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Development Work for Improved Heavy-Duty Vehicle Modeling Capability Data Mining – FHWA Datasets

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DEVELOPMENT WORK FOR IMPROVED HEAVY-DUTY VEHICLE MODELING CAPABILITY DATA MINING – FHWA DATASETS

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ABSTRACT

Heavy-duty vehicles have been seen as contributing a large fraction of emissions from on-road vehicles and are coming under more intense scrutiny because light-duty emissions have been controlled to a greater extent than heavy-duty vehicle emissions. A heavy-duty vehicle can produce 10 to 100 times the emissions (of NO_X and PM emissions especially) of a light-duty vehicle. Thus, heavy-duty vehicle activity needs to be better characterized. Key uncertainties with the use of MOBILE6 regarding heavy-duty vehicle emissions include the fraction of heavy-duty vehicles on all types of roadways at all times of day. In addition, there may be regional variability in both the fraction of different vehicle classes and the vehicle weights within each class.

With the Motor Vehicle Emissions Simulator (MOVES) model, greater emphasis is given to physical parameters affecting the engine loads and therefore the emissions from individual vehicles. One primary factor affecting the engine load is the vehicle weight; the weight of the vehicle on the road is needed to estimate its in-use emissions. Because the effect of vehicle weight may be nonlinear for certain types of driving, it is important to incorporate the weight distribution of vehicles into emission estimates.

Databases collected by the Federal Highway Administration (FHWA) include vehicle count and classification from the Highway Performance Monitoring System (HPMS) using automated traffic recorders (ATR) used to produce the Travel Volume Trends (TVT) reports. Other data sets compile the results of data collection from weigh in motion (WIM) sensors, and other data sources (visual observation, weigh stations, and other special projects) maintained by the FHWA and compiled in the Vehicle Travel Information System (VTRIS). A discussion of these data sources including original sources, representativeness, and quality and data reduction procedures used in this work are provided in Appendix A.

This work consisted of an investigation and evaluation of these databases for the purpose of assisting in the development of improved emissions estimates of heavy-duty vehicles. The goal of the project was therefore to produce estimates of the fraction of heavy-duty vehicles of all vehicle traffic, and weight distributions for those vehicles according to the time of day, day of week, and other temporal variables, and an investigation of regional differences.

FOREWORD

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

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This publication has been produced as part of the laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

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AM	ante meridiem
ATR	automated traffic recorders
EPA	U. S. Environmental Protection Agency
FHWA	Federal Highway Administration
FIPs	Federal Information Processing Standards
HPMS	Highway Performance Monitoring System
lbs.	pounds
MEASURE	Mobile Emissions Assessment System for Urban and Regional Evaluation
MOBILE	EPA's mobile source emission factor model
MOVES	Motor Vehicle Emissions Simulator
NOX	oxides of nitrogen
OMB	Office of Management and Budget
PM	particulate matter
PM	post meridiem
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
SIP	state implementation plan
TCEQ	Texas Commission on Environmental Quality
TTI	Texas Transportation Institute
TVT	Travel Volume Trends
VMT	vehicle miles of travel
VTRIS	Vehicle Travel Information System
WIM	weigh-in-motion

1. INTRODUCTION

Heavy-duty vehicles have been seen as contributing a large fraction of emissions from on-road vehicles and are coming under more intense scrutiny because light-duty emissions have been controlled to a greater extent than heavy-duty vehicle emissions. A heavy-duty vehicle can produce 10 to 100 times the emissions (of NO_X and PM emissions especially) of a light-duty vehicle. Thus, heavy-duty vehicle activity needs to be better characterized. Key uncertainties with the use of MOBILE6 regarding heavy-duty vehicle emissions include the fraction of heavy-duty vehicles on all types of roadways at all times of day. In addition, there may be regional variability in both the fraction of different vehicle classes and the vehicle weights within each class.

With the MEASURE[1] model and the developing MOVES[2] model (the eventual replacement for MOBILE[3]), greater emphasis is given to physical parameters affecting the engine loads and therefore the emissions from individual vehicles. One primary factor affecting the engine load is the vehicle weight; the weight of the vehicle on the road is needed to estimate the in-use emissions of given vehicles. Because the effect of vehicle weight may be nonlinear for certain types of driving, it is important to incorporate the weight distribution of vehicles into emission estimates.

Databases collected by the Federal Highway Administration (FHWA) include vehicle count and classification from the Highway Performance Monitoring System (HPMS) using automated traffic recorders (ATR) used to produce the Travel Volume Trends (TVT) reports. Other data sets compile the results of data collection from weigh in motion (WIM) sensors, and other data sources (visual observation, weigh stations, and other special projects) maintained by the FHWA and compiled in the Vehicle Travel Information System (VTRIS). A discussion of these

[1]MEASURE = Mobile Emissions Assessment System for Urban and Regional Evaluation. Model. This model is a prototype GIS-based modal emissions model.

[2]MOVES = Mobile Vehicle Emissions Estimator, next generation mobile source emissions model. The model will be used for State Implementation Plan emission inventories and will replace the current MOBILE model.

[3]MOBILE = Current mobile source emissions model used for State Implementation Plan emission inventories.

data sources including original sources, representativeness, and quality and data reduction procedures used in this work are provided in Appendix A.

The primary goals of this work were to investigate the vehicle weights and mix of vehicle classes depending upon a number of regional and temporal factors by vehicle and roadway types. ENVIRON reviewed and in this report suggests how the TVT data can be used to estimate temporal variability (by month, day of week, time of day) of total traffic volumes for all vehicles types combined. Using the VTRIS data the results of this work are provided as summary data in a series of files that combine and average weight, weight distributions, and vehicle mix depending upon the state where the measurement was taken or as a national average, time period (month, day of week, or hour of day), roadway type as described in Table 1, and vehicle classification as described in Table 2.

Table 1. FHWA roadway functional classification (types) in VTRIS.

Rural		Urban	
Code	Classification Description	Code	Classification Description
1	Principal Arterial – Interstate	11	Principal Arterial – Interstate
2	Principal Arterial – Other	12	Principal Arterial – Other Freeways or Expressways
6	Minor Arterial	14	Principal Arterial – Other
7	Major Collector	16	Minor Arterial
8	Minor Collector	17	Collector
9	Local System	19	Local System

Table 2. FHWA vehicle classifications.

FHWA	VTRIS Vehicle Type
1	Motorcycle
2	Passenger cars
3	Other 2-axle, 4-tire single unit vehicles
4	Buses
5	2-axle, 6-tire single-unit vehicles
6	3-axle, 6-tire single-unit vehicles
7	4+ axle single-unit vehicles
8	4 or less axle combination vehicles
9	5-axle combination vehicles
10	6+ axle combination vehicles
11	5-axle multitrailer vehicles
12	6-axle multitrailer vehicles
13	7+ axle multi-trailer vehicles
14	Unclassified
15	Unclassifiable

1.1 Average Vehicle Weight and Weight Distributions

The vehicle weight observations were not grouped by any method prior to averaging by the categories described in this report, namely roadway class, vehicle class grouping, month, day of week, or hour. Each observation was treated with equal weight in the calculation of the summary statistics.

The vehicle weight can be presented as both an average and as a distribution of the vehicles across a weight bin spectrum. Table 3 provides the average weight range over the states by vehicle class across various roadway types and using the 1999 and 2000 VTRIS data. The smaller vehicle classes have vehicle weights that are higher than one might expect and have more relatively variability than heavier vehicles, especially vehicle classes 1-3. The variability could be a function of the error in the measurement itself where the error is constant without regard to the vehicle weight, but a detailed evaluation of the measurement error is beyond the scope of the current project. The average weight likely demonstrates which vehicles are most like other vehicle classes, for instance vehicle class 7 is more like vehicle classes 9-13 while vehicle class 8 is more like vehicle class 6.

Table 3. Vehicle identifiers and typical average vehicle weight range.

FHWA Class	Description	Average Vehicle Weight (lbs.)
1	Motorcycles*	8,000 – 25,000
2	Passenger vehicles	4,500 – 9,000
3	Two-axle, four-tire single-unit trucks	7,000 – 9,000
4	Buses	25,000 – 29,000
5	Six-tire, two-axle single-unit vehicles	12,000 – 14,000
6	Three-axle single-unit vehicles	24,000 – 30,000
7	Four or more axle single-unit vehicles	41,000 – 58,000
8	Three or four axle single-trailer vehicles	26,000 – 31,000
9	Five-axle single-trailer vehicles	48,000 – 58,000
10	Six-axle multi-trailer vehicles	60,000 – 65,000
11	Five or less axle multi-trailer vehicles	50,000 – 61,000
12	Six-axle multi-trailer vehicles	56,000 – 63,000
13	Seven or more axle multi-trailer vehicles	72,000 - 92,000

*Motorcycle data highly variable and not used in this analysis.

When investigating vehicle weight distribution, the weight bin distribution listed in Table 4 was used to demonstrate the range of vehicle weights.

Table 4. Vehicle weight bin descriptions.

Weight Bin Number	Weight Class ID	Weight Range (lbs)		Mid-point Weight (lbs)
		Low Weight (≤)	High Weight (<)	
0	0	NA	NA	NULL
1 – B20	20	0	X < 2,000	1,000
2 – B25	25	2,000 ≤ X	X < 2,500	2,250
3 – B30	30	2,500	3,000	2,750
4 – B35	35	3,000	3,500	3,250
5 – B40	40	3,500	4,000	3,750
6 – B45	45	4,000	4,500	4,250
7 – B50	50	4,500	5,000	4,750
8 – B60	60	5,000	6,000	5,500
9 – B70	70	6,000	7,000	6,500
10 – B80	80	7,000	8,000	7,500
11 – B90	90	8,000	9,000	8,500
12 – B100	100	9,000	10,000	9,500
13 – B140	140	10,000	14,000	12,000
14 – B160	160	14,000	16,000	15,000
15 – B195	195	16,000	19,500	17,750
16 – B260	260	19,500	26,000	22,750
17 – B330	330	26,000	33,000	29,500
18 – B400	400	33,000	40,000	36,500
19 – B500	500	40,000	50,000	45,000
20 – B600	600	50,000	60,000	55,000
21 – B800	800	60,000	80,000	70,000
22 – B1000	1000	80,000	100,000	90,000
23 – B1300	1300	100,000	130,000	115,000
24 – B9999	9999	130,000	Not applicable	130,000

The typical weight distributions for the more important vehicle classes are shown in the Figures 1 through 5, which show weight bin populations by day of week. Vehicle classes 2 and 3 are typically associated with light-duty vehicles, however the weight bin segments range typically from 5,000 to 8,000 pounds, somewhat higher than the typical curb weights for light-duty vehicles.

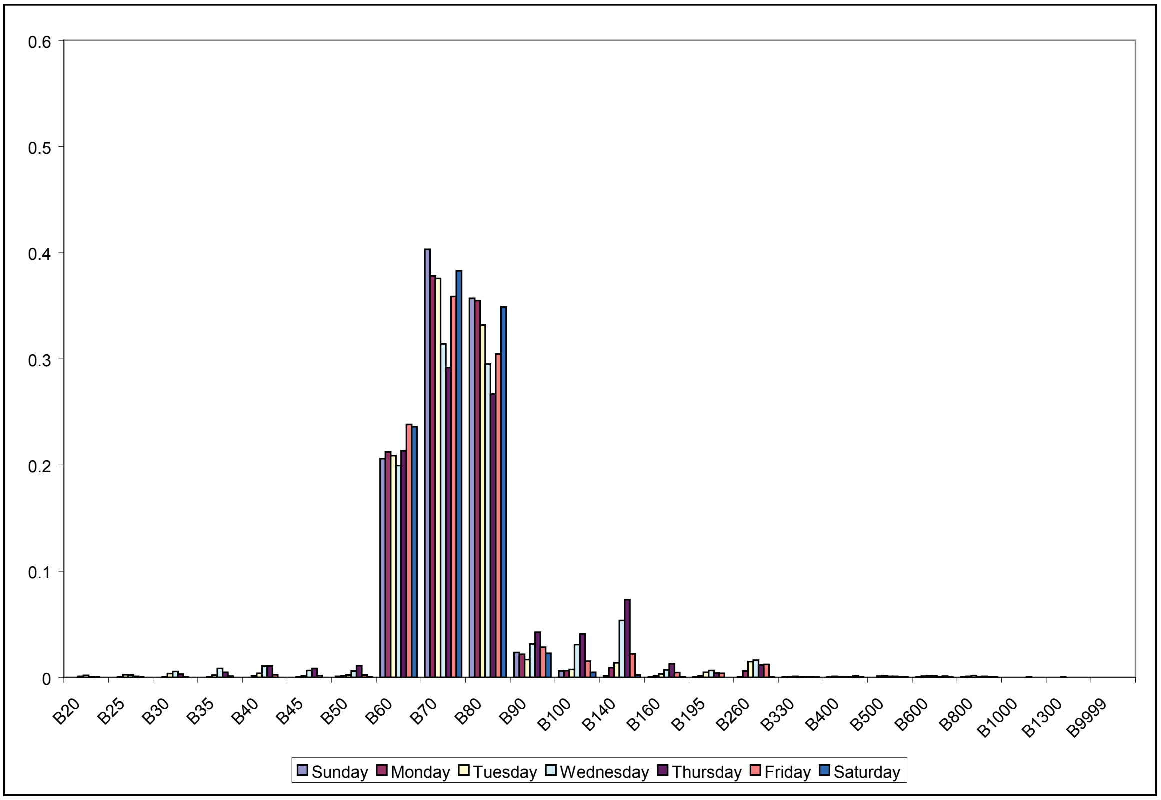

Figure 1. Weight bin distribution by day of week for vehicle class 2 (passenger cars) on road type 11 in 2000.

