volume (the year used as the basis for design computations).
- Vehicle (truck) operational speed.
- Truck-traffic directional and lane distribution factors.
- Vehicle (truck) class distribution.
- Axle load distribution factors.
- Axle and wheel base configurations.
- Tire characteristics and inflation pressure.
- Truck lateral distribution factor.
- Truck growth factors.

Agencies typically collect three types of traffic data—weigh-in-motion (WIM), automatic vehicle classification (AVC), and vehicle counts. These data can be augmented by traffic estimates computed using traffic forecasting and trip generation models. WIM data are typically reported in a format similar to the FHWA W-4 Truck Weight Tables (i.e., data is presented as tabulations of the number of axles observed within a series of load groups, with each load group covering a specified load interval [1,000-, 2,000-, and 3,000-lb]). AVC data are reported as the number of vehicles by vehicle type counted over a period of time, while vehicle counts are reported as the number of vehicles counted over a period of time.

This chapter describes the traffic data (truck volumes and loadings characterized terms of the volume of heavy trucks applied over the pavements design life and axle load spectra for single, tandem, tridem, and quad axles) required for new and rehabilitated pavement design using the Design Guide. It also provides pavement designers with default traffic input data that may be used in traffic characterization when sufficient site-specific or regional/statewide traffic data are unavailable.

The equivalent single axle load (ESAL) approach used for traffic characterization in previous versions of the AASHTO Guide for Pavement Design is not needed for analysis presented in this Guide. The Design Guide software outputs on a monthly basis the cumulated number of heavy trucks in the design lane as an overall indicator of the magnitude of truck traffic loadings (FHWA class 4 and above) (*1*). The cumulated number of heavy trucks in the design lane can be considered as a general indicator of the level of truck traffic. For example, a pavement can be described as carrying 1 million heavy trucks or 100 million trucks over its design life.

More detailed guidance on determining the traffic inputs for pavement structural design is given in Appendix AA.

2.4.2 DESCRIPTION OF THE HIERARCHICAL APPROACH USED IN TRAFFIC CHARACTERIZATION

The full axle-load spectrum data for each axle type are needed for the Design Guide for both new pavement and rehabilitation design procedures. It is recognized, however, that some agencies may not have the resources that are needed to collect detailed traffic data over the years to accurately characterize future traffic for design. To facilitate the use of the Guide regardless of the level of detail of available traffic data, a hierarchical approach was adopted for developing the traffic inputs required for new and rehabilitated pavement design. The Design Guide defines three broad levels of traffic data input (Levels 1 through 3) based on the amount of traffic data available. These levels represent how well the pavement designer can estimate future truck traffic characteristics for the roadway being designed. The three levels can be defined simply as:

- Level 1 – There is a very good knowledge of past and future traffic characteristics.
- Level 2 – There is a modest knowledge of past and future traffic characteristics.
- Level 3 – There is a poor knowledge of past and future traffic characteristics.

Truck volumes and weights can vary considerably from road to road and even from location to location along a road. Thus, a very **good knowledge** of traffic loads can only be obtained where past traffic volume and weight data have been collected along or near the roadway segment to be designed. The data acquired through traffic monitoring is used to characterize future traffic characteristics, providing the designer with a high level of confidence in the accuracy of the truck traffic used in design.

Where only regional/statewide truck volume and weights data are available for the roadway in question, the design process assumes a **modest knowledge** of past and thus future traffic characteristics exists. In this case, the designer has the ability to predict with reasonable certainty the basic pattern of loads the trucks will carry. Where the designer must rely on default values computed from a national database and/or relatively little truck volume and weight information are available, the design process assumes a **poor knowledge** of past and thus future traffic characteristics.

2.4.2.1 Level 1 Inputs – A Very Good Knowledge of Traffic Characteristics

Level 1 requires the gathering and analysis of historical site-specific traffic volume and load data. The traffic data measured at or near a site must include counting and classifying the number of trucks traveling over the roadway, along with the breakdown by lane and direction, and measuring the axle loads for each truck class to determine the truck traffic for the first year after construction. 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 (e.g., the same segment of roadway without any intersecting roadways that would significantly change the loading pattern of the segment in question).

2.4.2.2 Level 2 Inputs – A Modest Knowledge of Traffic Characteristics

Level 2 requires the designer to collect enough truck volume information at a site to measure truck volumes accurately. This includes being able to account for any weekday/weekend volume variation, and any significant seasonal trends in truck loads (e.g., in areas affected by heavy, seasonal, agricultural hauls). Vehicle weights are taken from regional weight summaries maintained by each State (the "truck weight road groups" defined in FHWA's Traffic Monitoring Guide, 2001 Edition) that are used to differentiate routes with heavy (i.e., loaded trucks) weights, versus those with light (i.e., unloaded trucks) weights. The analyses of regional axle load spectra for each truck class are completed external to the traffic module.

2.4.2.3 Level 3 Inputs – A Poor Knowledge of Traffic Characteristics

Level 3 is used when the designer has little truck volume information for the roadway in question (for example, if all that is available is a value for Average Annual Daily Traffic [AADT] and a truck percentage). This level starts from AADT and percent trucks or from simple truck volume counts with no site-specific (or segment-specific) knowledge on the size of the loads those trucks are carrying. This lack of load knowledge means that a regional or statewide average load distribution (or other default load distribution table) must be used. An estimate of traffic inputs based on local experience is also considered Level 3.

2.4.2.4 Summary

For new alignments and roadways, pavement designers may not have access to past site-specific traffic data. For this condition, traffic inputs can be estimated using detailed traffic forecasting and trip generation models, and this is considered a Level 1 input. The important point is that the designer has a good understanding of the truck traffic loads and volumes, even though the truck loading patterns were estimated through traffic forecasting and trip generation models. Traffic forecasting and trip generation models can also be used to develop Level 2 and Level 3 input data. The application of traffic forecasting and trip generation models is beyond the scope and intent of the traffic module for the Design Guide. These types of studies need to be completed external to the traffic module in the Design Guide software.

For those roadways where there is a very good knowledge of both past and future truck volumes and weights, a high level of reliability is expected in the traffic-loading estimate and, thus, a much more reliable pavement design. Where the traffic loads (truck volumes and weights) are less well known, the traffic-loading estimates are less reliable, and consequently, the pavement design becomes less reliable. The use of Level 1 or 2 traffic inputs is preferable for the design of roadways that may eventually be a high-volume and very important route for transporting goods and the public. Regardless of the "level" of traffic data provided as input to the software, however, the traffic module software determines the total number of axle applications for each axle type and load group over the design or analysis period. The number of applications for each axle type and load increment is then used in pavement analysis, the computation of pavement responses, damage computation, and eventually for predicting load-related distresses for both new and rehabilitated rigid and flexible pavements.

Finally, for roadways with anticipated special future traffic characteristics, user-defined gear loads and axle configurations can be used to characterize future traffic. The user-defined axle loads and axle configurations are a subset wide array of load types and axle configurations that may be defined as part of the traffic characterization. This allows the designer to input a specific axle load and configuration so far as it falls within the range of loads and axles types provided. For example, this approach could be used for characterizing future traffic for parking lots or facilities used by heavy transport vehicles or to determine the effect on pavement performance of special vehicles in transporting very heavy loads.

2.4.3 DESCRIPTION OF DATA SOURCES AND DATA ELEMENTS USED IN TRAFFIC CHARACTERIZATION

Four main sources of traffic data are typically used for the traffic characterization in the Design Guide, as identified in table 2.4.1. Data from these sources are also used to identify the input data hierarchical level. Miscellaneous data elements used in traffic characterization but not necessarily obtained from the data sources listed in table 2.4.1 are presented in table 2.4.2. The sources of data are described in the following sections.

2.4.3.1 Traffic Load/Volume Data Sources

<u>WIM Data</u>

WIM data are a tabulation of the vehicle type and the number, spacing, and weight of axles for each vehicle weighed over a period of time. WIM data are used to determine the normalized axle load distribution or spectra for each axle type within each truck class. Analysis of the WIM data to determine the normalized axle load distributions is completed external to the Design Software, as described in Appendix AA. Classification of WIM data as Level 1 through 3 is based on the specific location at which data are collected (e.g., site-specific, regional/statewide, or national).

Table 2.4.1. Traffic data required for each of the three hierarchical input levels.

Data Sources		**Input Level**		
		1	**2**	**3**
Traffic load/volume data	WIM data – site/segment specific	X		
	WIM data – regional default summaries		X	
	WIM data –national default summaries			X
	AVC data – site/segment specific	X		
	AVC data – regional default summaries		X	
	AVC data – national default summaries			X
	Vehicle counts – site/segment specific[1]		X	X
	Traffic forecasting and trip generation models[2]	X	X	X

[1]Level depends on whether regional or national default values are used for the WIM or AVC information.
[2]Level depends on input data and model accuracy/reliability.

Table 2.4.2. Traffic data required for each of the three hierarchical input levels.

Data Elements/Variables		Input Level 1	Input Level 2	Input Level 3
Truck Traffic and Tire Factors	Truck 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
	Number of axles by axle type per truck class	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle and tire spacing	Hierarchical levels not applicable for this input		
	Tire pressure or hot inflation pressure	Hierarchical levels not applicable for this input		
	Truck traffic growth function	Hierarchical levels not applicable for this input		
	Vehicle operational speed	Hierarchical levels not applicable for this input		
	Truck lateral distribution factor	Hierarchical levels not applicable for this input		
	Truck monthly distribution factors	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Truck hourly distribution factors	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
Truck traffic distribution and volume variables	AADT or AADTT for base year	Hierarchical levels not applicable for this input		
	Truck distribution/spectra by truck class for base year	Site specific WIM or AVC	Regional WIM or AVC	National WIM or AVC
	Axle load distribution/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 pavement design	Hierarchical levels not applicable for this input		
	Percentage of trucks	Hierarchical levels not applicable for this input		

AVC Data

AVC data are a tabulation of the number and types of vehicles (FHWA Class 4 through 13) counted over a period of time. AVC data are used to determine the normalized truck class distribution. Analysis of the AVC data to determine the normalized truck class distribution is completed external to the Design Software, as described in Appendix AA. Classification of AVC data as Level 1 through 3 is based on the specific location at which data are collected (e.g., site-specific, regional/statewide, or national).

Vehicle Counts

Vehicle counts are simply a counting of the total number of vehicles categorized by passenger vehicles (FHWA Class 1 through 3), buses (FHWA Class 4), and trucks (FHWA Class 5 through 13) over a period of time. Vehicle counts can be continuous, seasonal, or short duration. Continuous counts are taken 365 days a year and are the most consistent and accurate types of vehicle count data that can be used in traffic characterization. Seasonal counts are performed usually from 2 to 12 times a year, for periods of time ranging from 24 hours to 2 weeks, while short duration counts range from 6 hours to 7 days. Vehicle counts are needed for input Levels 2 and 3 when detailed truck traffic data are unavailable. Classification of vehicle count data as Levels 2 or 3 is based on the specific location at which data are collected (e.g., site-specific, regional/statewide, or national).

Traffic Forecasting and Trip Generation Models

Level 1 or Level 2 traffic inputs can be estimated using detailed traffic forecasting and trip generation models calibrated with site-specific or regional/statewide data. Traffic forecasting and trip generation models are particularly useful in urban areas and are based on information obtained from turning movement studies, origin and destination studies, license plate surveys, and so on. The use of nationally calibrated traffic forecasting and trip generation models is not recommended. The application of traffic forecasting and trip generation models is beyond the scope of the Design Guide.

2.4.4 ASSUMPTIONS

Two major assumptions are used in the traffic characterization module for the Design Guide software:

1. The normalized axle load distributions by axle type for each truck class remain constant from year to year unless there are political and/or economical changes that have an affect on the maximum axle or gross truck loads. The normalized truck traffic volume distributions, however, can change from year to year.
2. The normalized axle load distribution by axle type and truck class and normalized truck volume distribution do not change throughout the time of day or over the week (weekday versus weekend and night versus day) within a specific season.

2.4.5 INPUTS REQUIRED FOR TRAFFIC CHARACTERIZATION

Four basic types of traffic data are required for pavement structural design:

- Traffic volume—base year information.
- Traffic volume adjustment factors.
    - Monthly adjustment.
    - Vehicle class distribution.
    - Hourly truck distribution.
    - Traffic growth factors.
- Axle load distribution factors.
- General traffic inputs.
    - Number axles/trucks.
    - Axle configuration.
    - Wheel base.

Detailed description of the information required is presented in the remaining sections of this chapter. Guidance on determining these traffic inputs is presented in Appendix AA.

2.4.5.1 Traffic Volume – Base Year Information

The base year for the traffic inputs is defined as the first year that the roadway segment under design is opened to traffic. The following base year information is required:

- Two-way annual average daily truck traffic (AADTT).
- Number of lanes in the design direction.
- Percent trucks in design direction.
- Percent trucks in design lane.
- Vehicle (truck) operational speed.

<u>Two-Way Annual Average Daily Truck Traffic</u>

Two-way AADTT is the total volume of truck traffic (the total number of heavy vehicles [classes 4 to 13] in the traffic stream) passing a point or segment of a road facility to be designed in both directions during a 24-hour period. It is commonly obtained from traffic counts obtained from WIM, AVC, vehicle counts, and traffic forecasting and trip generation models during a given time period (whole days greater than 1 day and less than 1 year). AADTT is simply the total number of truck traffic of the given time period divided by the number of days in that time period. Base year AADTT is defined as follows:

- Level 1—AADTT estimated from site-specific WIM, AVC, vehicle count data or site calibrated traffic forecasting and trip generation models. It is recommended that the average of the three most recent years with adequate data be used as the base year AADTT. This average value may need to be adjusted to account for truck-traffic growth depending on the amount of time between the three historical years and the base year.

- Level 2— AADTT estimated from regional/statewide WIM, AVC, or vehicle count data or from regionally calibrated traffic forecasting and trip generation models. It is recommended that the average of the last three years prior to the base year be used as the base year AADTT.
- Level 3—AADTT is estimated from AADT obtained mostly from traffic counts and an estimate of the percentage of trucks expected in the traffic stream. The AADT and percentage of trucks (vehicle class 4-13) should be averaged over the three most recent years with data. Estimates based on local experience are also considered Level 3.

Note that for both Levels 2 and 3 the regional/statewide or national data must be from routes with similar characteristics (e.g., functional class, urban versus rural, adjacent land use, and so on). Also, for Level 3 inputs local agencies should determine the best way to estimate percent trucks in the traffic stream based on the information available. One method used is to assign known site-specific values obtained along roadways/routes located in the same geographical area with similar traffic characteristics (traffic volume and vehicle class distribution) or to assign known site-specific values to other roadways that are in the same functional class and are located in the same area type (rural, small urban, urbanized) with similar travel characteristics. Average regional/statewide values calculated by functional class only are not recommended.

<u>Number of Lanes in the Design Direction</u>

The number of lanes in the design direction is determined from design specifications and represents the total number of lanes in one direction.

<u>Percent Trucks in Design Direction</u>

Percent trucks in the design direction, or the directional distribution factor (DDF), is used to quantify any difference in the overall volume of trucks in two directions. It is usually assumed to be 50 percent when the AADT and AADTT are given in two directions; however, this is not always the case. In fact, using a different route for transporting goods to and from certain areas and facilities is common, and depends on the commodities being transported as well as other regional/local traffic patterns. The levels of input for percent trucks in design direction are described as follows:

- Level 1—a site-specific directional distribution factor determined from WIM, AVC, and vehicle count data.
- Level 2—a regional/statewide directional distribution factor determined from WIM, AVC, and vehicle count data. Estimates from trip generation models may also be used.
- Level 3—a national average value or an estimate based on local experience.

The Design Guide software provides a default value (Level 3) of 55 percent for Interstate type facilities computed using traffic data from the LTPP database (*1*, *2*). Figure 2.4.1 shows the mean directional distribution factors for selected vehicle classes (2, 3, 5, 8 and 9), total truck traffic, and all vehicles combined (obtained from LTPP data).

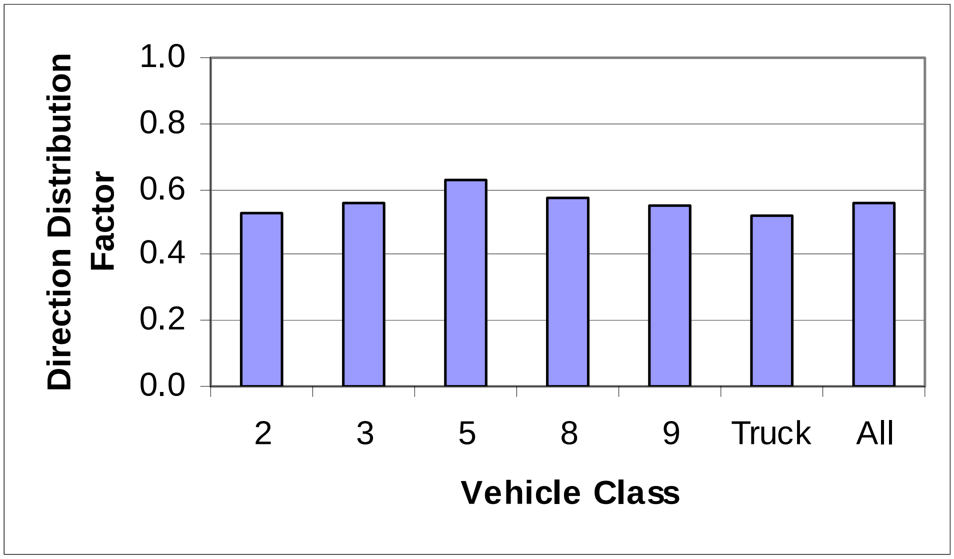

Figure 2.4.1. Directional distribution factors computed for different vehicle classes using LTPP data.

With the exception of vehicle class 5, the observed directional distribution factors lie in the range of 0.5 to 0.6. Those values computed using data from the LTPP traffic database are listed below (see also Appendix AA).

- Vehicle Class 4, Buses – 0.50, except for local or municipal bus routes. For local routes, the DDF for buses varies from 0.8 to 1.0.
- Vehicle Classes 5 – 7, Single Unit Trucks – 0.62. These types of trucks consistently have the greatest directional distribution factors.
- Vehicle Classes 8 – 10, Tractor-Trailer Trucks – 0.55.
- Vehicle Classes 11 – 13, Multi-Trailer Trucks – 0.50.

The default or Level 3 values for the DDF should represent the predominant type of truck using the roadway. If detailed site-specific or regional/statewide truck traffic data are unavailable, the truck DDF for the most common truck type (e.g., vehicle class 9) is suggested for use as the default value for all truck traffic.

Percent Trucks in Design Lane

Percent trucks in the design lane, or truck lane distribution factor (LDF), accounts for the distribution of truck traffic between the lanes in one direction. For two-lane, two-way highways (one lane in one direction), this factor is 1.0 because all truck traffic in any one direction must use the same lane. For multiple lanes in one direction, it depends on the AADTT and other geometric and site-specific conditions. The level of input for LDF is described as follows:

- Level 1—a site-specific lane distribution factor determined from WIM, AVC, or vehicle count data.

- Level 2—a regional/statewide lane distribution factor determined from WIM, AVC, or vehicle count data.
- Level 3—a national average value or an estimate obtained from traffic forecasting and trip generation models. An estimate based on local experience is also considered Level 3.

Figure 2.4.2 shows the mean lane distribution factors computed for the vehicle classes 2, 3, 5, 8, 9, all trucks, and all vehicles for 2- and 3-lanes/direction roads using data from the LTPP database. In general, the LDF for 2-lane/direction roads is 0.89 for truck class 9 and 0.78 for all trucks. For 3-lane/direction roads, the LDF is 0.59 for truck class 9 and 0.43 for all trucks. The default (Level 3) values recommended for use based on the LDF for the most common type of truck (vehicle class 9 trucks) is as follows:

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

<u>Vehicle Operational Speed</u>

The vehicle operational speed of trucks or the average travel speed generally depends on many factors, including the roadway facility type (Interstate or otherwise), terrain, percentage of trucks in the traffic stream, and so on. A description of a detailed methodology used for determining operational speeds can be found in the Transportation Research Board (TRB) *Highway Capacity Manual* or AASHTO's *A Policy on Geometric Design of Highways and Streets* (often called the "Green Book") (*3, 4*). The Design Guide software uses 60 mph as the default operational speed value, but this speed can be modified to reflect local/site conditions.

2.4.5.2 Traffic Volume Adjustments

The following truck-traffic volume adjustment factors are required for traffic characterization, and each is described in the following sections:

- Monthly adjustment factors.
- Vehicle class distribution factors.
- Hourly truck distribution factors.
- Traffic growth factors.

<u>Monthly Adjustment Factors</u>

Truck traffic monthly adjustment factors simply represent the proportion of the annual truck traffic for a given truck class that occurs in a specific month. In other words, the monthly distribution factor for a specific month is equal to the monthly truck traffic for the given class for the month divided by the total truck traffic for that truck class for the entire year. Truck traffic monthly adjustment factors (MAF) depend on factors such as adjacent land use, the location of industries in the area, and roadway location (urban or rural). In reality, monthly differences in the truck traffic distribution could vary over the course of several years during the pavement life.