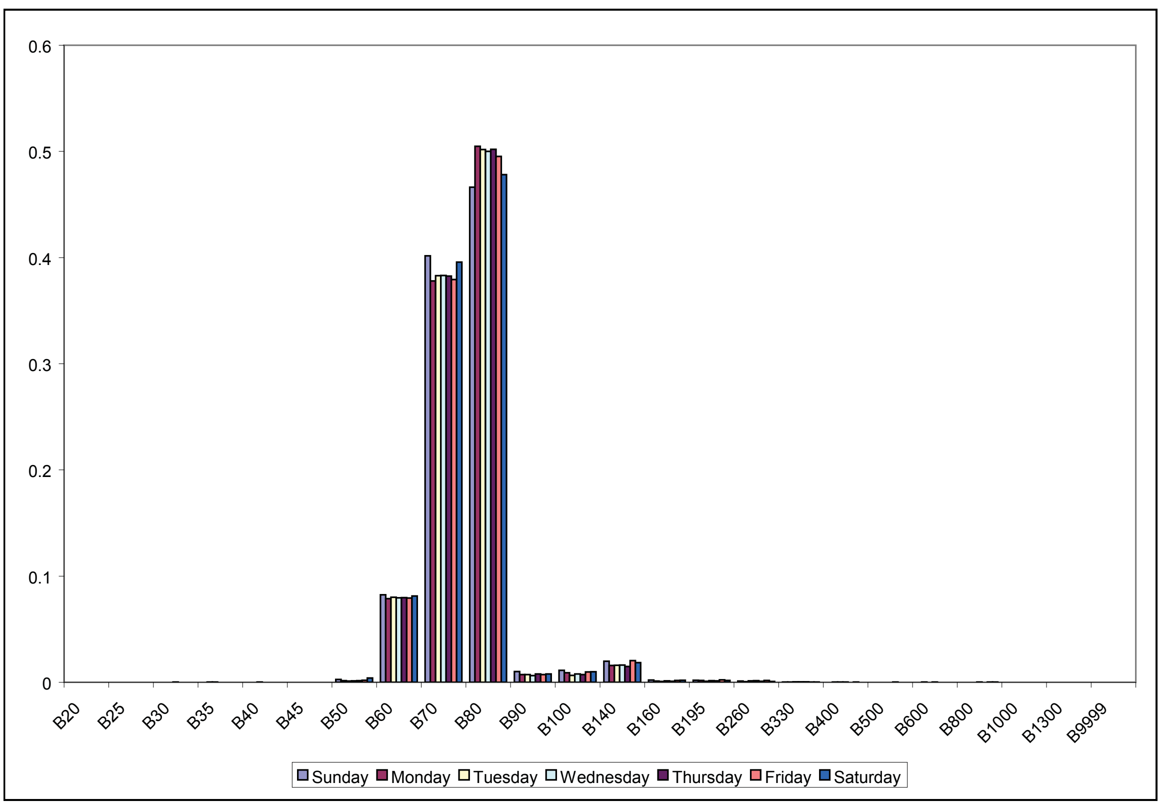

Figure 2. Weight bin distribution by day of week for vehicle class 3 (7000-9000 lb two-axle, four-tire single-unit trucks) on road type 11 in 2000.

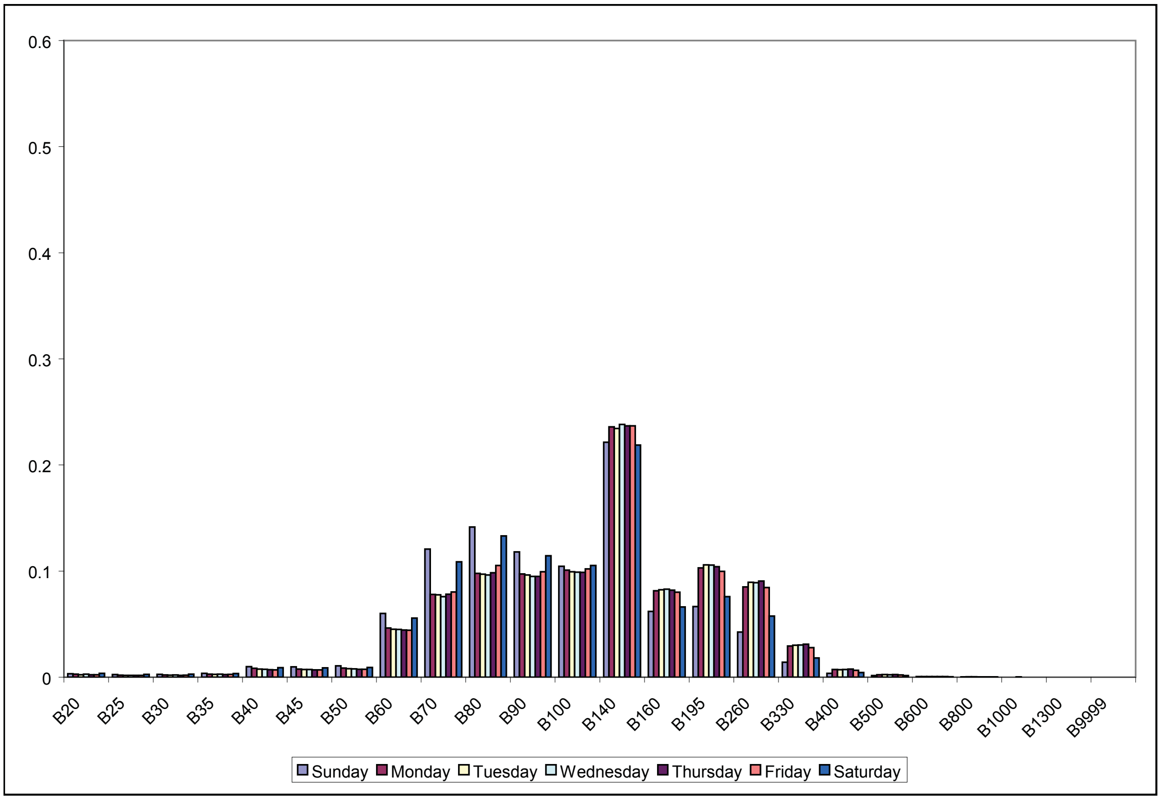

Figure 3. Weight bin distribution by day of week for vehicle class 5 (12,000-14,000 lb six-tire, two-axle single-unit vehicles) on road type 11 in 2000.

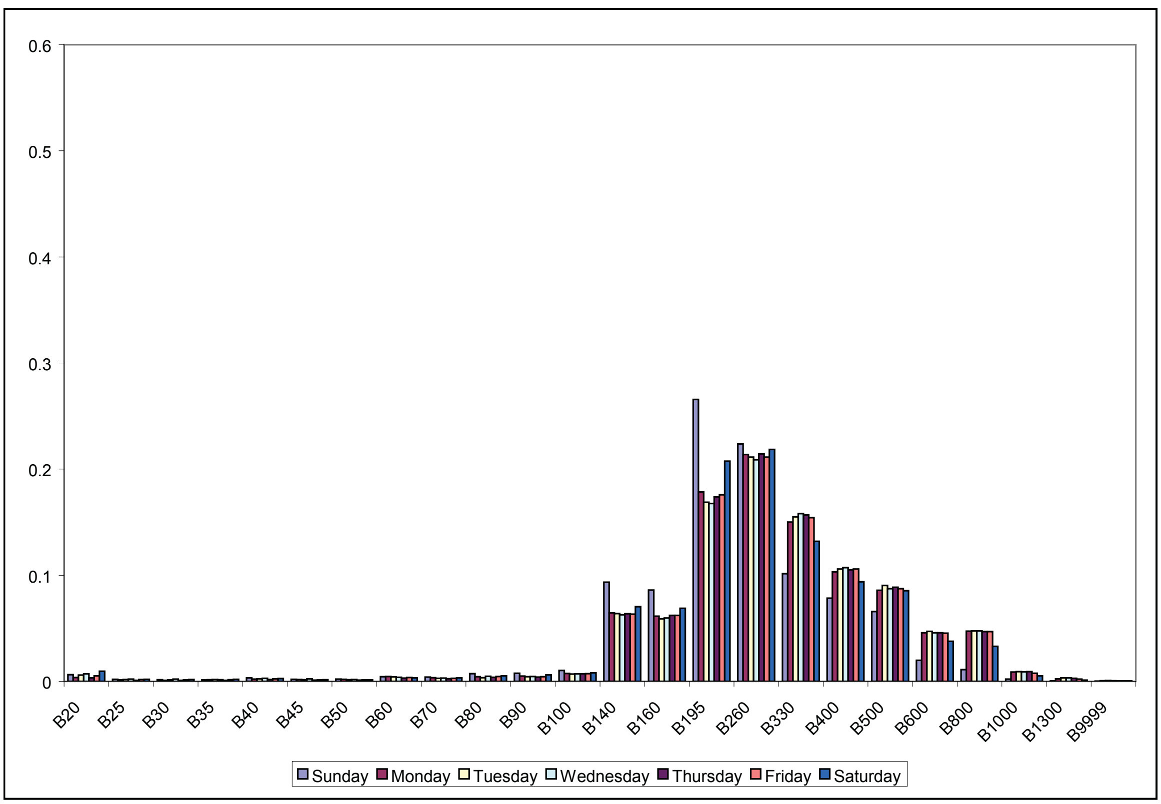

Figure 4. Weight bin distribution by day of week for vehicle class 6 and 7 (24,000-58,000 lb three or more axle single-unit vehicles) on road type 11 in 2000.

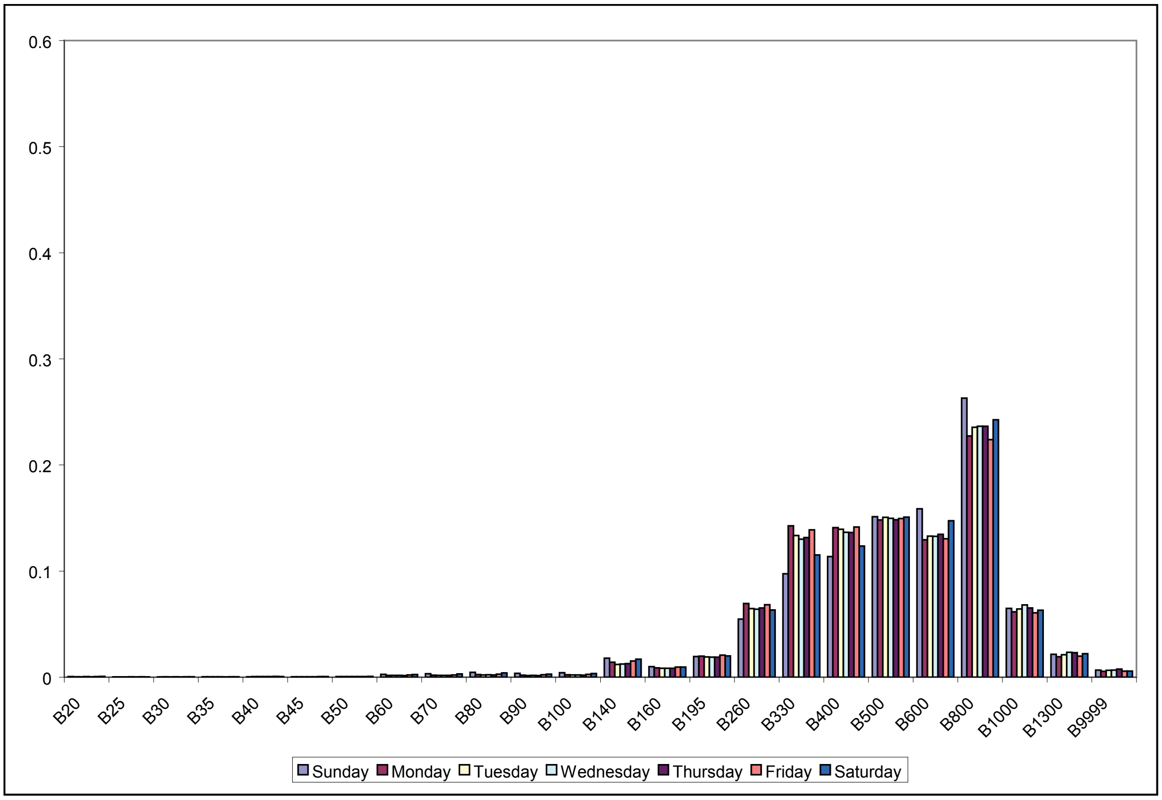

Figure 5. Weight bin distribution by day of week for vehicle type 8 – 13 (26,000-92,000 single- and multi-trailer vehicles) on road type 11 in 2000.