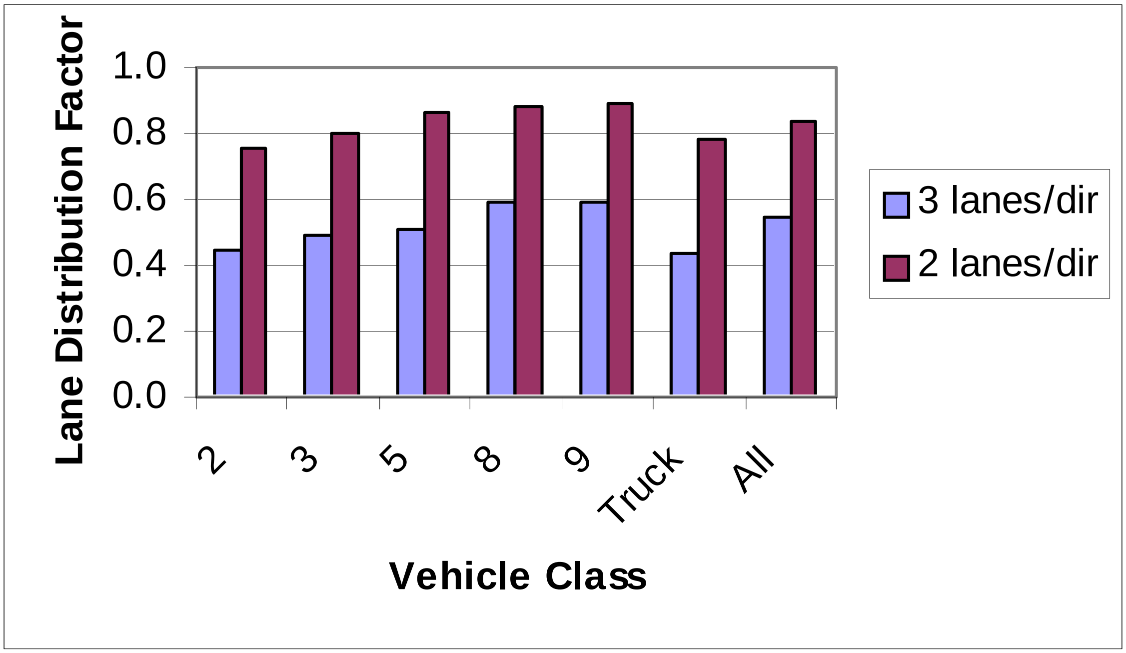

Figure 2.4.2. Lane distribution factors for four and six-lane roadways.

For this Design Guide, however, monthly distribution of truck traffic is assumed to be constant over the entire design period.

Figure 2.4.3 shows an example of the variation in monthly ADTT for LTPP test section 18-5022, while figure 2.4.4 shows the truck monthly distribution factors computed from ADTT for the same site (*2*). It must be noted that even though figure 2.4.3 shows a variation in the absolute ADTT values for weekday and weekend traffic (daily variation of traffic), the Design Guide assumes a uniform distribution of traffic for all days within a given month or year. The traffic data collection plan (discussed in section 2.4.6) should recognize the potential difference between the weekday and weekend truck traffic and consider that difference in determining the base year AADTT.

As noted, monthly variations in truck traffic volumes are site-specific as well as highly dependent on the local economy and climatic conditions. The following levels of input are specified:

- Level 1 – site- or segment-specific MAF for each vehicle class (classes 4 through 13) computed from WIM, AVC, or vehicle count data or trip generation models.
- Level 2 – regional/statewide MAF for each vehicle class (classes 4 through 13) computed from WIM, AVC, or vehicle count data or trip generation models.
- Level 3 –national MAF computed from WIM, AVC, or vehicle count data. The use of estimates based on local experience is also considered Level 3 data.

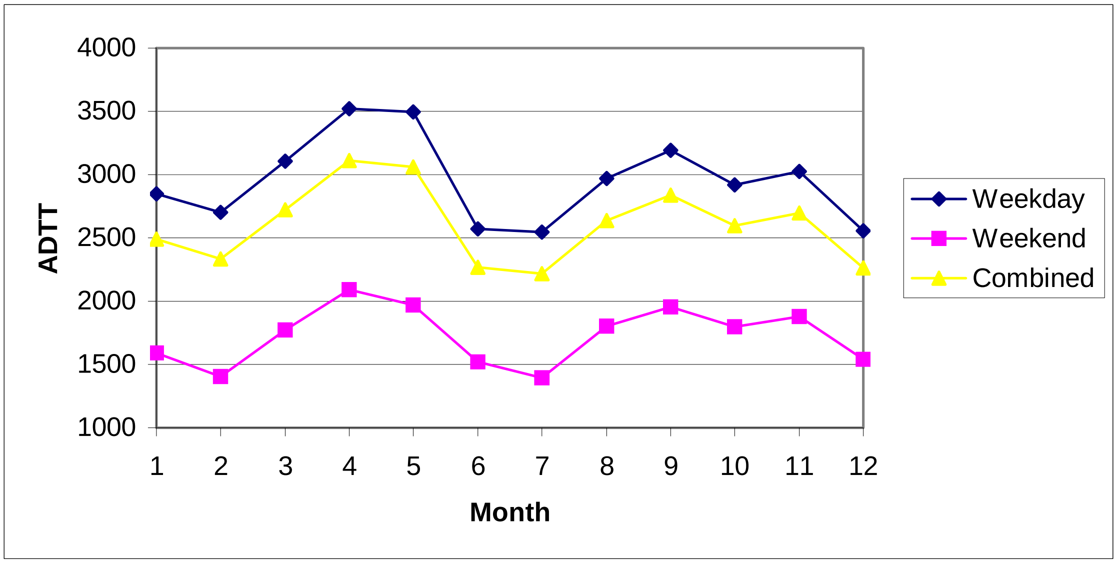

Figure 2.4.3. Average daily truck traffic for the weekdays, weekends, and weighted average by month for LTPP site 18-5022.

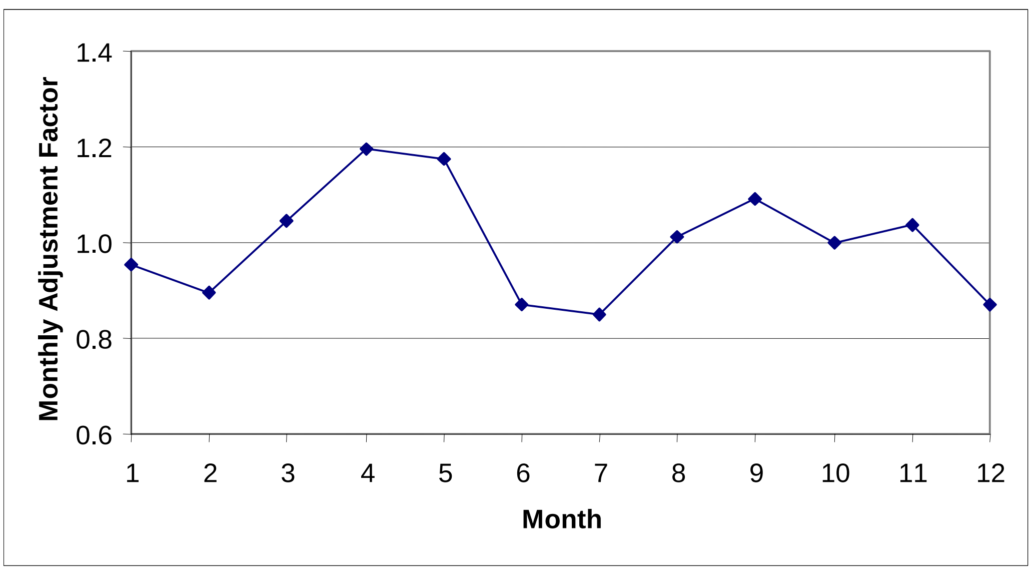

Figure 2.4.4. Truck monthly adjustment factors from the combined ADTT data presented in figure 2.4.3.

Regardless of the source of the data (WIM, AVC, vehicle count, and so on), each agency can develop these monthly adjustment factors for different types of highways as follows:

1. For the given traffic data (24-hours of continuous data collection), determine the total number of trucks (in a given class) for each 24-hour period. If data were not collected for the entire 24-hour period, the measured daily truck traffic should be adjusted to be representative of a 24-hour period.
2. Using representative daily data collected for the different months within a year, determine the average daily truck traffic for each month in the year.
3. Sum up the average daily truck traffic for each month for the entire year.
4. Calculate the monthly adjustment factors by dividing the average daily truck traffic for each month by summing the average daily truck traffic for each month for the entire year and multiplying it by 12 as given below:

$$MAF_i = \frac{AMDTT_i}{\sum_{i=1}^{12} AMDTT_i} * 12 \tag{2.4.1}$$

where

MAF_i = monthly adjustment factor for month i
$AMDTT_i$ = average monthly daily truck traffic for month i

The sum of the MAF of all months must equal 12.

Pavement designs can be sensitivity to MAF. If no information is available, it is recommended that designers assume an even or equal distribution (i.e., 1.0 for all months for all vehicle classes) as shown in table 2.4.3. The Design Software allows designers to directly input the MAF or import MAF from an already prepared file. The format of the input file must be compatible with the information presented in table 2.4.3.

Table 2.4.3. MAF default values for traffic characterization.

Month	**Class 4**	**Class 5**	**Class 6**	**Class 7**	**Class 8**	**Class 9**	**Class 10**	**Class 11**	**Class 12**	**Class 13**
January	1	1	1	1	1	1	1	1	1	1
February	1	1	1	1	1	1	1	1	1	1
March	1	1	1	1	1	1	1	1	1	1
April	1	1	1	1	1	1	1	1	1	1
May	1	1	1	1	1	1	1	1	1	1
June	1	1	1	1	1	1	1	1	1	1
July	1	1	1	1	1	1	1	1	1	1
August	1	1	1	1	1	1	1	1	1	1
September	1	1	1	1	1	1	1	1	1	1
October	1	1	1	1	1	1	1	1	1	1
November	1	1	1	1	1	1	1	1	1	1
December	1	1	1	1	1	1	1	1	1	1

Note that the sum of all factors for a given vehicle/truck class for the year is 12.

<u>Vehicle Class Distribution</u>

Vehicle class distribution is computed from data obtained from vehicle classification counting programs such as AVC, WIM, and vehicle counts. Vehicle classification counting programs can be of short or continuous duration. Typically, the majority of data used to compute vehicle class distributions come from short duration counts such as WIM and AVC sites, urban traffic management centers, toll facilities, and other agencies that collect truck volume information. The key to a successful classification data collection program is not the source of the data, but the ability to routinely obtain it, verify its validity, summarize it into useable formats, report it in a manner that is useful to designers, and manage the process efficiently. Figure 2.4.5 shows the standard vehicle classes that have been used to summarize and vehicle classification data for FHWA and LTPP (*1*, *2*).