1.2 VMT Mix

The vehicle mix data were provided in FHWA vehicle classes. Appendix B provides a suggested method to cross-reference the FHWA vehicle class into MOBILE vehicle types. The FHWA vehicle mix categories do not necessarily correspond to the MOBILE vehicle types, so some estimates and governing assumptions about the vehicle fleet make-up must be made to cross-reference the FHWA classes into vehicle classes useful for emission estimation. Many states including Texas, Wisconsin, Illinois, Michigan, and Minnesota are using the FHWA vehicle classification data to better estimate the vehicle mix for their emissions modeling. The vehicle mix results presented in this work also provide an understanding of the more important vehicle classes when investigating the vehicle weight.

In order to ensure that the vehicle classes count data was not more heavily weighted by sites with longer periods of observation than others, but rather weighted by sites with heavier traffic volume, the class counts were averaged at individual sites before being averaged across sites. The steps followed in processing the class count data are as follows:

1. All counts across lanes in the same roadway direction were totaled. Different directions at site were treated separately.

2. All counts (either total volume or count for each vehicle class) were averaged for each site-direction pair by hour, day of week (i.e., Sunday through Saturday), month, and roadway classification. This means that at most five values were averaged together, corresponding to the total number of days in a week during one month. In other words, all Monday counts during January for hour 10 were averaged together at each site-direction pair.
3. The hourly class counts were averaged across the sites by roadway function class, vehicle class, month, day of week, and hour of the day.

2. INVESTIGATION OF REGIONAL AGGREGATION

An investigation was conducted to determine if are were any regional differences in the vehicle weight and vehicle mix. In this study, the average vehicle weight was used rather than the weight bin distribution because it is more difficult to understand state-to-state differences in the distributions and any differences in the weight distribution are nearly always reflected in the average weight. The vehicle mix was also grouped into primarily light-duty and heavy-duty vehicle classes to avoid confusion that might result from a large number of vehicle classes. The term regional may describe groups of adjacent states or states that exhibit similar travel patterns perhaps for similar reasons.

2.1 Average Weight by State

The VTRIS site information (where vehicle class counts are made and vehicle weights are measured) contains the state and county FIPs codes. Using this information, it is possible to aggregate vehicle class count and vehicle weight distributions by designated state and county groupings, where the groupings could extend from one state into another. ENVIRON extracted the data corresponding to interstates and freeways by county to look for possible regional effects.

The vehicle weight information was compared using average weight ranges for vehicle classes 8 – 13, the larger combination vehicles, and vehicle classes 5 – 7, single-unit trucks. The larger combination vehicles represent a nearly homogenous grouping of class 8 trucks, while vehicle classes 5 – 7 include all types of trucks. Therefore the vehicle classes 8 – 13 show a more uniform vehicle weight range than other truck types.

Figures 6 and 7 show the relative average weight by state for vehicle classes 8 – 13 on rural and urban interstate (average weight 50,000 lbs.) roadway types, which were those with the greatest number of vehicle measurements. The 1999 data is represented by the solid blue bars, and the 2000 data is represented by the red hashed bars. The number of observations is reported underneath each bar. No individual state had an average vehicle weight in excess or less than 30 percent of the national average. On rural interstates, only Indiana, Michigan, and New Jersey had consistent (two year) averages with an average weight less than 10% of the national average, while only South Dakota had consistently higher average weight readings. On urban interstates, the data are more variable from state to state with some states showing extraordinary averages, especially Georgia where the estimate was based on only 597 observations and South Carolina based on less than 2,000 observations for each year. However, Connecticut and Wyoming both show consistently higher average vehicle weights.

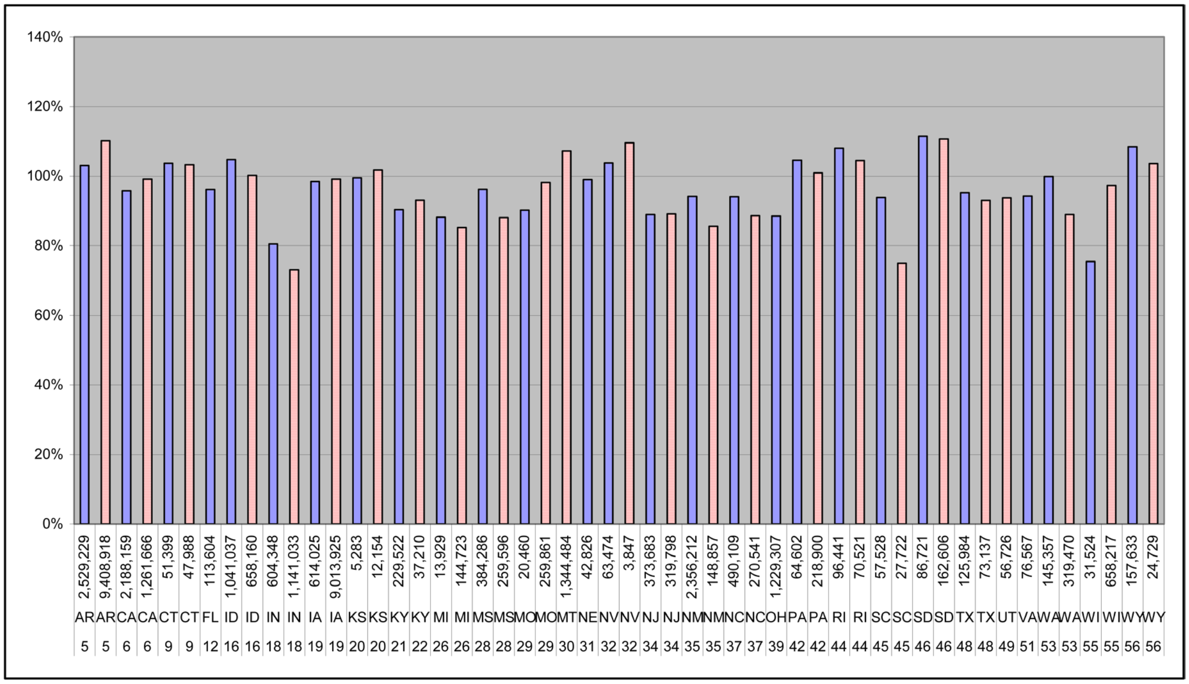

Figure 6. Relative average weight by state for vehicles 8 – 13 in 1999 and 2000 on road type 1, rural interstates. (Number of observations used for each state average reported along axis. 1999 data is solid blue and 2000 is red on white hash.)

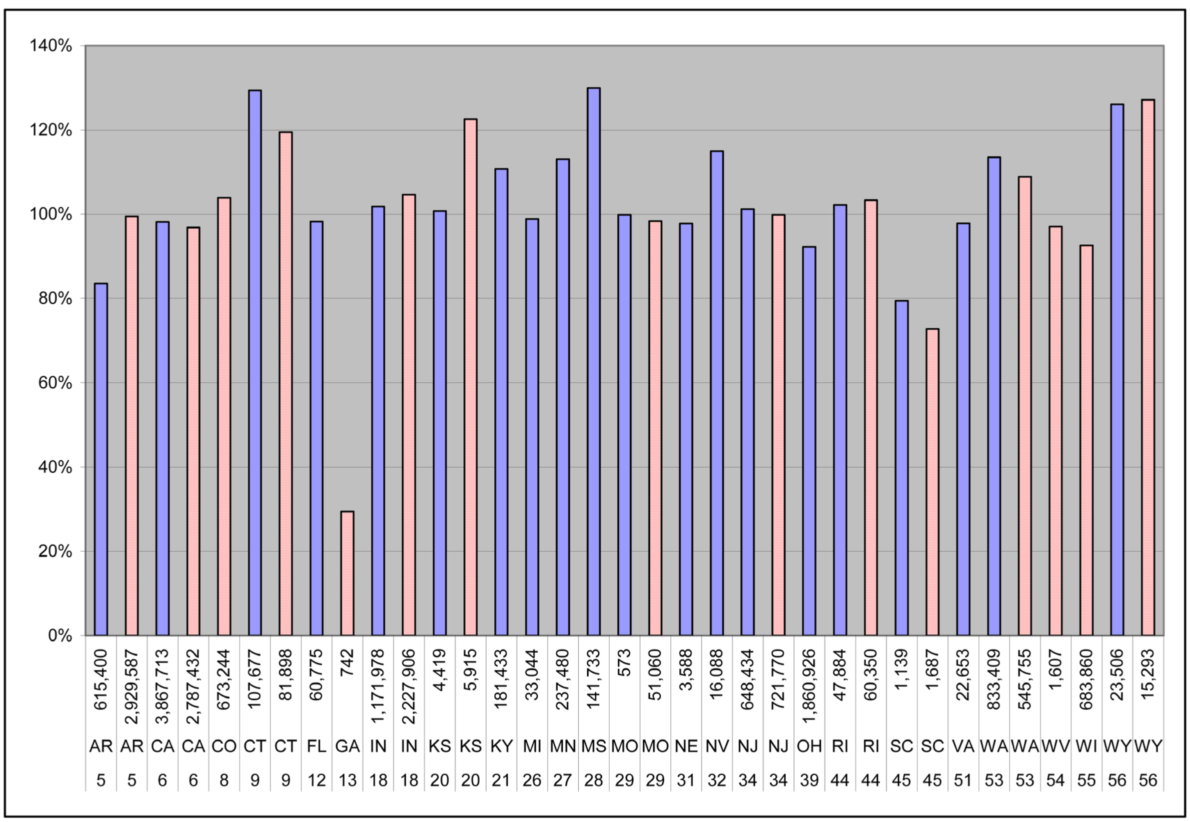

Figure 7. Relative average weight by state for vehicles 8 – 13 in 1999 and 2000 on road type 11, urban interstates. (Number of observations used for each state average reported along axis. 1999 data is solid blue and 2000 is red on white hash.)

Figures 8 and 9 show the relative average weight by state for vehicle class 5 on rural (average weight 13,000 lbs.) and urban interstates (12,000 lbs.) roadway types. The average weight for this vehicle class varies more widely from state to state and year to year, perhaps because the vehicle represented by this vehicle class could be one of several gross vehicle weight ranges from light-duty up to Class 8 trucks.

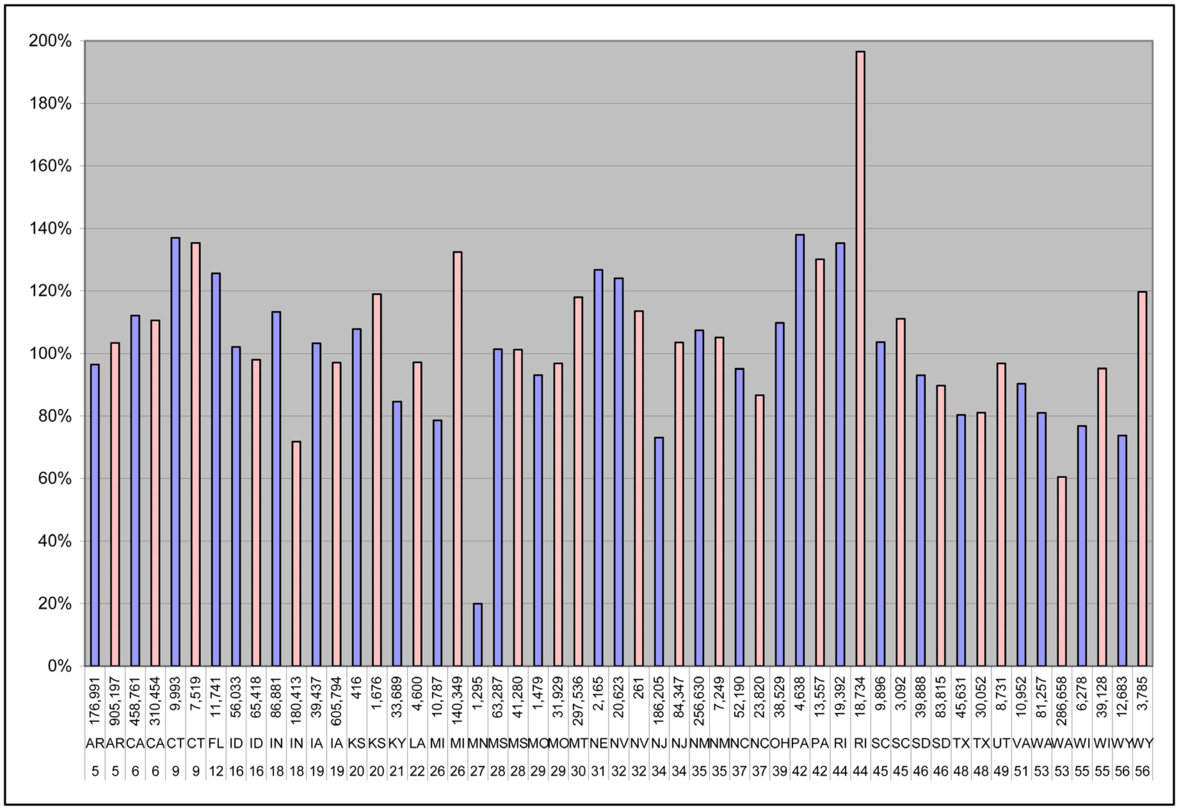

Figure 8. Relative average weight by state for vehicle 5 in 1999 and 2000 on road type 1, rural interstates. (Number of observations used for each state average reported along axis. 1999 data is solid blue and 2000 is red on white hash.)

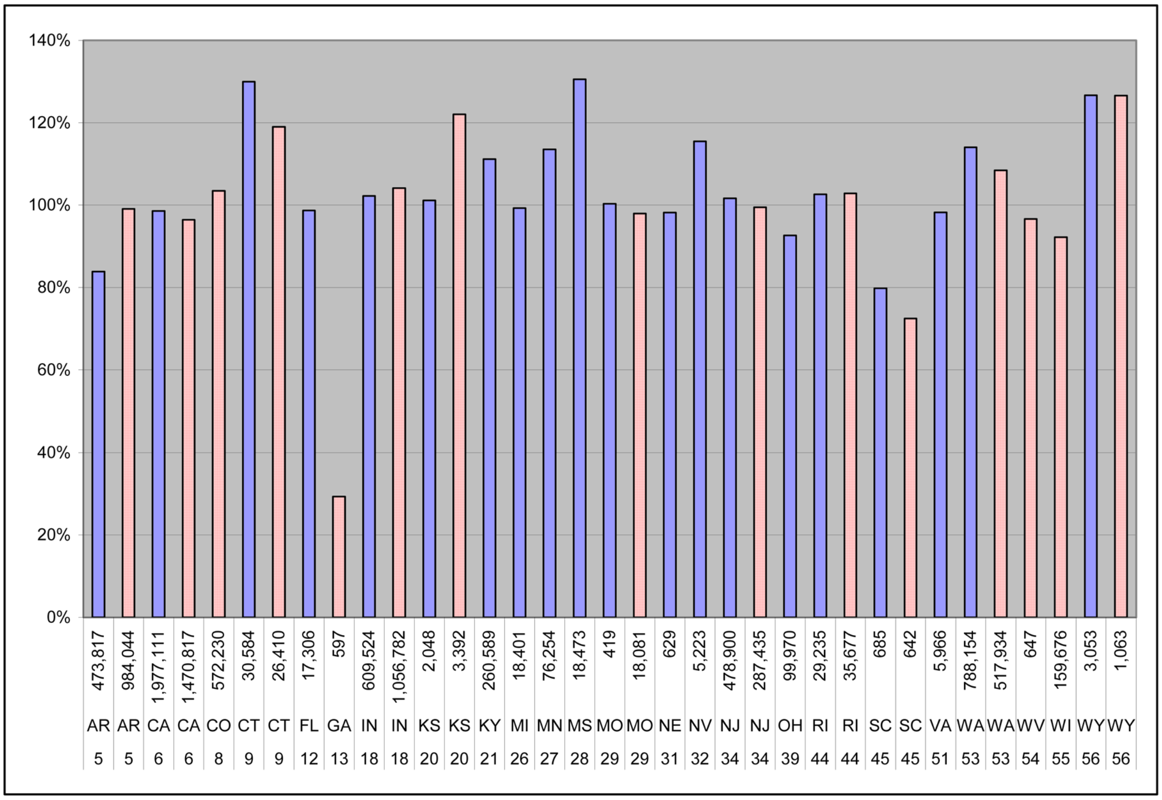

Figure 9. Relative average weight by state for vehicle 5 in 1999 and 2000 on road type 11, urban interstates. (Number of observations used for each state average reported along axis. 1999 data is solid blue and 2000 is red on white hash.)

No discernable regional pattern in vehicle weights could be determined from their data, as shown in Figure 10 for rural interstates. Some states (e.g., Wyoming, Indiana) show consistently higher or lower weights than the national average, but neighboring states do not show a similar pattern. Therefore a clear determination of state-to-state regions that affect vehicle weight could not be found.

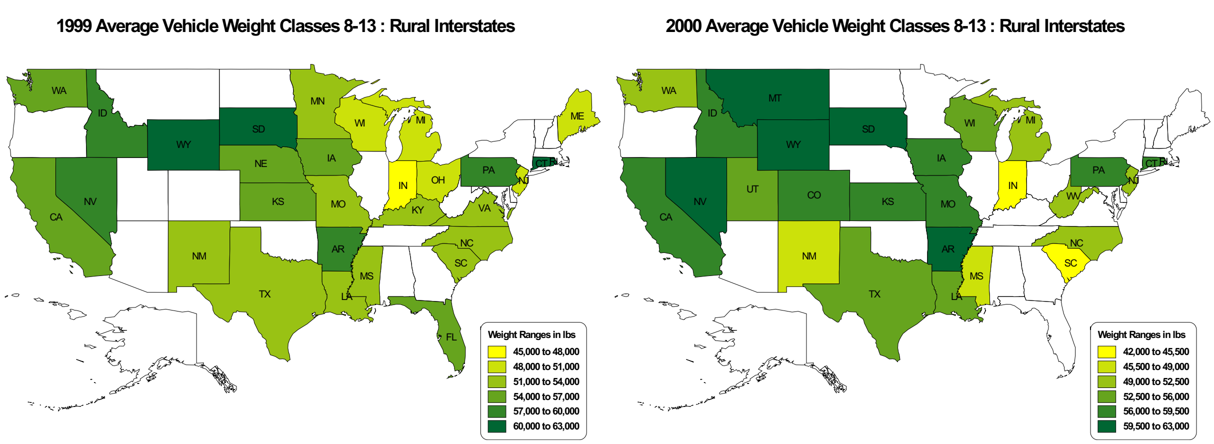

Figure 10. State by state average weight for vehicle classes 8 – 13 on rural interstates in 1999 and 2000.

2.2 Vehicle Mix

The vehicle mix could depend upon a number of factors including the road type, month and day of week as well as regional definitions. It was discovered that by and large the weekdays could be combined, although the day of week does have some subtle effects on the class fractions. This is discussed in more detail later.

The vehicle mix information shows some potential regional variability, especially on rural interstates during the week. Figure 11 shows the distribution of vehicle mix by state for 1999 and 2000, where the state and year is indicated at the base of the bar. States that show a low heavy-duty (vehicle classes 4 – 13) mix were California, Florida, New Jersey, and Rhode Island. Those states with high heavy-duty mixes were Arkansas, Georgia, Iowa, Missouri, New Mexico, Ohio, Oklahoma, and Pennsylvania. Therefore, ocean coastal states tended to have low truck activity relative to that of light-duty vehicles while interior states had higher truck activity on rural interstates.

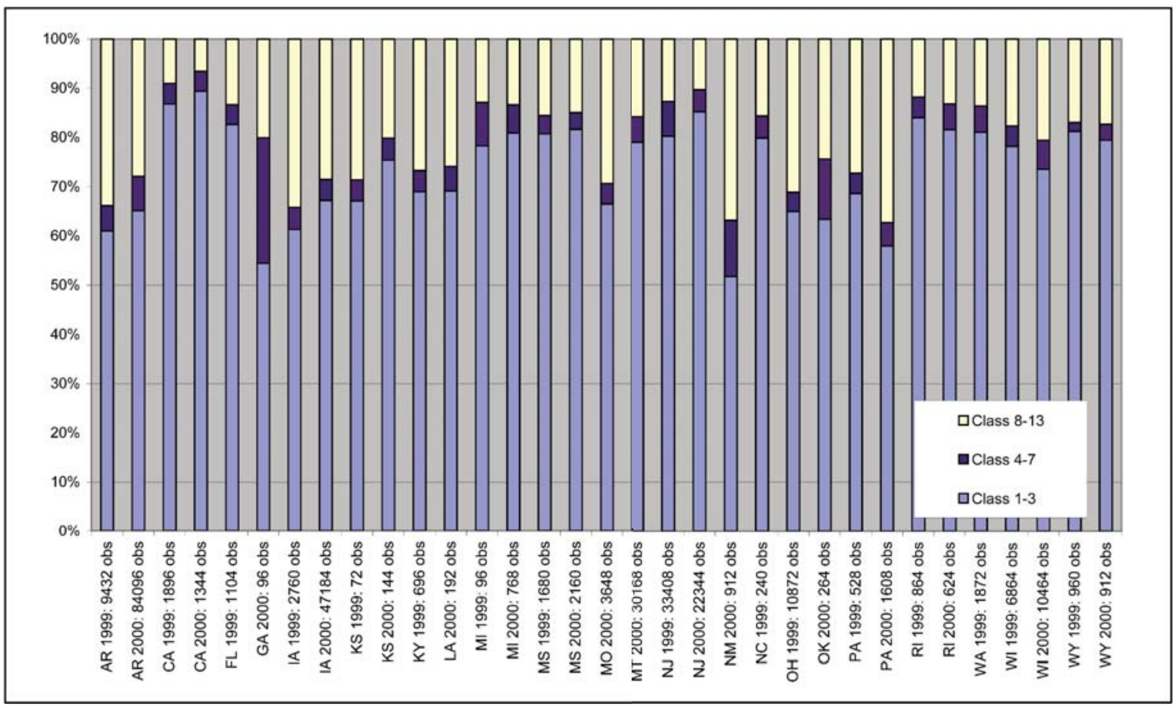

Figure 11. Vehicle mix for weekdays on rural interstates for 1999 and 2000 data. (Number of site-days of observations used in the state average reported along axis.)

The vehicle mix pattern was less discernable when other rural and urban roadway types were considered. Figures 12 and 13 show the rural principal arterial and urban interstate vehicle mix results. Regional patterns were not as clearly defined for these road types, although one may find similarities among the coastal states, which tend to have higher fractions of vehicle classes 1-3.

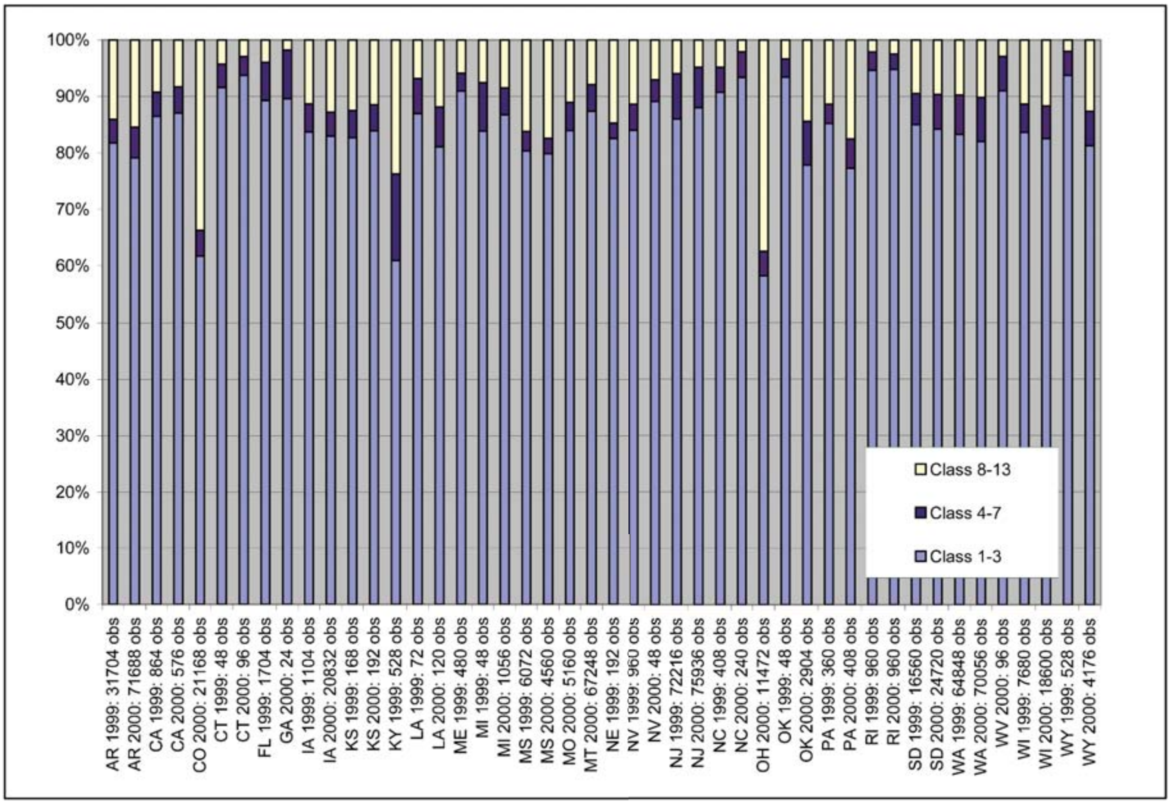

Figure 12. Vehicle mix for weekdays on rural principal arterials for 1999 and 2000. (Number of site-days of observations used in the state average reported along axis.)