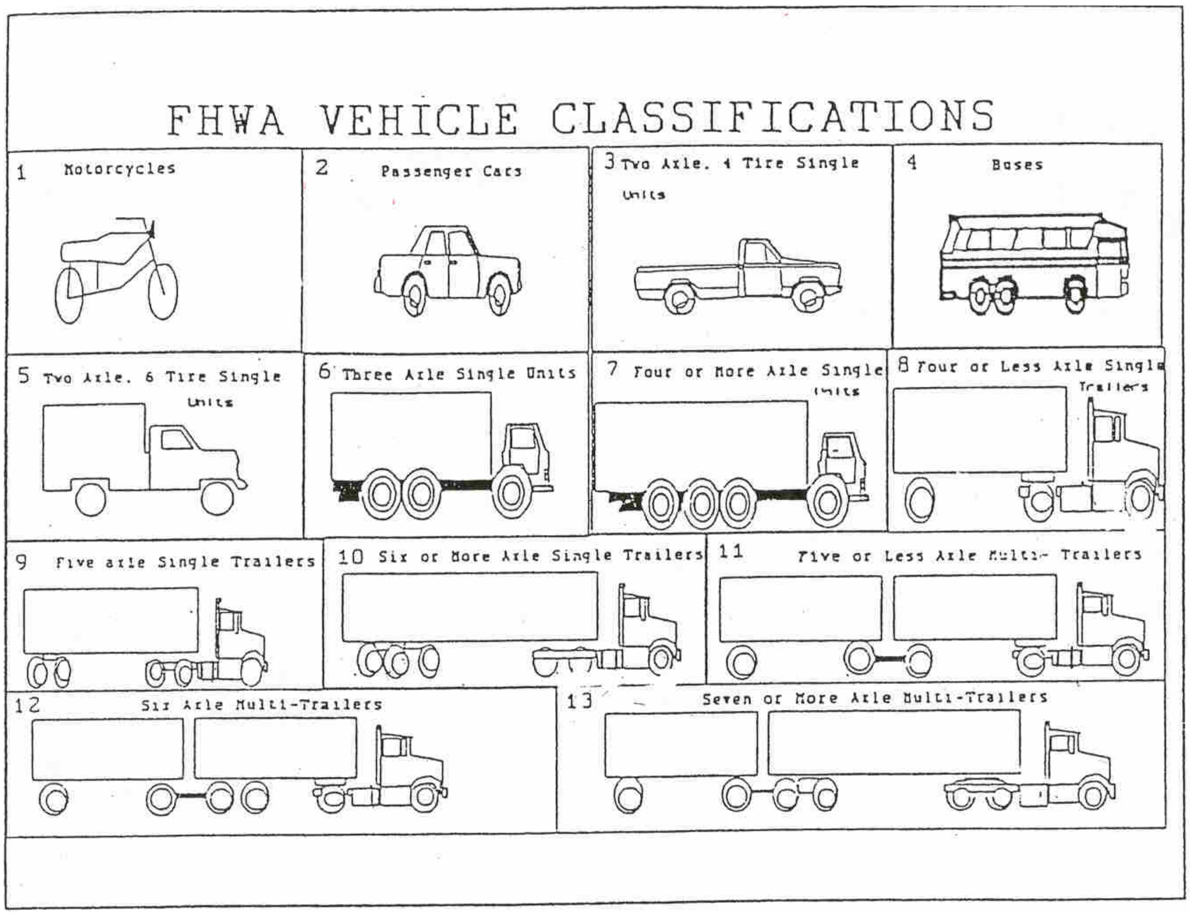

Figure 2.4.5. Illustrations and definitions of the vehicle classes used for collecting traffic data that are needed for design purposes (*1*).

Normalized vehicle class distribution represents the percentage of each truck class (classes 4 through 13) within the AADTT for the base year. The sum of the percent AADTT of all truck classes should equal 100. The inputs at different levels are as follows:

- Level 1 – data obtained from site or segment specific WIM, AVC, or vehicle counts.
- Level 2 – data obtained from regional/statewide WIM, AVC, or vehicle counts.
- Level 3 – data obtained from national WIM, AVC, or vehicle counts or local experience.

Default vehicle class distribution factors (Level 3) determined using LTPP traffic data are provided as part of the Design Guide software. The default vehicle class distribution factors are chosen based on the roadway function class and the best combination of Truck Traffic Classification (TTC) groups that describes the traffic stream expected on the given roadway. An example of the default vehicle class distribution factors for principal arterials (Interstate and Defense Routes) is shown in table 2.4.4. The default values were obtained by choosing a functional class and the combination of TTC groups (i.e., 1, 2, 3, 4, 5, 8, 11, and 13) that best characterized the traffic stream expected. A standardized set of TTC groups that best describes the traffic stream for the different functional classes are presented in table 2.4.5. Each TTC group represents a traffic stream with unique truck traffic characteristics (see table 2.4.4). For example, TTC 1 describes a traffic stream heavily populated with single-trailer trucks, while TTC 17 is populated with buses. Vehicle class distribution factors for a route populated with single-trailer trucks and buses would be computed using a combination of TTC 1 and 17.

Designers must choose the default set of vehicle class distribution for the TTC that most closely describes the design traffic stream for the roadway under design. This can be done with the information presented in tables 2.4.4 through 2.4.6. Details of how the TTC groups were developed using LTPP data are presented in Appendix AA. *For Level 1 and Level 2 inputs, it must be noted that the collection of site- or segment-specific or regional/statewide traffic data must begin years in advance of the start of design to ensure that an adequate amount of data is used in analysis.* This maybe impractical, so for many projects, an agency may elect to use a combination of site-specific and regional data to reduce the time required to collect the necessary data. The Design Software allows designers to directly input the vehicle classification distribution factors (Levels 1 through 3) or import from an already prepared file for Level 3.

<u>Truck Hourly Distribution Factors</u>

The hourly distribution factors (HDF) represent the percentage of the AADTT within each hour of the day. The inputs at different levels are as follows:

- Level 1 – a site- or segment-specific distribution determined from AVC, WIM, or vehicle count data.
- Level 2 – a regional/statewide distribution determined from AVC, WIM, or vehicle count data.
- Level 3 – the factors determined from a national data or local experience.

Table 2.4.4. Truck traffic classification (TTC) group description and corresponding vehicle (truck) class distribution default values (percentages) considered in the Design Guide Software.

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

Table 2.4.5. Suggested guidance for selecting appropriate TTC groups for different highway functional classifications.

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

Table 2.4.6. Definitions and descriptions for the TTC groups.

<table>
<tr><th rowspan="2">Buses in Traffic Stream</th><th colspan="2">Commodities being Transported by Type of Truck</th><th rowspan="2">TTC Group No.</th></tr>
<tr><th>Multi-Trailer</th><th>Single-Trailers and Single-Units</th></tr>
<tr><td rowspan="9">Low to none (<2%)</td><td rowspan="5">Relatively high amount of multi-trailer trucks (>10%)</td><td>Predominantly single-trailer trucks</td><td>5</td></tr>
<tr><td>High percentage of single-trailer trucks, but some single-unit trucks</td><td>8</td></tr>
<tr><td>Mixed truck traffic with a higher percentage of single-trailer trucks</td><td>11</td></tr>
<tr><td>Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks</td><td>13</td></tr>
<tr><td>Predominantly single-unit trucks</td><td>16</td></tr>
<tr><td rowspan="4">Moderate amount of multi-trailer trucks (2-10%)</td><td>Predominantly single-trailer trucks</td><td>3</td></tr>
<tr><td>Mixed truck traffic with a higher percentage of single-trailer trucks</td><td>7</td></tr>
<tr><td>Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks</td><td>10</td></tr>
<tr><td>Predominantly single-unit trucks</td><td>15</td></tr>
<tr><td rowspan="7">Low to moderate (>2%)</td><td rowspan="7">Low to none (<2%)</td><td>Predominantly single-trailer trucks</td><td>1</td></tr>
<tr><td>Predominantly single-trailer trucks, but with a low percentage of single-unit trucks</td><td>2</td></tr>
<tr><td>Predominantly single-trailer trucks with a low to moderate amount of single-unit trucks</td><td>4</td></tr>
<tr><td>Mixed truck traffic with a higher percentage of single-trailer trucks</td><td>6</td></tr>
<tr><td>Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks</td><td>9</td></tr>
<tr><td>Mixed truck traffic with a higher percentage of single-unit trucks</td><td>12</td></tr>
<tr><td>Predominantly single-unit trucks</td><td>14</td></tr>
<tr><td>Major bus route (>25%)</td><td>Low to none (<2%)</td><td>Mixed truck traffic with about equal single-unit and single-trailer trucks</td><td>17</td></tr>
</table>

For Level 1 through 3 inputs, HDF may be computed using truck traffic data measured continuously over a 24-hour period of time. The hourly data are used to determine the percentage of total trucks within each hour as follows:

1. Determine the total number of trucks counted within each hour of traffic data in the sample.
2. Average the number of trucks for each of the 24 hours of the day in the sample. For example, if the data include truck counts for the first hour of the day for 6 days, then total those 6 counts and divide by 6.
3. Total the 24 hourly averages from step 3.
4. Divide each of the 24 hourly averages from step 2 by the total from step 3 and multiply by 100.

The sum of the percent of daily truck traffic per time increment must add up to 100 percent.

Default HDF are provided in the Design Guide software computed from the LTPP traffic database and it is recommended as Level 3. Table 2.4.7 presents a summary of the default HDF values presented in the Design Guide software.

Table 2.4.7. Hourly truck traffic distribution default values based on LTPP traffic data.

Time Period	**Distribution, percent**	**Time Period**	**Distribution, percent**
12:00 a.m. - 1:00 a.m.	2.3	12:00 p.m. - 1:00 p.m.	5.9
1:00 a.m. - 2:00 a.m.	2.3	1:00 p.m. - 2:00 p.m.	5.9
2:00 a.m. - 3:00 a.m.	2.3	2:00 p.m. - 3:00 p.m.	5.9
3:00 a.m. - 4:00 a.m.	2.3	3:00 p.m. - 4:00 p.m.	5.9
4:00 a.m. - 5:00 a.m.	2.3	4:00 p.m. - 5:00 p.m.	4.6
5:00 a.m. - 6:00 a.m.	2.3	5:00 p.m. - 6:00 p.m.	4.6
6:00 a.m. - 7:00 a.m.	5.0	6:00 p.m. - 7:00 p.m.	4.6
7:00 a.m. - 8:00 a.m.	5.0	7:00 p.m. - 8:00 p.m.	4.6
8:00 a.m. - 9:00 a.m.	5.0	8:00 p.m. - 9:00 p.m.	3.1
9:00 a.m. - 10:00 a.m.	5.0	9:00 p.m. - 10:00 p.m.	3.1
10:00 a.m. – 11:00 a.m.	5.9	10:00 p.m. - 11:00 p.m.	3.1
11:00 a.m. – 12:00 p.m.	5.9	11:00 p.m. - 12:00 a.m.	3.1

Traffic Growth Factors

Traffic growth factors at a particular site or segment are best estimated when a continuous traffic count data is available (assuming that the data is reliable and that the differences found from year to year can be attributed to growth), since it is well known that traffic volumes at a single site can be affected by a variety of extraneous factors, and thus growth factors computed from limited data collected from a limited number of locations can be biased. A less reliable estimate of growth factors can also be computed from data obtained from short duration counts, since the individual estimates of AADTT from such counts are not nearly as accurate as those available from continuous traffic counts.

both continuous and short duration counts, if data from the same count locations collected over several years are used to compute growth factors, errors at any one given location due to the inaccuracy of the AADTT estimate tend to self-correct. That is, if this year's AADTT count is too high, making this year's growth estimate too high, next year's "correct" AADT value will cause a much lower growth estimate to be computed, resulting in a more reliable growth estimate over the years.