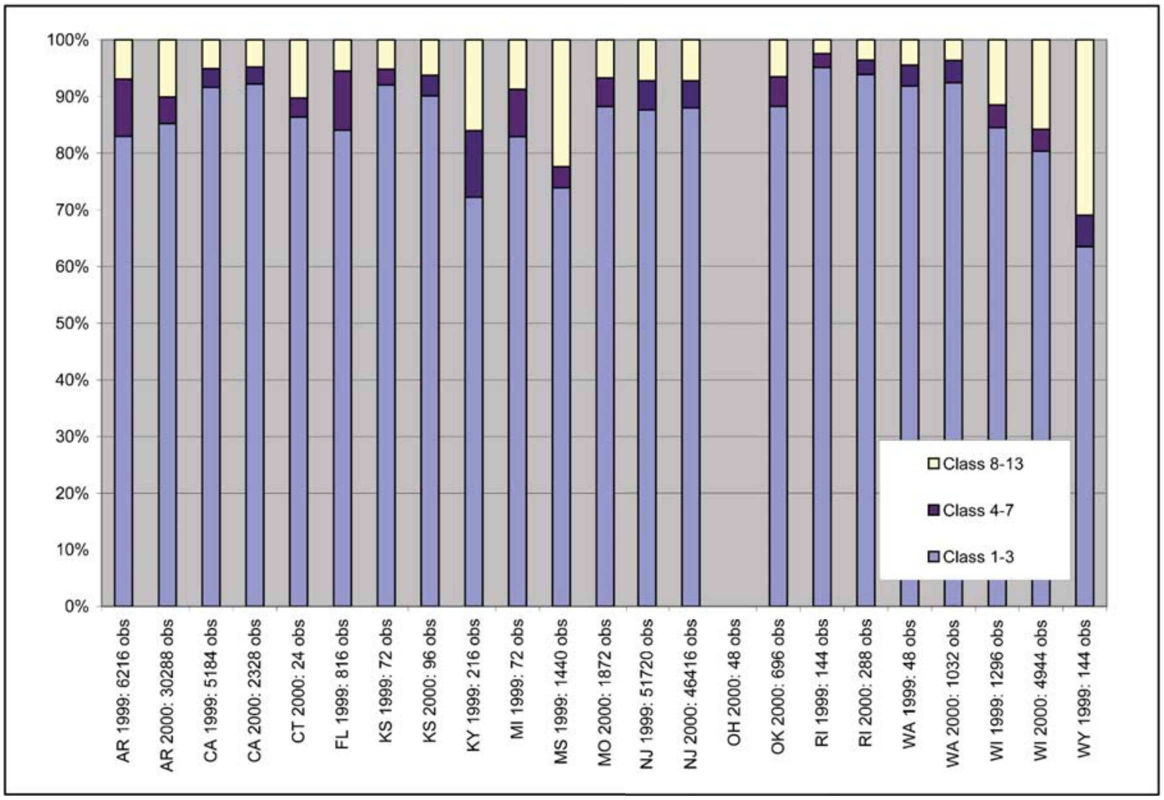

Figure 13. Vehicle mix for weekdays on urban interstates for 1999 and 2000. (Number of site-days of observations used in the state average reported along axis.)

One of the difficulties with the 1999 and 2000 VTRIS data is the inconsistency in data availability by state as shown in Table 5. Many adjacent states are missing when defining regional aggregations. Because of the lack in the geographical coverage of the VTRIS data, it may not be possible to establish specific state-to-state travel patterns using the VTRIS data. In order to begin to discern regions of like rural interstate vehicle class mixes, five regional categories were defined as shown in Table 5 and Figure 14 primarily based on states with like vehicle mix, which maximized the chi square statistical significance of each region/state combination. The choice of regional aggregation was therefore made on the basis of the empirical observations rather than an assumption of typical travel behavior.

Table 5. Availability of VTRIS vehicle counts for weekday rural interstates and suggested regional categories.

State	Vehicle Class Counts 1999	Vehicle Class Counts 2000	Regional Group
Alabama			
Alaska			
Arizona			
Arkansas	X	X	4
California	X	X	1
Colorado			
Connecticut			
Delaware			
Florida	X		1
Georgia		X	5
Hawaii			
Idaho			
Illinois			
Indiana			
Iowa	X	X	4
Kansas	X	X	3
Kentucky	X		3
Louisiana		X	3
Maine			
Maryland			
Massachusetts			
Michigan	X	X	2
Minnesota			
Mississippi	X	X	2
Missouri		X	4
Montana		X	2
Nebraska			
Nevada			
New Hampshire			
New Jersey	X	X	1
New Mexico		X	5
New York			
North Carolina	X		2
North Dakota			
Ohio	X		4
Oklahoma		X	4
Oregon			
Pennsylvania	X	X	4
Rhode Island	X	X	1
South Carolina			
South Dakota			
Tennessee			
Texas			
Utah			
Vermont			
Virginia			
Washington	X		2
West Virginia			
Wisconsin	X	X	3
Wyoming	X	X	2

x = data is present.

The average vehicle mix for each region is shown in Table 6 for weekdays. An average weekday was used to combine data to demonstrate the state-to-state differences, though it is also demonstrated later in this report that each weekday can have a distinct average. The vehicle categories were combined in either two (vehicle classes 1-3 or 4-13) or three (shown in Table 6) different categories, though the regions were defined with the two-category groupings. In general, group 1 consisted of coastal states (east and west), while groups 2-5 consisted of interior states. Among the interior states rural interstates might be expected to have higher fractions of heavy-duty vehicles engaged in interstate commerce. Five regional groups were needed to show that the vehicle mix distribution was similar for the states within a group and significantly different between groups. The chi square probability, comparing the individual state distribution to the regional average, is reported and shows a high probability (>0.05) for most states and years that they are reasonably explained by the average for that region. The probability is usually higher but not always so when using a two-category (group 1-3 and 4-13) test compared with the three-category test.

Table 6. Vehicle class fractions for weekdays on road type 1, rural interstates.

Year	State FIPs	State	Region	Class 1-3	Class 4-7	Class 8-13	Number of Observations	Chi Square, p-values	
								2 Cat.	3 Cat.
1999	5	Arkansas	4	61%	5%		9432	0.16	0.32
2000	5	Arkansas	4	65%	7%	28%	84096	0.56	0.11
1999	6	California	1	87%	4%	9%	1896	0.08	0.21
2000	6	California	1	89%	4%	7%	1344	0.00	0.00
1999	12	Florida	1	83%	4%	13%	1104	0.07	0.02
2000	13	Georgia	5	54%	25%	20%	96	0.70	0.01
1999	19	Iowa	4	61%	4%	34%	2760	0.27	0.29
2000	19	Iowa	4	67%	4%	29%	47184	0.12	0.27
1999	20	Kansas	3	67%	4%	29%	72	0.13	0.23
2000	20	Kansas	3	75%	4%	20%	144	0.16	0.34
1999	21	Kentucky	3	69%	4%	27%	696	0.04	0.05
2000	22	Louisiana	3	69%	5%	26%	192	0.22	0.47
1999	26	Michigan	2	78%	9%	13%	96	0.16	0.00
2000	26	Michigan	2	81%	6%	13%	768	0.61	0.59
1999	28	Mississippi	2	81%	4%	16%	1680	0.73	0.20
2000	28	Mississippi	2	82%	3%	15%	2160	0.35	0.10
2000	29	Missouri	4	67%	4%	29%	3648	0.30	0.48
2000	30	Montana	2	79%	5%	16%	30168	0.70	0.90
1999	34	New Jersey	1	80%	7%	13%	33408	0.00	0.00
2000	34	New Jersey	1	85%	4%	10%	22344	0.94	0.92
2000	35	New Mexico	5	52%	11%	37%	912	0.61	0.00
1999	37	North Carolina	2	80%	4%	16%	240	0.81	0.42
1999	39	Ohio	4	65%	4%	31%	10872	0.58	0.27
2000	40	Oklahoma	4	63%	12%	24%	264	0.84	0.00
1999	42	Pennsylvania	4	69%	4%	27%	528	0.06	0.17
2000	42	Pennsylvania	4	58%	5%	37%	1608	0.01	0.01
1999	44	Rhode Island	1	84%	4%	12%	864	0.36	0.28
2000	44	Rhode Island	1	82%	5%	13%	624	0.01	0.02
1999	53	Washington	2	81%	5%	14%	1872	0.73	0.91
1999	55	Wisconsin	3	78%	4%	18%	6864	0.00	0.01
2000	55	Wisconsin	3	73%	6%	21%	10464	0.44	0.18
1999	56	Wyoming	2	81%	2%	17%	960	0.78	0.20
2000	56	Wyoming	2	79%	3%	17%	912	0.84	0.45
All		Average	All	77%	5%	18%			
Region 1		Average	1	85%	5%	10%			
Region 2		Average	2	80%	5%	15%			
Region 3		Average	3	72%	5%	23%			
Region 4		Average	4	64%	5%	31%			
Region 5		Average	5	53%	20%	26%			

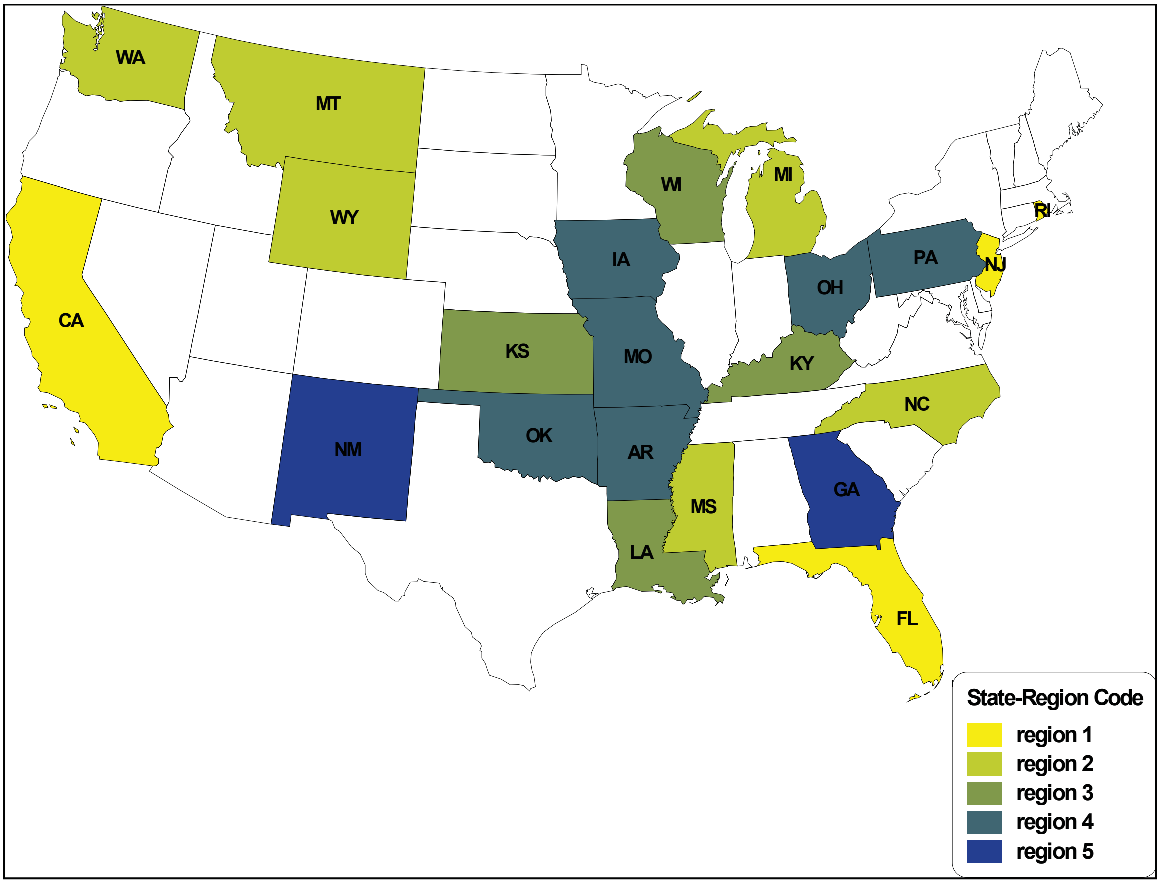

Figure 14. Regions defined for rural interstate vehicle mix.

While there are similar regional differences for other road types, the same regional patterns for rural interstates do not completely match those for other road types. For instance, as shown in Table 7 for road type 2 (rural principal arterials), the coastal states (including California, Connecticut, Florida, New Jersey, and Rhode Island) have higher fractions of light-duty vehicles (group 1-3) similar to road type 1, but other states (such as Michigan and Montana) also have high fractions for this vehicle group (1-3). Likewise as shown in Table 8 for road type 11 (urban interstates), the coastal states have higher fractions of light-duty vehicle group (1-3), but so does the interior state of Kansas.

Table 7. Vehicle class fractions for weekdays on road type 2, rural principal arterials.

Year	State	Class 1-3	Class 4-7	Class 8-13	Number of Observations
1999	Arkansas	82%	4%	14%	31,704
2000	Arkansas	79%	5%	15%	71,688
1999	California	86%	4%	9%	864
2000	California	87%	5%	8%	576
2000	Colorado	62%	5%	34%	21,168
1999	Connecticut	92%	4%	4%	48
2000	Connecticut	94%	3%	3%	96
1999	Florida	89%	7%	4%	1,704
2000	Georgia	90%	9%	2%	24
1999	Iowa	84%	5%	11%	1,104
2000	Iowa	83%	4%	13%	20,832
1999	Kansas	83%	5%	13%	168
2000	Kansas	84%	5%	11%	192
1999	Kentucky	61%	15%	24%	528
1999	Louisiana	87%	6%	7%	72
2000	Louisiana	81%	7%	12%	120
1999	Maine	91%	3%	6%	480
1999	Michigan	84%	9%	8%	48
2000	Michigan	87%	5%	8%	1,056
1999	Mississippi	80%	3%	16%	6,072
2000	Mississippi	80%	3%	17%	4,560
2000	Missouri	84%	5%	11%	5,160
2000	Montana	87%	5%	8%	67,248
1999	Nebraska	83%	3%	15%	192
1999	Nevada	84%	5%	11%	960
2000	Nevada	89%	4%	7%	48
1999	New Jersey	86%	8%	6%	72,216
2000	New Jersey	88%	7%	5%	75,936
1999	North Carolina	91%	4%	5%	408
2000	North Carolina	93%	5%	2%	240
2000	Ohio	58%	4%	37%	11,472
1999	Oklahoma	93%	3%	3%	48
2000	Oklahoma	78%	8%	14%	2,904
1999	Pennsylvania	85%	3%	11%	360
2000	Pennsylvania	77%	5%	18%	408
1999	Rhode Island	95%	3%	2%	960
2000	Rhode Island	95%	3%	2%	960
1999	South Dakota	85%	5%	10%	16,560
2000	South Dakota	84%	6%	10%	24,720
1999	Washington	83%	7%	10%	64,848
2000	Washington	82%	8%	10%	70,056
2000	West Virginia	91%	6%	3%	96
1999	Wisconsin	84%	5%	11%	7,680
2000	Wisconsin	83%	6%	12%	18,600
1999	Wyoming	94%	4%	2%	528
2000	Wyoming	81%	6%	13%	4,176

Table 8. Vehicle class fractions for weekdays on road type 11, urban interstates.

Year	State	Class 1-3	Class 4-7	Class 8-13	Number of Observations
1999	Arkansas	83%	10%	7%	6,216
2000	Arkansas	85%	5%	10%	30,288
1999	California	92%	3%	5%	5,184
2000	California	92%	3%	5%	2,328
2000	Connecticut	86%	3%	10%	24
1999	Florida	84%	10%	5%	816
1999	Kansas	92%	3%	5%	72
2000	Kansas	90%	4%	6%	96
1999	Kentucky	72%	12%	16%	216
1999	Michigan	83%	8%	9%	72
1999	Mississippi	74%	4%	22%	1,440
2000	Missouri	88%	5%	7%	1,872
1999	New Jersey	88%	5%	7%	51,720
2000	New Jersey	88%	5%	7%	46,416
2000	Oklahoma	88%	5%	6%	696
1999	Rhode Island	95%	2%	2%	144
2000	Rhode Island	94%	3%	4%	288
1999	Washington	92%	4%	4%	48
2000	Washington	92%	4%	4%	1,032
1999	Wisconsin	84%	4%	11%	1,296
2000	Wisconsin	80%	4%	16%	4,944
1999	Wyoming	63%	6%	31%	144

In summary, the regional vehicle mix does not generally vary by region or state. While vehicle mix differences between states identified for rural interstates were found to be significant, no discernable patterns could be identified for other road facility types. Regional groupings made on the basis of the empirical data identified similar states that were not contiguous. One might speculate that the different regions identified for rural interstates may be explained in part by cross-country interstate freight movements, where core interior states experience higher fractions of heavy truck activity than states outside of this core. Therefore regions geographically dispersed, such as the east and west coasts of lower 48 states, may be more similar in the nature of their traffic than would regional groupings based on proximity.

3. REGIONAL VARIATIONS IN WEIGHT BIN DISTRIBUTIONS BY ROAD TYPE FOR VEHICLE CLASSES 5-13

One of goals of this effort was to determine the regional variability in weight distributions by road type, if any. Weight bin distributions for each state by road type were prepared for review. During the analysis, it became apparent no regional truck traffic groupings could be clearly defined and the weight distributions could not be well defined either. Figure 15 (combines the data in Figures 7 and 9 for vehicle classes 5 and 8-13 with the more rare vehicle classes 6 and 7 converted to actual measured weights) shows the state-by-state variability for vehicles 5-13, but these averages were based on very little data for the states of Georgia (lowest average weight ratings for vehicles 5-13), Kansas, Missouri, Nebraska, Nevada, South Carolina, West Virginia, and Wyoming.

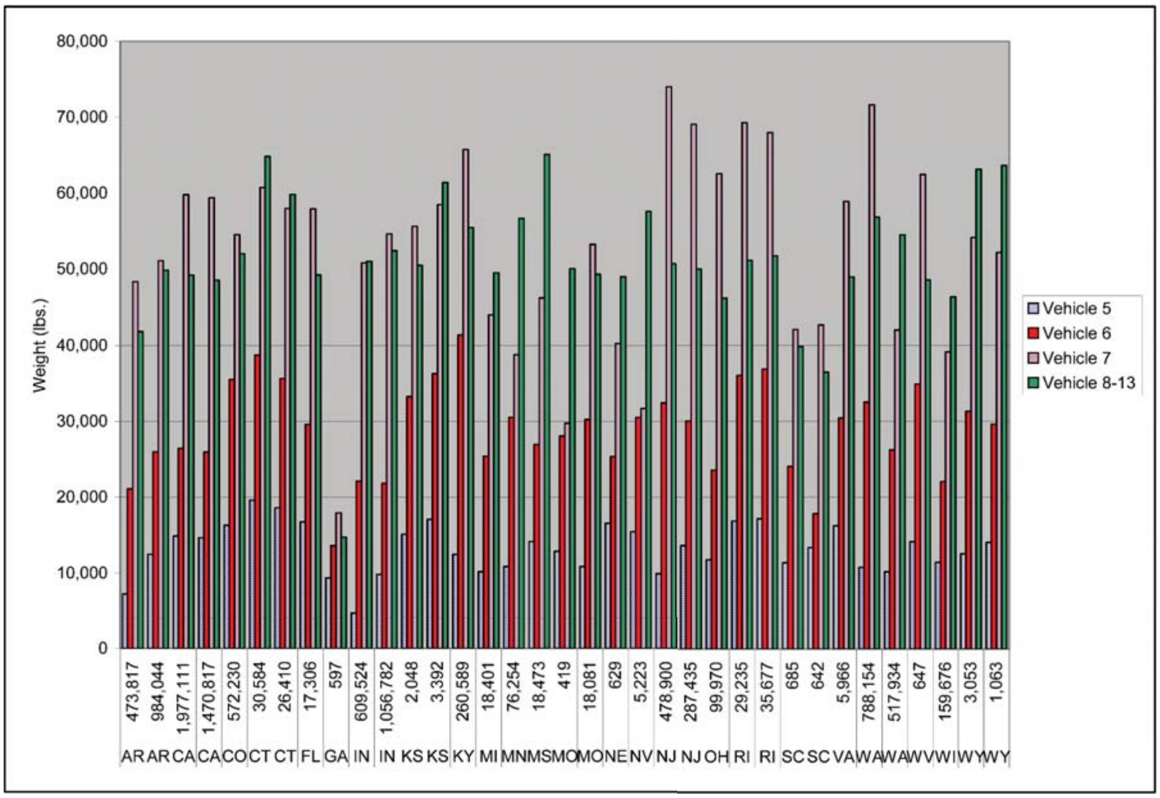

Figure 15. Average vehicle weight for vehicle classes 5 – 13 on urban interstates, road 11. (Number of site-days of observations used in the state average reported along axis.)

4. TEMPORAL VARIATIONS IN WEIGHT BIN DISTRIBUTIONS FOR VEHICLE CLASSES 5-13

The temporal weight distributions are typically difficult to visualize, so average vehicle weights are also reported here to better understand the temporal distributions in vehicle weight. Changes in the weight bin distributions are normally reflected in the average weight. Overall the variability in the average monthly weights does not reflect a consistent pattern, but the variability in the daily and hourly average weights do reflect patterns.

4.1 Monthly Variation

Vehicle weight does not appear to vary much or consistently by season. Both the average vehicle weights and weight bin distributions show little change from one season to the next. Figures 16 and 17 demonstrate that the month-to-month variability in the average vehicle weight does not depend upon the season. Based on the vehicle mix and the sample sizes, the vehicle classes with the highest fraction of the fleet are in order, vehicles 9, 5, and 8. The variability between months in Figures 16 and 17 are well within the standard deviation, but the very large sample sizes provided in Table 9 reduce the 90% confidence level ranges to those shown in Figures 16 and 17. However the uncertainty ranges shown in Figures 16 and 17 do not include sampling variability by site.

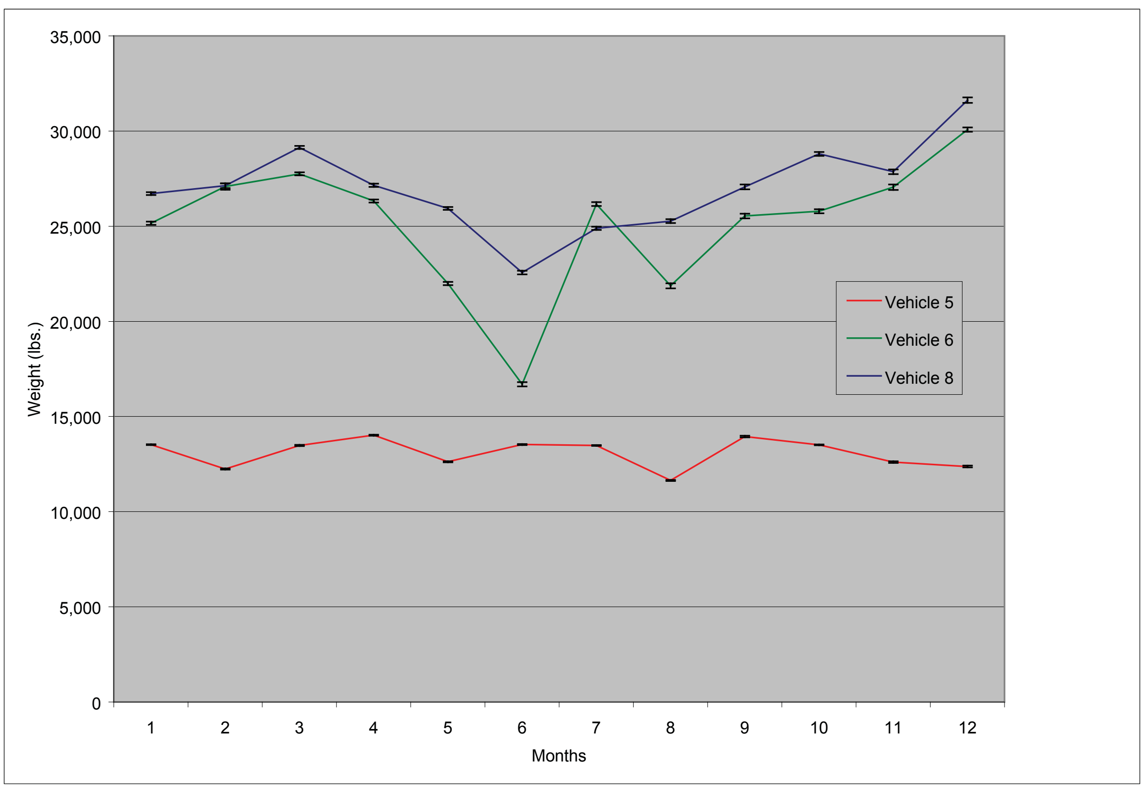

Figure 16. Average weight by month for lighter heavy vehicle classes in 1999 on road type 1. (Uncertainty ranges were based on 90% confidence levels of the sample.)

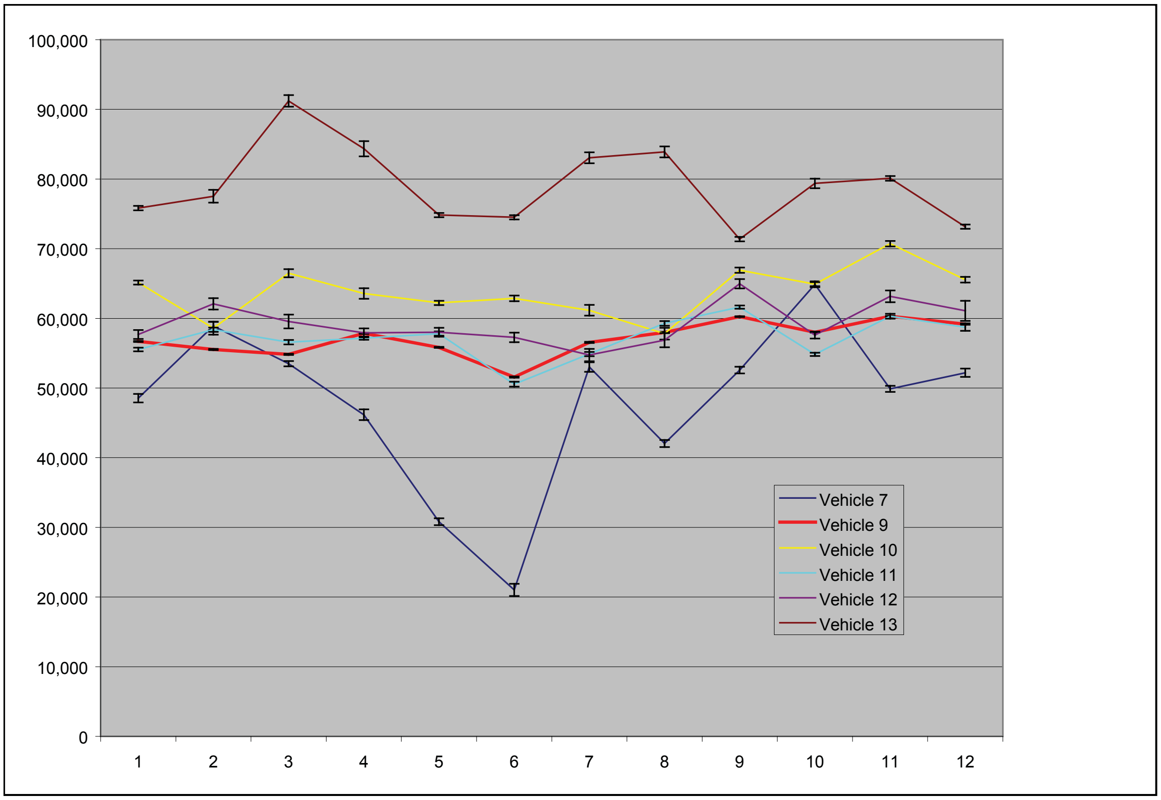

Figure 17. Average weight by month for heavier vehicle classes in 1999 on road type 1.