It must be emphasized no single procedure is best in all cases for estimating traffic growth factors, and it is recommended that instead of concentrating on a specific procedure (e.g., short duration versus continuous counts or site specific versus regional) a better approach is to use all the tools and data available to examine traffic growth from several perspectives for a given site. Rather than develop a single estimate, the different data sources may be used to develop a number of growth factors from which appropriate growth factor estimate can be derived.

The Design Guide software allows users to use three different traffic growth functions to compute the growth or decay in truck traffic over time (forecasting truck traffic). The three functions provided to estimate future truck traffic volumes are presented in table 2.4.8.

Table 2.4.8. Function used in computing/forecasting truck traffic over time.

Function Description	**Model**
No growth	$AADTT_X = 1.0 * AADTT_{BY}$
Linear growth	$AADTT_X = GR * AGE + AADTT_{BY}$
Compound growth	$AADTT_X = ADTT_{BY} * (GR)^{AGE}$

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

The Design Guide software allows users to input both a growth rate and the growth function. A common growth function may be chosen for all truck classes, or different functions may be chosen for the different truck classes. Based on the function chosen, the opening date of the roadway to traffic (excluding construction traffic) and the pavement design life, AADTT is forecast for the entire design life of the pavement.

2.4.5.3 Axle Load Distribution Factors

The axle load distribution factors simply represent the percentage of the total axle applications within each load interval for a specific axle type (single, tandem, tridem, and quad) and vehicle class (classes 4 through 13). A definition of load intervals for each axle type is provided below:

- Single axles – 3,000 lb to 40,000 lb at 1,000-lb intervals.
- Tandem axles – 6,000 lb to 80,000 lb at 2,000-lb intervals.
- Tridem and quad axles – 12,000 lb to 102,000 lb at 3,000-lb intervals.

The normalized axle load distribution or spectra can only be determined from WIM data. Therefore, the level of input depends on the data source (site, regional, or national). For this design procedure, load spectra are normalized on an annual basis because no systematic or significant year-to-year or month-to-month differences were found in the analysis of the LTPP WIM data (*5*).

Figures 2.4.6 and 2.4.7 show the single and tandem axle load spectra for truck class 9 from two LTPP test sections with multiple years of data, respectively. Figure 2.4.8 shows the average normalized tandem axle load distribution for each month for truck class 9. As shown in figure 2.4.8, the normalized tandem axle load spectrum was found to be month/season independent. Figure 2.4.9 shows an example of the annual average (5 years of data) normalized tandem axle load spectra for vehicle classes 8, 9, and 10. The normalized tandem axle load spectra for vehicle classes 9 and 10 are approximately the same, whereas the one for vehicle class 8 is significantly different. Figure 2.4.10 shows an example of the annual normalized tandem axle load distribution for vehicle class 7, 8, and 9 for all years of available data combined. The tandem axle load spectra for these three types of trucks are different. Based on the results obtained from analyzing the LTPP traffic data the following input levels for axle load distribution factors were defined:

- Level 1 – the distribution factors determined based on an analysis of site- or segment-specific WIM data.
- Level 2 – the distribution factors determined based on an analysis of regional/statewide WIM data.
- Level 3 – the default distribution factors computed from a national database such as LTPP.

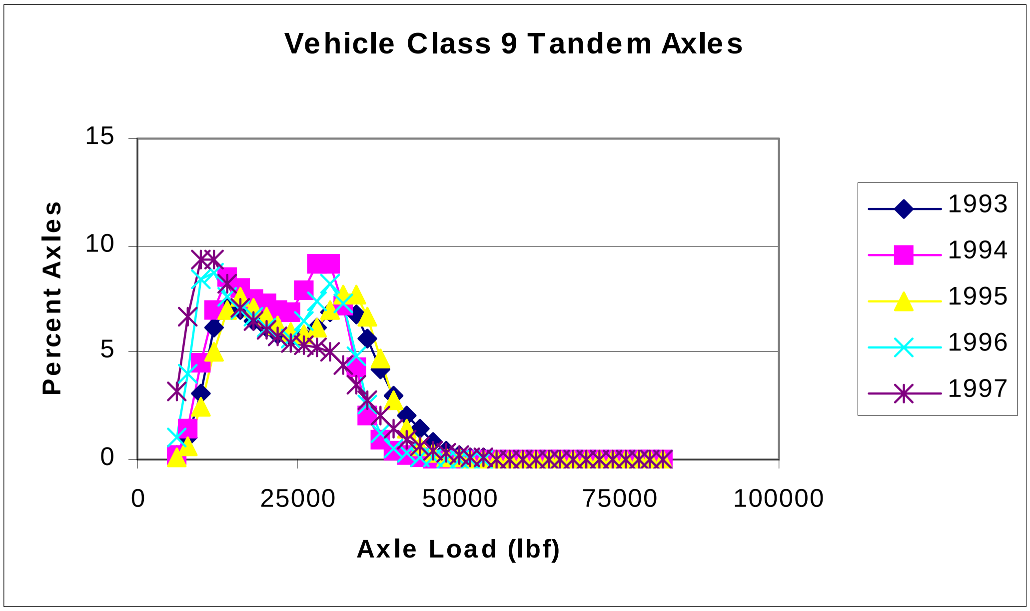

Figure 2.4.6. Average normalized single axle load spectra for truck class 9 for 5 years of WIM data.

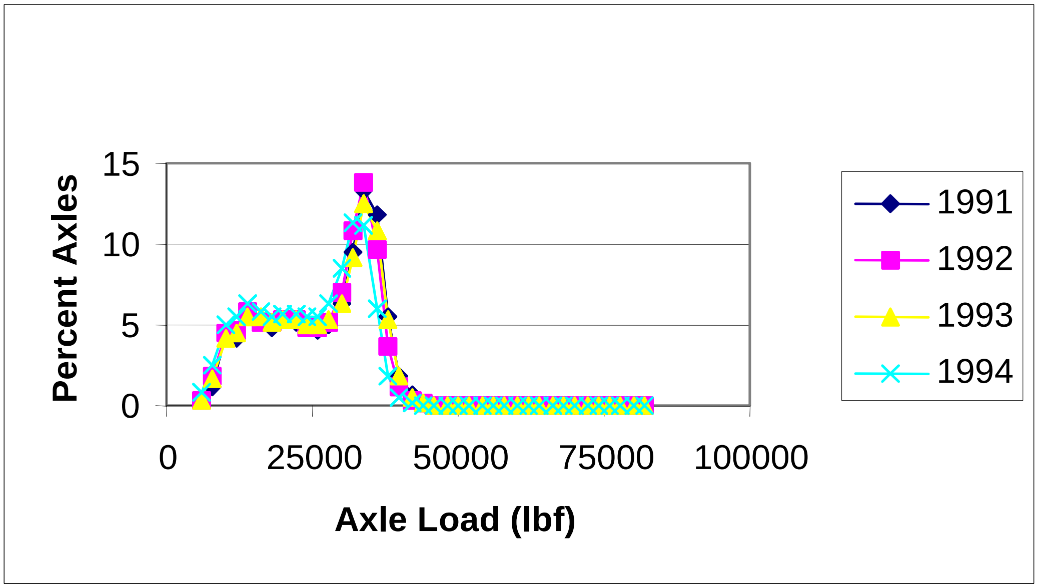

Figure 2.4.7. Average normalized tandem axle load distribution for truck class 9 for 4 years of WIM data.

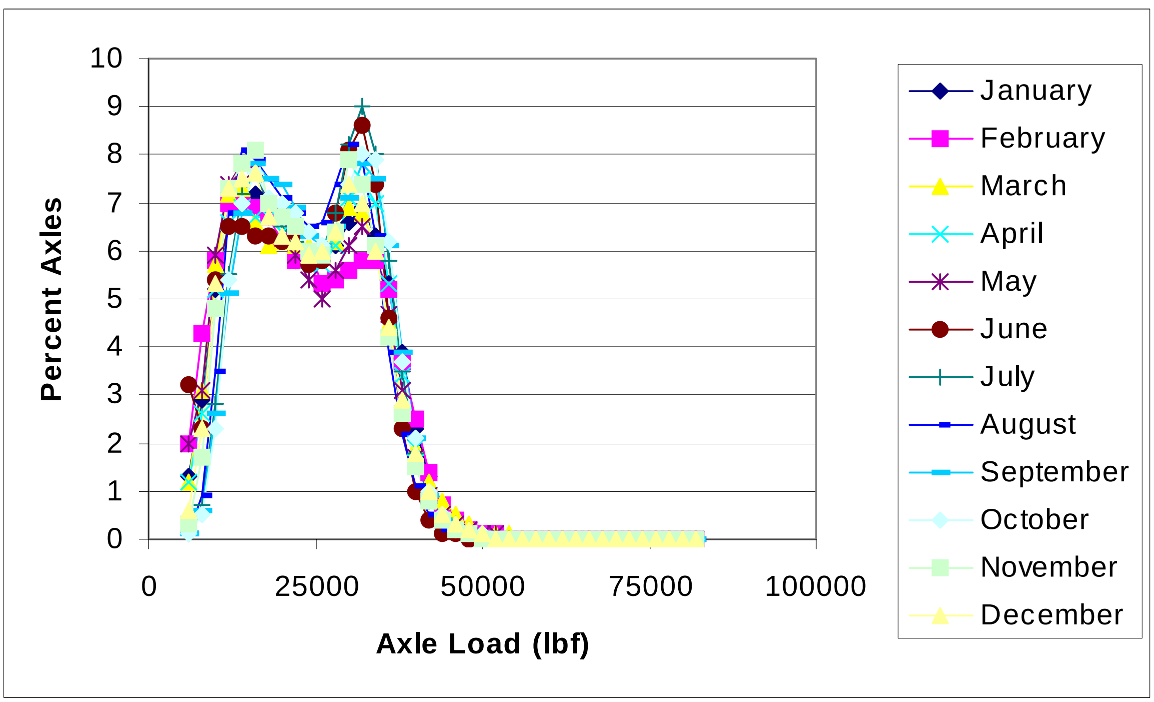

Figure 2.4.8. Monthly differences in the average normalized tandem axle load spectra for truck class 9 (LTPP test section 185022).