Table 9. Number of observations for Figures 16 and 17.

Month	Vehicle class								
	5	6	7	8	9	10	11	12	13
1	198,451	49,242	3,381	97,131	1,323,544	30,501	107,188	19,345	22,733
2	110,475	24,247	3,433	48,656	664,163	6,324	33,788	3,075	3,413
3	137,986	102,717	9,220	158,003	1,225,367	22,381	63,106	9,392	4,850
4	179,017	81,381	2,627	129,504	1,278,718	22,394	104,815	18,480	3,980
5	235,213	88,309	15,012	143,477	1,505,906	30,995	72,635	11,828	21,048
6	116,013	40,642	5,332	57,473	640,491	19,282	30,660	5,829	17,490
7	177,481	31,622	1,050	60,793	889,347	11,578	79,424	11,760	5,205
8	143,708	31,968	6,028	56,318	655,697	6,916	32,430	5,112	4,200
9	95,184	25,002	4,404	56,406	742,091	18,476	30,451	5,948	19,382
10	187,238	46,237	2,952	79,567	805,333	15,474	87,282	13,709	6,815
11	98,449	33,368	2,603	70,070	767,994	33,015	33,589	9,200	32,130
12	58,532	36,540	2,922	45,128	471,771	20,871	21,389	7,061	23,352

4.2 Hourly Variation Over an Average Week

Using national averages, the average weight of vehicles is shown to vary by day of week and hour of day in Figures 18 and 19 for vehicle class 5 and vehicle group (8-13). (Hour 1 in Figures 18 and 19 is 12-1 a.m. on Sunday.) The average weight for vehicle class 5 is clearly lower on weekends and had a distinctive hourly profile during weekdays that was also apparent in the 2000 data as in the 1999 data shown in Figure 18. For the vehicle group (8-13), the vehicle weight increases on weekends and overnight during the week, with a similar pattern in 2000 as that shown in Figure 19 for 1999.

The average weight by hour for all seven days in the week shown in Figures 18a and 19 reflect the distribution of vehicle weights for various vehicle classes. (Outlier data from Indiana, as presented in Figure 23, was identified that greatly affected the average weights for vehicle class 5. While there was no obvious reason to eliminate this data, alternative versions of Figures 18b and Figure 21b are provided without the Indiana data.) Figures 20 to 28 show the effect from the day of week for vehicle class 5 and vehicle class group (8-13) on the population by weight bin. For vehicle class 5, the distribution of weight shifts to lower weight bins on weekend days for road types 1 (rural interstates) and 11 (urban interstates). This effect is demonstrated dramatically in Figure 21a of the 1999 data including the state of Indiana, but it is not as great in Figure 21b of the 1999 data excluding Indiana. The opposite effect is demonstrated for vehicle group (8-13) in Figure 23, where vehicle weights on weekends are higher than during the week. This effect is most apparent in the weight bin B800 vehicle fractions.

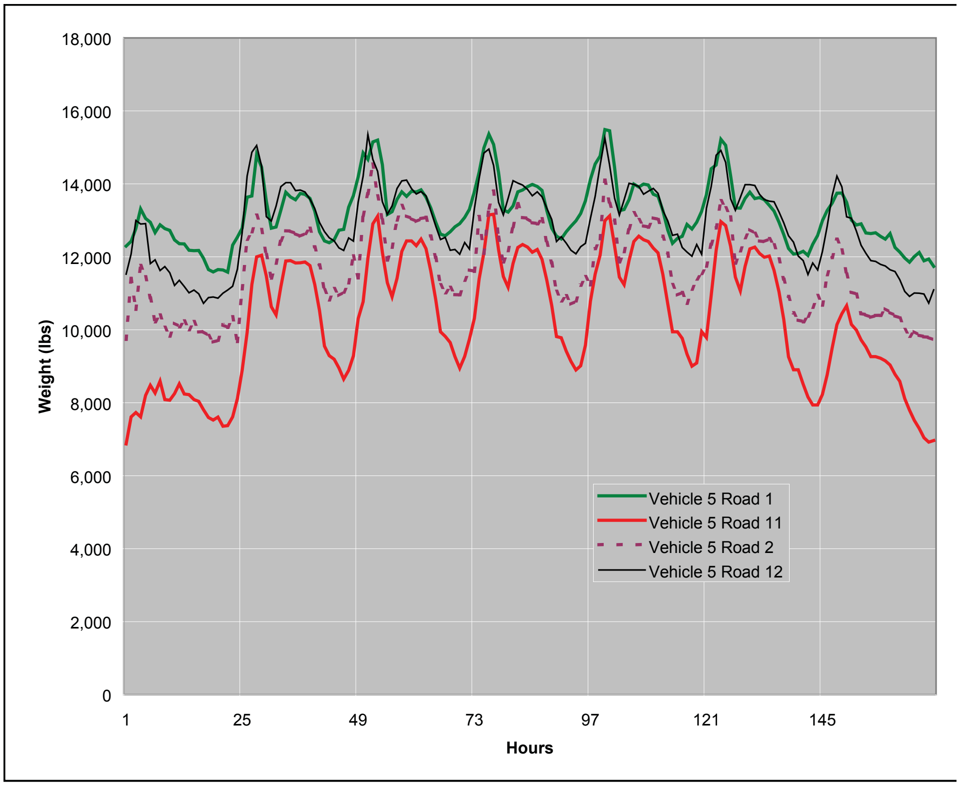

Figure 18a. Average weight for vehicle 5 by hour over a typical week in 1999.

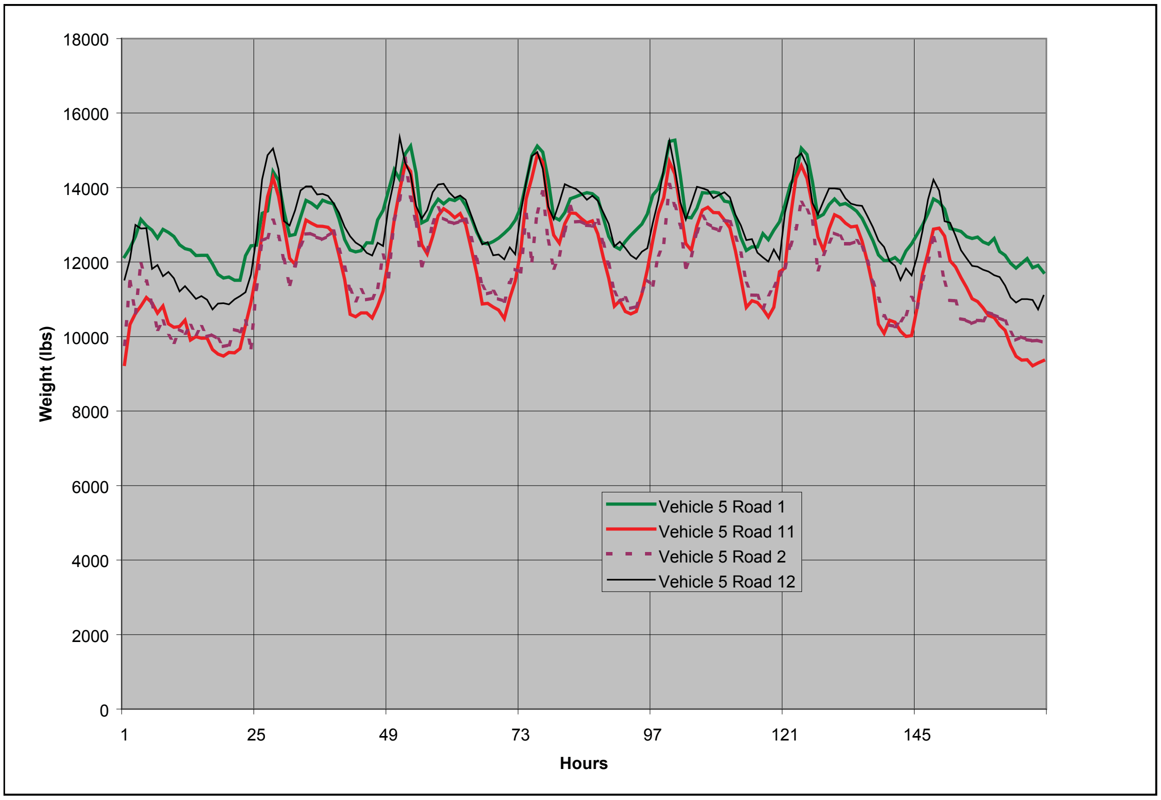

Figure 18b. Average weight for vehicle 5 by hour over a typical week in 1999. (Without Indiana Data)

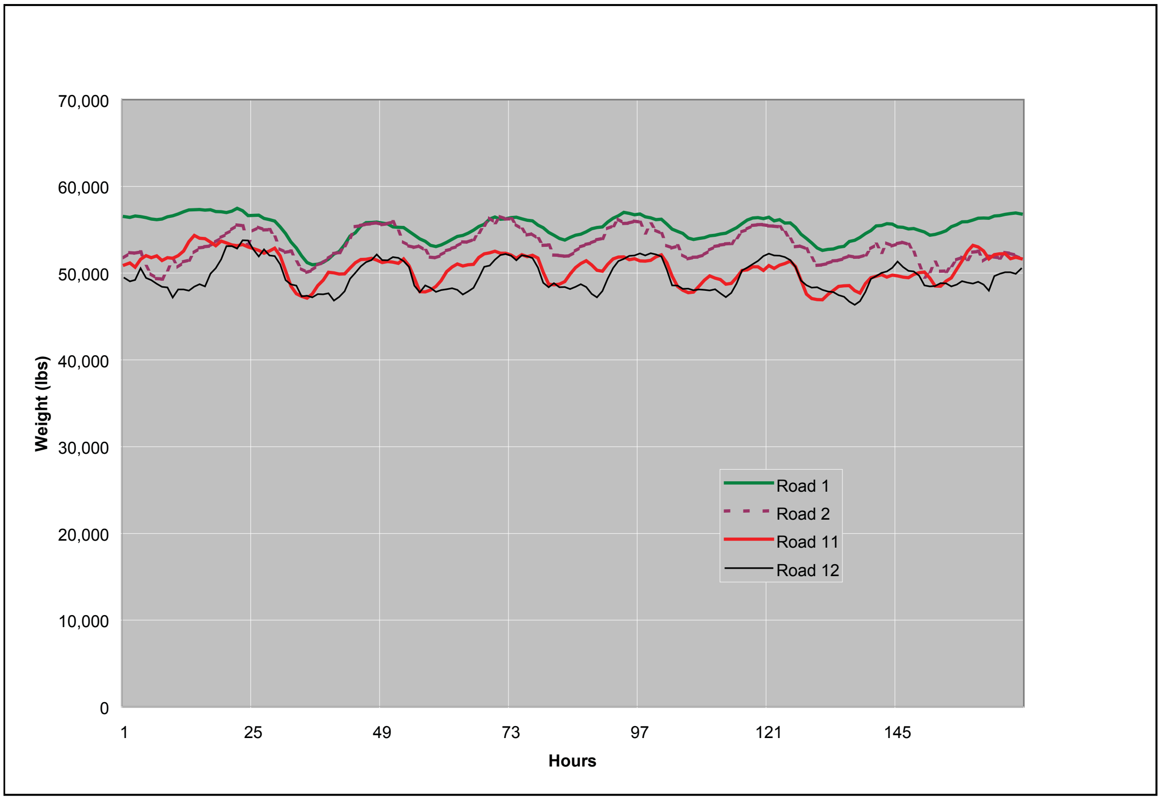

Figure 19. Average weight for vehicle group (8 – 13) by hour over a typical week in 1999.

The hourly averages in Figures 18 and 19 represent data for each hour. Typically there were more observations during daytime hours and during weekdays than at night or on the week-end days. The range in the number of observations for each hour is shown in Table 10.

Table 10. Range in the number of observations for Figures 18 and 19.