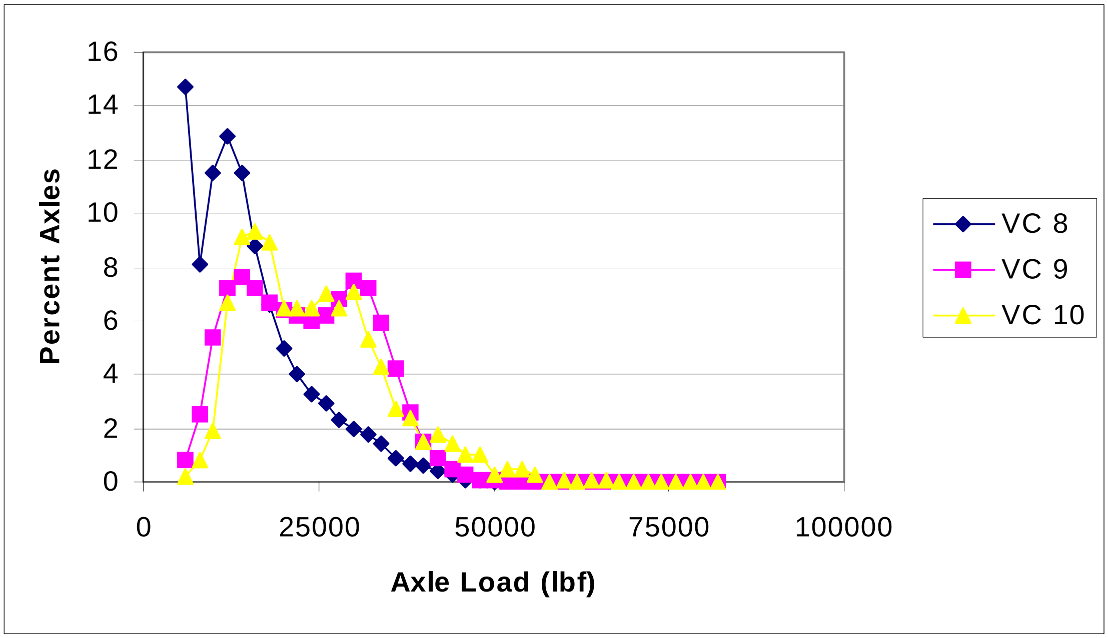

Figure 2.4.9. Average normalized tandem axle load spectra for truck classes 8, 9, and 10 (LTPP test section 185022).

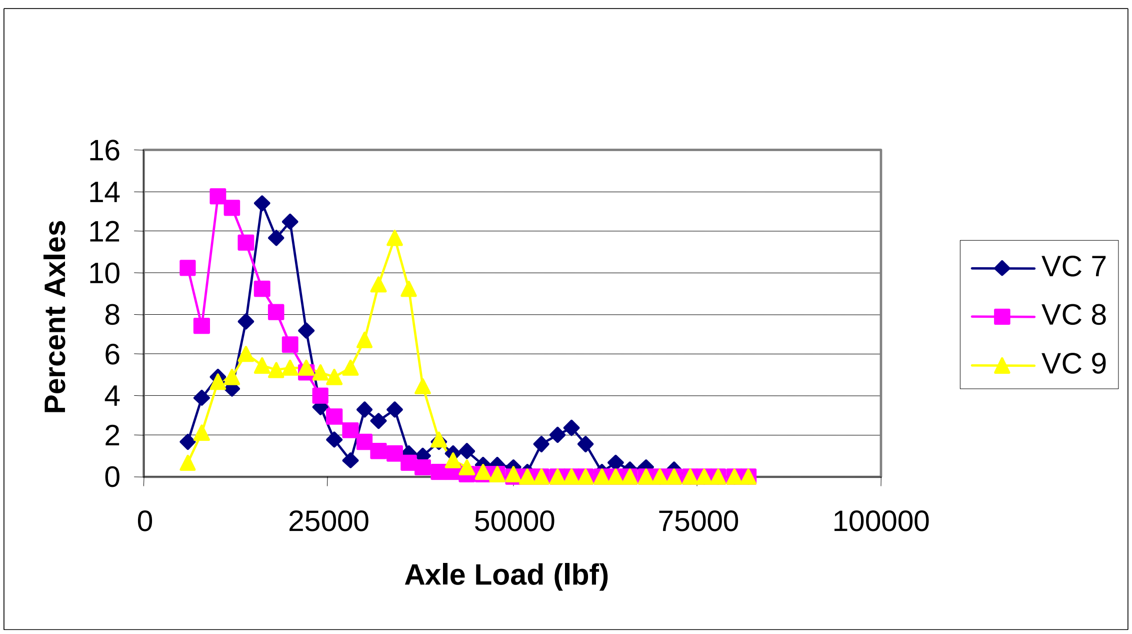

Figure 2.4.10. Average annual tandem axle load distribution for truck class 7, 8, and 9 for all available years of "good" data (LTPP test section 421627).

The Design Guide software allows user to input the following for level 1 through 3 inputs:

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

For Level 1 inputs, the axle load distribution factors can be imported from already prepared text files, while for Level 3 inputs default values prepared using data from the LTPP database is provided. As an example, tables 2.4.9 and 2.4.10 list the axle load distribution default values for single and tandem axles for each truck class in all TTC groups. The following guide is recommended for computing axle load distribution factors using WIM data:

1. Assemble WIM data (total the number of axles measured within each axle load range by axle type within each truck class) and calculate the percentage of the total number of axle applications within each load range for each axle type and truck class for each year of data. In other words, normalize the number of axle load applications within each truck class and axle type.
2. Calculate the annual mean and variance for each axle load range for each axle type within each truck class. Both the mean and variance are important for determining if there are significant differences between years.
3. Compare the annual normalized axle load spectra or distributions for the truck class that has the greatest number of truck applications at the site. If the annual normalized values are not significantly different from year to year, all of the years can be combined to result in a site normalized load distribution for each truck class and axle type. If statistical differences (defined based on local experience) are found, the years should be considered separately, and the designer has the following options:
    a. Decide which axle load distribution should be used as the base year. It is suggested that one axle load distribution for each axle type and truck class be used and that distribution be kept constant throughout the analysis period.
    b. Decide whether to combine all years, selected years or use only one year of data to determine the base annual axle load distribution for each axle type and truck class.
    c. Determine how the normalized load distributions change with time and then predict the load distribution values for future years. The load distribution values for future years can then be used to compute an effective load distribution value to design.

In summary, the axle load spectra for each axle type for the different truck classes may be significantly different and should be considered separately in the analysis. Appendix AA provides greater detail on how default Level 3 axle load spectra values were computed using LTPP data.

Table 2.4.9. Single-axle load distribution default values (percentages) for each vehicle/truck class.

Mean Axle Load, lbs.	Vehicle/Truck Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
3000	1.80	10.03	2.47	2.14	11.62	1.74	3.64	3.55	6.68	8.88
4000	0.96	13.19	1.78	0.55	5.36	1.37	1.24	2.91	2.29	2.67
5000	2.91	16.40	3.45	2.42	7.82	2.84	2.36	5.19	4.87	3.81
6000	3.99	10.69	3.95	2.70	6.98	3.53	3.38	5.27	5.86	5.23
7000	6.80	9.21	6.70	3.21	7.98	4.93	5.18	6.32	5.97	6.03
8000	11.45	8.26	8.44	5.81	9.69	8.43	8.34	6.97	8.85	8.10
9000	11.28	7.11	11.93	5.26	9.98	13.66	13.84	8.07	9.57	8.35
10000	11.04	5.84	13.55	7.38	8.49	17.66	17.33	9.70	9.95	10.69
11000	9.86	4.53	12.12	6.85	6.46	16.69	16.19	8.54	8.59	10.69
12000	8.53	3.46	9.47	7.41	5.18	11.63	10.30	7.28	7.09	11.11
13000	7.32	2.56	6.81	8.99	4.00	6.09	6.52	7.16	5.86	7.34
14000	5.55	1.92	5.05	8.15	3.38	3.52	3.94	5.65	6.58	3.78
15000	4.23	1.54	2.74	7.77	2.73	1.91	2.33	4.77	4.55	3.10
16000	3.11	1.19	2.66	6.84	2.19	1.55	1.57	4.35	3.63	2.58
17000	2.54	0.90	1.92	5.67	1.83	1.10	1.07	3.56	2.56	1.52
18000	1.98	0.68	1.43	4.63	1.53	0.88	0.71	3.02	2.00	1.32
19000	1.53	0.52	1.07	3.50	1.16	0.73	0.53	2.06	1.54	1.00
20000	1.19	0.40	0.82	2.64	0.97	0.53	0.32	1.63	0.98	0.83
21000	1.16	0.31	0.64	1.90	0.61	0.38	0.29	1.27	0.71	0.64
22000	0.66	0.31	0.49	1.31	0.55	0.25	0.19	0.76	0.51	0.38
23000	0.56	0.18	0.38	0.97	0.36	0.17	0.15	0.59	0.29	0.52
24000	0.37	0.14	0.26	0.67	0.26	0.13	0.17	0.41	0.27	0.22
25000	0.31	0.15	0.24	0.43	0.19	0.08	0.09	0.25	0.19	0.13
26000	0.18	0.12	0.13	1.18	0.16	0.06	0.05	0.14	0.15	0.26
27000	0.18	0.08	0.13	0.26	0.11	0.04	0.03	0.21	0.12	0.28
28000	0.14	0.05	0.08	0.17	0.08	0.03	0.02	0.07	0.08	0.12
29000	0.08	0.05	0.08	0.17	0.05	0.02	0.03	0.09	0.09	0.13
30000	0.05	0.02	0.05	0.08	0.04	0.01	0.02	0.06	0.02	0.05
31000	0.04	0.02	0.03	0.72	0.04	0.01	0.03	0.03	0.03	0.05
32000	0.04	0.02	0.03	0.06	0.12	0.01	0.01	0.04	0.01	0.08
33000	0.04	0.02	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.06
34000	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.02
35000	0.02	0.02	0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.01
36000	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
37000	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
38000	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.01
39000	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01
40000	0.01	0.00	0.01	0.01	0.00	0.00	0.04	0.02	0.00	0.00
41000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.4.10. Tandem-axle load distribution default values (percentages) for each vehicle/truck class.

Mean Axle Load, lbs.	Vehicle/Truck Class									
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6000	5.88	7.06	5.28	13.74	18.95	2.78	2.45	7.93	5.23	6.41
8000	1.44	35.42	8.42	6.71	8.05	3.92	2.19	3.15	1.75	3.85
10000	1.94	13.23	10.81	6.49	11.15	6.51	3.65	5.21	3.35	5.58
12000	2.73	6.32	8.99	3.46	11.92	7.61	5.40	8.24	5.89	5.66
14000	3.63	4.33	7.71	7.06	10.51	7.74	6.90	8.88	8.72	5.73
16000	4.96	5.09	7.50	4.83	8.25	7.00	7.51	8.45	8.37	5.53
18000	7.95	5.05	6.76	4.97	6.77	5.82	6.99	7.08	9.76	4.90
20000	11.58	4.39	6.06	4.58	5.32	5.59	6.61	5.49	10.85	4.54
22000	14.20	2.31	5.71	4.26	4.13	5.16	6.26	5.14	10.78	6.45
24000	13.14	2.28	5.17	3.85	3.12	5.05	5.95	5.99	7.24	4.77
26000	10.75	1.53	4.52	3.44	2.34	5.28	6.16	5.73	6.14	4.34
28000	7.47	1.96	3.96	6.06	1.82	5.53	6.54	4.37	4.93	5.63
30000	5.08	1.89	3.21	3.68	1.58	6.13	6.24	6.57	3.93	7.24
32000	3.12	2.19	3.91	2.98	1.20	6.34	5.92	4.61	3.09	4.69
34000	1.87	1.74	2.12	2.89	1.05	5.67	4.99	4.48	2.74	4.51
36000	1.30	1.78	1.74	2.54	0.94	4.46	3.63	2.91	1.73	3.93
38000	0.76	1.67	1.44	2.66	0.56	3.16	2.79	1.83	1.32	4.20
40000	0.53	0.38	1.26	2.50	0.64	2.13	2.24	1.12	1.07	3.22
42000	0.52	0.36	1.01	1.57	0.28	1.41	1.69	0.84	0.58	2.28
44000	0.30	0.19	0.83	1.53	0.28	0.91	1.26	0.68	0.51	1.77
46000	0.21	0.13	0.71	2.13	0.41	0.59	1.54	0.32	0.43	1.23
48000	0.18	0.13	0.63	1.89	0.20	0.39	0.73	0.21	0.22	0.85
50000	0.11	0.14	0.49	1.17	0.14	0.26	0.57	0.21	0.22	0.64
52000	0.06	0.20	0.39	1.07	0.11	0.17	0.40	0.07	0.23	0.39
54000	0.04	0.06	0.32	0.87	0.06	0.11	0.38	0.13	0.20	0.60
56000	0.08	0.06	0.26	0.81	0.05	0.08	0.25	0.15	0.12	0.26
58000	0.01	0.02	0.19	0.47	0.03	0.05	0.16	0.09	0.07	0.18
60000	0.02	0.02	0.17	0.49	0.02	0.03	0.15	0.03	0.19	0.08
62000	0.10	0.01	0.13	0.38	0.06	0.02	0.09	0.06	0.09	0.14
64000	0.01	0.01	0.08	0.24	0.02	0.02	0.08	0.01	0.04	0.07
66000	0.02	0.01	0.06	0.15	0.02	0.02	0.06	0.01	0.02	0.08
68000	0.01	0.00	0.07	0.16	0.00	0.02	0.05	0.01	0.04	0.03
70000	0.01	0.02	0.04	0.06	0.00	0.01	0.11	0.00	0.12	0.01
72000	0.00	0.01	0.04	0.13	0.00	0.01	0.04	0.00	0.01	0.04
74000	0.00	0.00	0.02	0.06	0.00	0.01	0.01	0.00	0.01	0.02
76000	0.00	0.00	0.01	0.06	0.00	0.00	0.01	0.00	0.01	0.04
78000	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.02
80000	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.08
82000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2.4.5.4 General Traffic Inputs

Most of the inputs under this category define the axle load configuration and loading details used for calculating pavement responses. The exceptions are "Number of Axles by Axle Type per Truck Class" and "Wheelbase" inputs, which are used in the traffic volume calculations.

Mean Wheel Location

Distance from the outer edge of the wheel to the pavement marking. The inputs at different levels are as follows:

- Level 1 – the value determined through direct measurements on site-specific segments (not applicable to new alignments).
- Level 2 – a regional/statewide average value determined from measurements on roadways with similar traffic characteristics and site conditions (e.g., functional class, pavement type, level of service and so on).
- Level 3 – national average value or estimates based on local experience.

A default (Level 3) mean wheel location of 18 inches is provided in the Design Guide software. This is recommended if more accurate information is not available.

Traffic Wander Standard Deviation

This is the standard deviation of the lateral traffic wander. The wander is used to determine the number of axle load applications over a point for predicting distress and performance. The different levels for traffic wander are:

- Level 1 – the value determined through direct measurements on site-specific segments (not applicable to new alignments).
- Level 2 – a regional/statewide average value determined from measurements on roadways with similar traffic characteristics and site conditions (e.g., functional class, pavement type, level of service and so on).
- Level 3 – national average value or estimates based on local experience.

A default (Level 3) mean truck traffic wander standard deviation of 10 inches is provided in the Design Guide software. This is recommended if more accurate information is not available.

Design Lane Width

This parameter refers to the actual traffic lane width, as defined by the distance between the lane markings on either side of the design lane. It is a design factor and may or may not equal the slab width. The default value for standard-width lanes is 12 ft.

Number of Axle Types per Truck Class

This input represents the average number of axles for each truck class (class 4 to 13) for each axle type (single, tandem, tridem, and quad). The inputs at different levels are as follows:

- Level 1 – the values determined through direct analysis of site-specific traffic data (AVC, WIM, or traffic counts).
- Level 2 – the values determined through direct analysis of regional/statewide traffic data (AVC, WIM, or traffic counts).
- Level 3 – the default values based on analysis of national databases such as the LTPP databases.

Default (Level 3) estimates of the number of axle types per truck class provided in the Design Guide software and estimated using LTPP data are presented table 2.4.11.

Table 2.4.11. Suggested default values for the average number of single, tandem, and tridem axles per truck class.

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

Note: The number of quad axles per truck class is 0.00, because there were too few counted in the LTPP traffic database.

Axle Configuration

A series of data elements are needed to describe the configurations of the typical tire and axle loads that would be applied to the roadway because computed pavement responses are generally sensitive to both wheel locations and the interaction between the various wheels on a given axle. These data elements can be obtained directly from manufacturers databases or measured directly in the field. Typical values are provided for each of the following elements; however, site-specific values may be used, if available.

- Average axle-width – the distance between two outside edges of an axle. For typical trucks, 8.5 ft may be assumed for axle width.
- Dual tire spacing – the distance between centers of a dual tire. Typical dual tire spacing for trucks is 12 in.
- Axle spacing – the distance between the two consecutive axles of a tandem, tridem, or quad. The average axle spacing is 51.6 inches for tandem and 49.2 inches for tridem and quad axles.

For analysis of jointed plain concrete pavement (JPCP), the spacing between the steering and drive axles is used to determine the critical location of the axles on the portland cement concrete (PCC) slab and hence must be provided. Default Level 3 values for spacing between the first and second axles of trucks have been developed using the LTPP WIM data. A review of the individual truck record data suggests a normal, skewed, or bimodal distribution between the first and second axles, and is dependent on the truck class. Table 2.4.12 lists the mean, median and peak spacing and type of distribution between the first (steering) and second (drive) axles. The spacing between the axles for the predominant truck class should be used.

Table 2.4.12. Spacing between the steering and drive axles and type of distribution between the axles that were found from an analysis of the LTPP WIM database.

Truck Class	**Spacing Between the Axles**			
	Type of Distribution	**Average Spacing, ft.**	**Median Spacing, ft.**	**Peaks of occurrence, ft.**
4	Bimodal	29.9	29.9	26.9 and 30.5
5	Skewed to higher spacing	19.7	18.7	16.1
6	Normal	20.7	21.0	21.7
7	Normal	15.7	15.1	14.8
8	Normal	13.8	16.1	16.1
9	Bimodal	19.4	20.0	15.1 and 22.0
10	Skewed to lower spacing	20.3	21.0	23.3
11	Skewed to higher spacing	17.7	16.4	16.7
12	Bimodal	18.0	17.1	15.1 and 21.7
13	Bimodal	17.7	16.4	15.7 and 23.0

Wheelbase

A series of data elements are needed to describe the details of the vehicles wheelbase for use in computing pavement responses. These data elements can be obtained directly from manufacturer's databases or measured directly in the field. Typical values are provided for each of the following elements; however, site-specific values may be used, if available.

Average axle spacing (ft) – short, medium, or long. The recommended values are 12, 15, and 18 ft for short, medium, and long axle spacing, respectively.
Percent of trucks in class 8 through 13 with the short, medium, and long axle spacing – use even distribution (e.g., 33, 33, and 34 percent for short, medium, and long axles, respectively), unless more accurate information is available.

Note that axle spacing distribution is applicable to only truck tractors (Class 8 and above). If other vehicles in the traffic stream also have the axle spacing in the range of the short, medium, and long axles defined above, the frequency of those vehicles should be added to the axle-spacing distribution of truck tractors. For example, if 10 percent of truck traffic is from multiple trailers (Class 11 and above) that have the trailer-to-trailer axle spacing in the "short" range, 10 percent should be added to the percent trucks for "short" axles. Thus, the sum of percent trucks in the short, medium, and long categories can be greater than 100.

Tire Dimensions and Inflation Pressures

Tire dimensions and inflation pressures are important inputs in the performance prediction models. An effort was undertaken to verify tire pressures used in the trucking industry based on information collected from the Tire and Rim Association (TRA), Rubber Manufacturers' Association (RMA), American Trucking Association (ATA), and Truck Trailer Manufacturers' Association (TTMA). Table 2.4.13 shows the section widths for new tires and overall widths for maximum grown tires as well as minimum dual spacing from the 1999 TRA yearbook. Maximum grown tires are tires that have reached their maximum possible increase in dimensions due to wear. These widths are used to determine the minimum dual spacing (spacing between tires in dual applications).

Table 2.4.13. Tire widths and minimum dual spacing from TRA yearbook.

RMA Size	**Ply Rating**	**Minimum Dual Spacing, in.**	**Tire Width, in.**	
			Section (New)	**Overall (Max. Grown)**
295/75R22.5	14	13.5	11.7	12.5
11R22.5	14	12.5	11.0	12.0
11R24.5	14	12.5	11.0	12.0
285/75R24.5	14	12.5	11.1	11.7
11R22.5	16	12.5	11.0	12.0
11R24.5	16	12.5	11.0	12.0
225/70R19.5	12	10.0	8.9	9.5
255/70R22.5	16	11.5	10.0	10.5

Table 2.4.14 shows the maximum allowable loads and cold inflation pressures for different tires. Hot inflation pressures should be used in the Design Guide Software. The hot inflation pressure is typically about 10 to 15 percent greater than the cold inflation pressure. A default hot inflation pressure of 120 psi is used in the Design Guide Software.

Table 2.4.14. Maximum loads and cold inflation pressures for different tires.

RMA Size	**Ply Rating**	**Tire Inflation Pressure, psi**		**Maximum Tire Load, lbs.**	
		Single-Usage	**Dual-Usage**	**Single-Usage**	**Dual-Usage**
295/75R22.5	14	110	110	6,200	5,700
11R22.5	14	104	104	6,200	5,900
11R24.5	14	104	104	6,600	6,000
285/75R24.5	14	110	110	6,200	5,700
11R22.5	16	120	120	6,600	6,000
11R24.5	16	120	120	7,200	6,600
225/70R19.5	12	96	96	3,600	3,400
255/70R22.5	16	120	120	5,500	5,100

2.4.6 INPUT PROCESSING

The traffic inputs described in the preceding sections of this chapter are processed in the Design Guide software/procedure for use in computing pavement responses due to applied wheel loads. The outputs are the number of axle loadings applied incrementally (hourly or monthly) at a specific location over the entire design period. The end result is to produce the following for each wheel load category and wheel location for on an hourly or monthly basis (depending on the analysis type):

- Number of single axles.
- Number of tandem axles.
- Number of tridem axles.
- Number of quad axles.
- Number of truck tractors (Class 8 and above for computing JPCP top-down cracking).

This section presents and discusses the 8 major steps that performed by the Design Guide software for developing the "processed inputs" needed for analysis. The steps are as follows:

1. Determine increments (hourly or monthly).
2. Determine the AADTT value for the base year.
3. Determine the normalized truck traffic class distribution for the base year.
4. Determine the number of axles by axle type for each truck class.
5. Determine the normalized axle load spectra for each axle type and truck class.
6. Decide on the truck traffic forecast or reverse forecast function, and revise the incremental truck traffic for each successive year in the design/analysis period.
7. Multiply the normalized axle load spectra and normalized truck class spectra to the incremental truck traffic to determine the total number of axle applications within each axle load group for each axle type for each hour of each month of each year in the design/analysis period.
8. Specify details of the axle and tire loads.

2.4.6.1 Step 1: Subdivide the Year into Traffic Seasons – Hours of the Day or Months of the Year with Similar Traffic Features

The traffic data for a design segment should be divided into different traffic increments for data collection purposes. An increment can be defined in various ways, but the length of each increment in the Design Guide software has been preset to 1 hour or month for simplicity and computation efficiency between the different modules in the software

2.4.6.2 Step 2: Determine AADTT for the Base Year

This step has been described in detail in the preceding sections of this chapter.

2.4.6.3 Step 3: Determine the Normalized Truck Traffic Distribution

The third step of the procedure is to determine the normalized distribution of the number of trucks by vehicle class and to determine if the percentages of the total number of trucks within each vehicle class are changing with time.

2.4.6.4 Step 4: Determine the Number of Axles by Each Axle Type and Truck Class

The number of axles by each axle type and truck class can be determined from an analysis of the WIM data as described in the preceding sections of this chapter by computing the total number of each axle type weighed (single, tandem, tridem, quad axles) for a specific truck class and dividing it by the total number of trucks weighed within that truck class to determine the average number of axles of each axle type for each truck class. The average number of axles per truck class is typically independent of site-specific conditions.

2.4.6.5 Step 5: Determine the Normalized Axle Load Spectra for Each Axle Type

The fifth major step of the process is to determine the normalized axle load distribution or spectra from the site-specific, regional/statewide, or national WIM data. The load spectra are normalized on an annual basis because no systematic or significant year-to-year or month-to-month differences were found in the analysis of the LTPP WIM data.

2.4.6.6 Step 6: Establish Traffic Growth/Decay Rates

The traffic inputs for the base year for pavement design and evaluation are estimated from historical and existing traffic levels. The base year input values are modified to account for future growth that reflects changes in the local conditions affecting the transport of goods and materials. While it may be possible to measure current traffic levels and axle loads along a roadway, the characteristics of the traffic stream change over time and some of these changes can be substantial and highly variable. Thus, estimating historical traffic and projecting future traffic levels are difficult and risky. The longer period of time the projections are made, the greater the potential error.

2.4.6.7 Step 7: Predict Total Traffic – Future and Historical

The normalized axle load distribution and the normalized traffic distribution are combined with the total number of vehicles that are predicted with time. These normalized relationships are used to determine the number of axle loads within each load group for each axle type. The following steps summarize the prediction of the future or historical total number of single, tandem and tridem axles within each load group.

1. The average annual number of trucks per day is obtained for year l based on the selected growth function, $AADTT_l$. This value is multiplied by the truck factors discussed in step 4 and by the number of days within month j to obtain the total number of trucks within time increment i of month j of year l, $TT_{l,j,i}$.

a. $TT_{l,j,i} = (AADTT_l)(MDF_j)(HDF_i)(DDF)(LDF)(\text{No. of Days}_j)$ (2.4.2)

2. The total number of trucks within each time increment of a particular year and month is multiplied by the normalized truck class distribution percentage for a particular truck class k (NTP_k) to obtain the total number of trucks for each truck class, $T_{l,j,I,k}$.

b. $T_{l,j,I,k} = (TT_{l,j,I})(NTP_k)$ (2.4.3)

3. The average number of axles by axle type (single, tandem and tridem) for each truck class (which is independent of time), $NAT_{k,a}$, is multiplied by the total number of trucks within each truck class to obtain the total number of axles for each axle type, a (single, tandem, tridem, and quad) for that truck class, $NA_{l,j,I,k,a}$.

c. $NA_{l,j,I,k,a} = (T_{l,j,I,k})(NAT_{k,a})$ (2.4.4)

b. The total number axles for each axle type for a specific truck class are multiplied by the normalized axle load distribution percentage of a specific load group to obtain the number of axles (by axle type) within each load group for a specific axle type under a specific truck class, $AL_{l,j,I,k,a,w}$.

d. $AL_{l,j,I,k,a,w} = (NWP_{a,w})(NA_{l,j,I,k,a})$ (2.4.5)

The axle applications for each axle type are then summed for all truck classifications within each time increment to obtain the total number of axle applications within each load group by axle type for that time increment. These number of axle applications by axle type and load group for each time increment by year are then used within the incremental damage module to predict the load related distresses with time.

It should be noted that the percentage of the total traffic population in the light axle load groups are not important regarding pavement design and prediction of load related distresses. Therefore, the normalized approach focuses more on the heavier load groups for which a sufficient number of axles were recorded in the WIM data.

2.4.6.8 Step 8: Determine the Axle and Tire Loading Details

Recommendations were presented in preceding sections of this chapter.

2.4.7 TRAFFIC SAMPLING PLAN FOR SITE SPECIFIC AVC AND WIM DATA

This section provides an overview of the sampling plan requirements to estimate the truck traffic characteristics from the AVC and WIM data measured for a specific design segment of a roadway. For the cases when the traffic inputs are determined from regional/statewide or national data the historical AVC and/or WIM traffic data measured on roadways with similar traffic characteristics should be combined and used to compute the require traffic inputs for design.

2.4.7.1 Sample Location—Location of Traffic Measurement Equipment

In most cases, the normalized axle load distribution or spectra for a project can be assumed to be constant for a specific truck class and axle type. However, the truck traffic spectra can change along a segment of highway, especially through urban areas. As such, one WIM location per project should be sufficient, but multiple locations of the AVC equipment may be needed to estimate truck volumes and distributions accurately along a project. The decision on the number of AVC sampling locations within the project limits should be based on experience and the locations of industries and intersecting highways along the project that have an effect on the truck volume and distribution.

2.4.7.2 Sample Size and Frequency

Traffic data should be collected in accordance with the procedures and equipment (that has been properly calibrated) specified by LTPP. Tables 2.4.15 through 2.4.17 can be used as guidance for initially selecting the number of days required to collect an adequate amount of data from the traffic population for a specific site. The number of days for sampling the traffic was based on analyses of LTPP traffic data using the predominant truck type and load for the site and is dependent on the level of confidence and expected error considered acceptable to the designer. The sample size (minimum number of days) was not based on measuring the heaviest loads (or overloaded trucks) or on a truck class with very few operations within the traffic stream.

Table 2.4.15. Minimum sample size (number of days per year) to estimate the normalized axle load distribution – WIM data.

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

Table 2.4.16. Minimum sample size (number of days per season) to estimate the normalized truck traffic distribution – AVC data.

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

***Continuous sampling is required for these conditions.

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

Table 2.4.17. Minimum sample size (number of days per year) to estimate the total vehicles per day and year – AVC or vehicle count data.

Expected Error (± percent)	**Level of Confidence or Significance, percent**				
	80	**90**	**95**	**97.5**	**99**
20	3	7	12	16	23
10	12	27	45	64	90
5	47	109	179	254	—***
2	292	—***	—***	—***	—***
1	—***	—***	—***	—***	—***

***Continuous sampling is required for these conditions.

WIM Data

The normalized axle load distribution has been found to be constant over time and season. Thus, the suggested lot size for collecting the WIM data is one year, unless previous experience or studies indicate significant changes in the axle load distribution with time. Table 2.4.15 can be used as a guide for selecting the continuous number of WIM days per year that are needed for a specific confidence interval and expected error.

AVC Data

Minimum Number of Years Included in Traffic Volume Sample.

A minimum of 3 years should be included in the traffic sample, if possible, to reduce any bias of the sample caused by an anomaly that may appear in any one year of the traffic data. Where an agency has extensive regional data for similar highways, this minimum value can be reduced to 1 year.

Seasonal Samples

The sampling plan should be consistent with the time frame used for the damage computations or performance predictions. The traffic module uses a monthly interval for determining the traffic inputs. If an agency has no regional data or knowledge on the traffic characteristics for a segment of highway, the lot size should be one month until sufficient data are collected and analyzed. However, some agencies have sufficient historical data to determine the seasonal effects, if any, and which months can be combined into one season. For these cases, the traffic-sampling plan can be revised and those months with similar truck traffic can be combined into one season. Table 2.4.16 can be used as a guide to estimate the number of days of AVC data per season.

Stratified Random Sampling Plan

A stratified random sampling plan should be developed and implemented to identify any monthly (or seasonal) and annual differences that may be present in the traffic population.

Traffic Volume Data

Collection of the traffic volume data should be consistent with the AVC data. Table 2.4.17 can be used as a guide to estimate the number of days of vehicle count data per year. The number of days should be stratified by season and day of week (weekends versus weekdays).

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