Vehicle class	Road Type	Minimum Observations	Maximum Observations
5	1	1,495 at 3am Sunday	20,228 at 3pm Wednesday
5	11	2,242 at 4am Sunday	41,021 at 3pm Tuesday
5	2	674 at 4am Sunday	14,888 at 3pm Friday
5	12	711 at 4am Sunday	22,292 at 2pm Friday
8-13	1	25,056 at 3am Sunday	126,553 at 1pm Wednesday
8-13	11	7,331 at 4am Sunday	88,510 at 11am Tuesday
8-13	2	3,039 at 3am Sunday	43,055 at 11am Tuesday
8-13	12	1,674 at 2am Sunday	27,829 at 11am Thursday

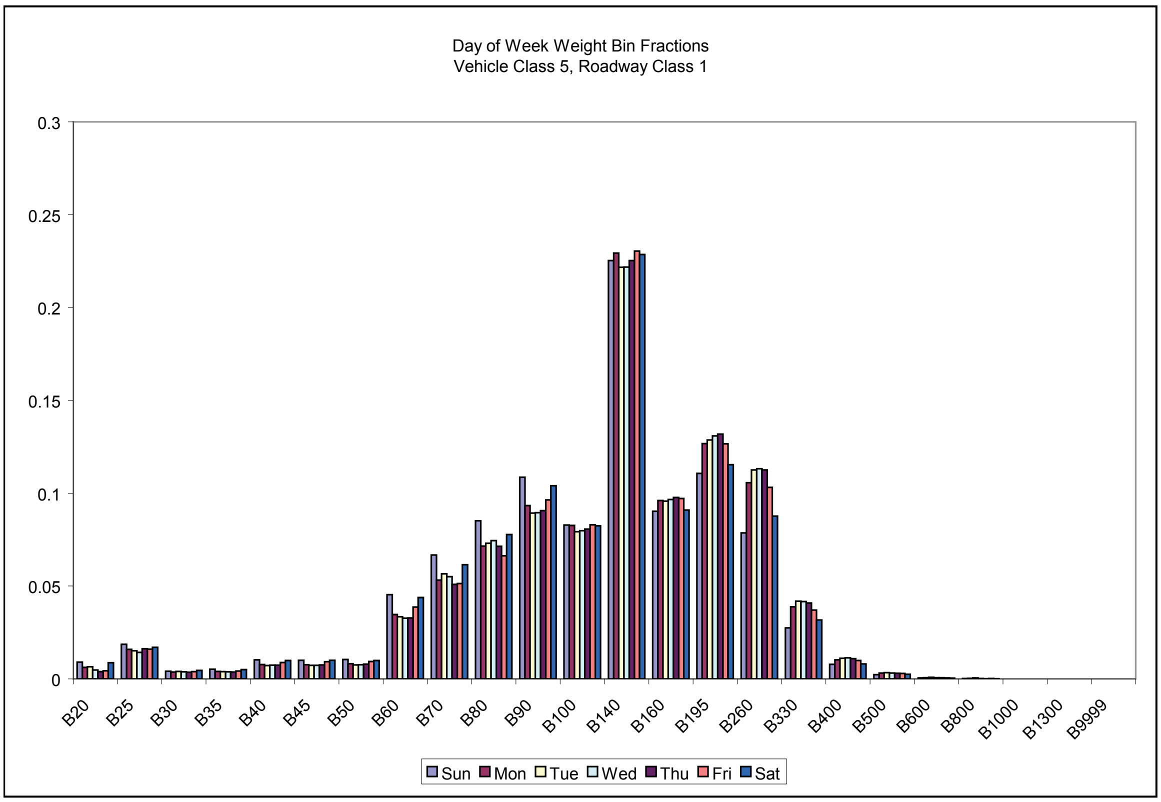

Figure 20. Day of week weight bin distribution for vehicle class 5 on road type 1 in 1999.

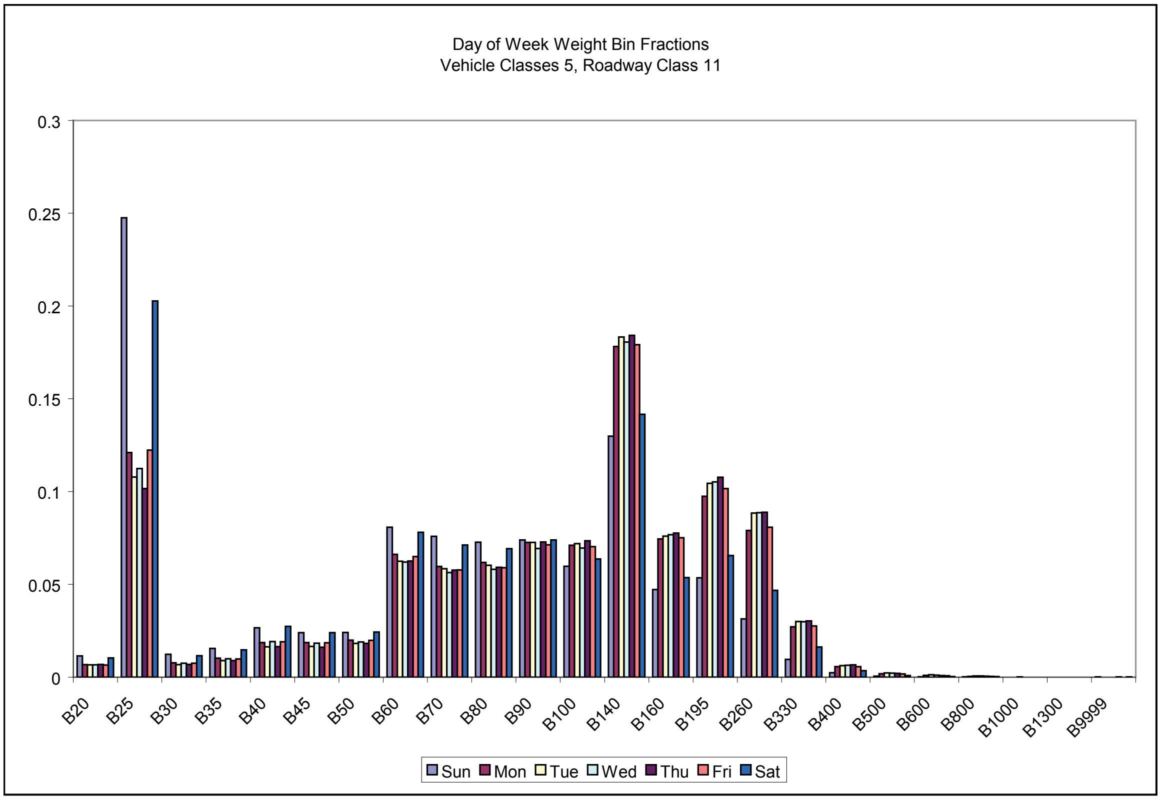

Figure 21a. Day of week weight bin distribution for vehicle class 5 on road type 11 in 1999 (including the Indiana data).

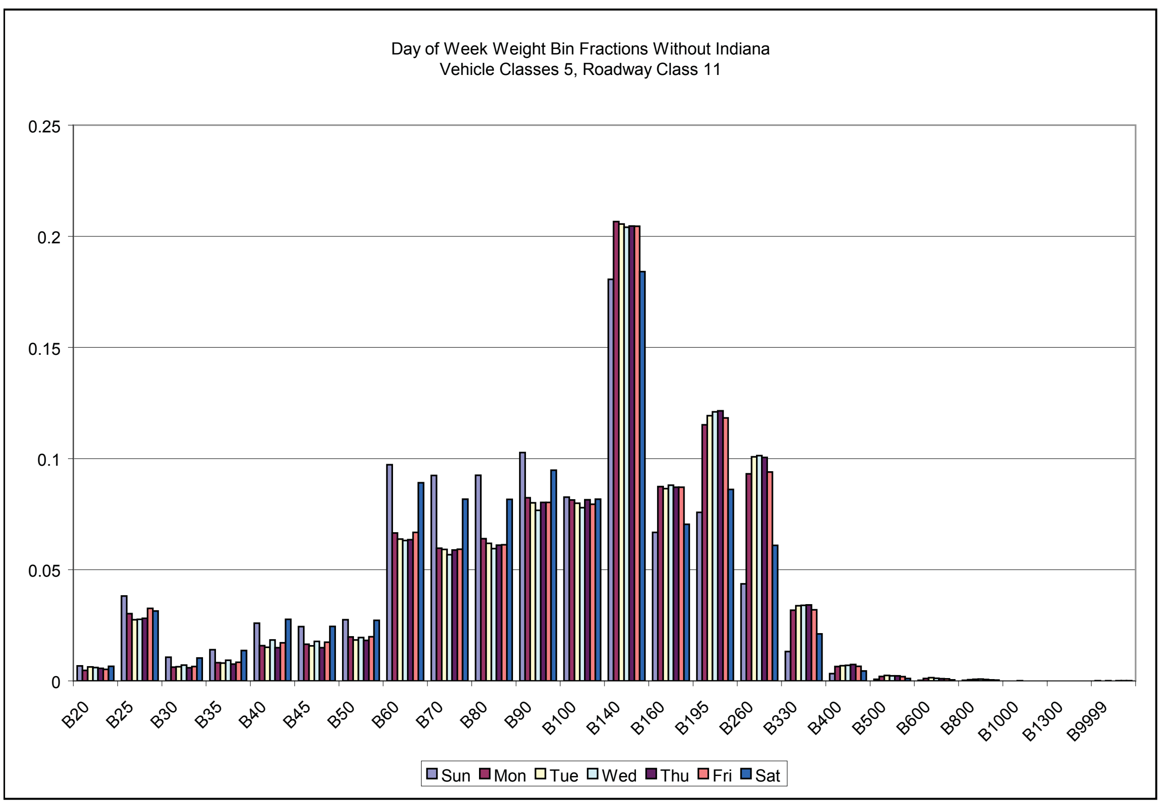

Figure 21b. Day of week weight bin distribution for vehicle class 5 on road type 11 in 1999 (excluding the Indiana data).

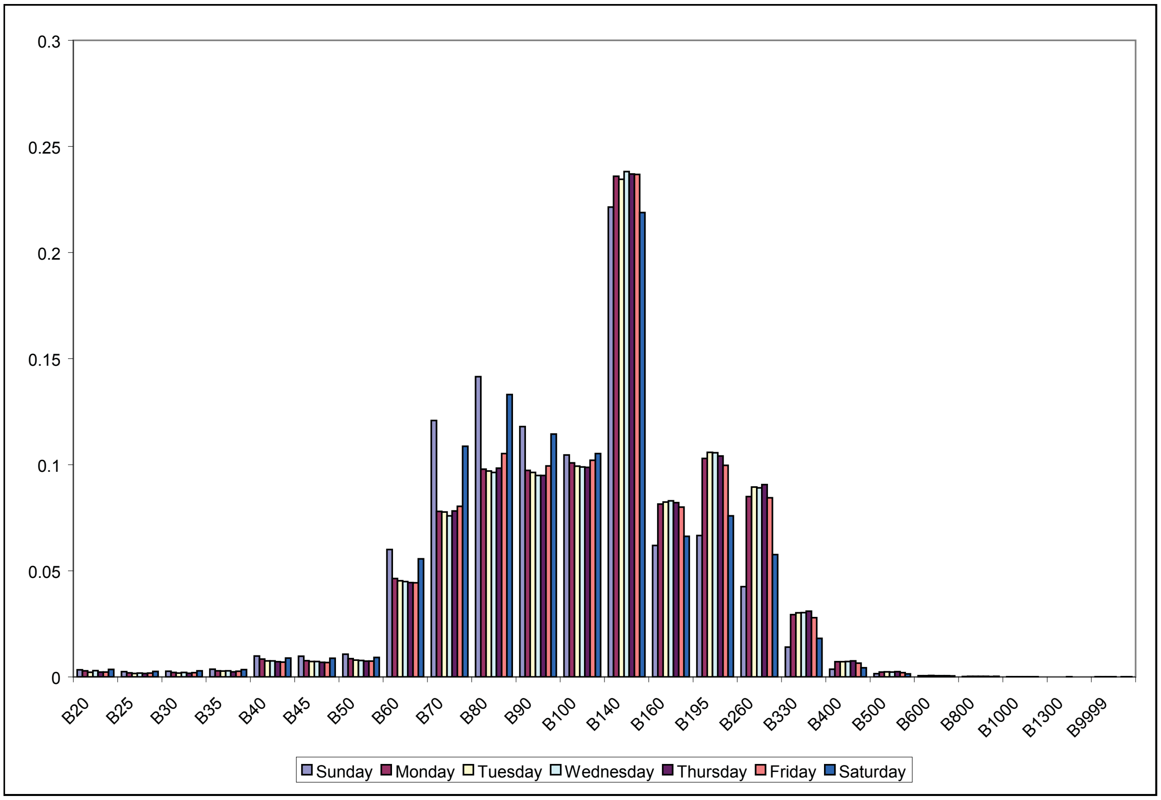

Figure 22. Day of week weight bin distribution for vehicle class 5 on road type 11 in 2000.

The number of weigh-in-motion observations used to generate the 1999 and 2000 weight-bin distributions for vehicle class 5 on road types 1 and 11 in Figures 20 through 22 are shown in Table 11.

Table 11. Number of observations for weight distributions, vehicle class 5, road types 1 and 11.

Road Type	Vehicle class	Day Of Week	No. 1999 Observations	No. 1999 Observations without Indiana	No. 2000 Observations
01	05	Sun	175,808	-	332,949
01	05	Mon	251,611	-	463,760
01	05	Tue	270,264	-	490,135
01	05	Wed	281,260	-	494,138
01	05	Thu	279,778	-	506,475
01	05	Fri	279,961	-	528,547
01	05	Sat	199,065	-	379,390
11	05	Sun	261,751	177,075	249,728
11	05	Mon	521,583	428,490	550,843
11	05	Tue	549,043	467,148	583,937
11	05	Wed	541,184	455,228	592,730
11	05	Thu	544,315	470,080	623,218
11	05	Fri	561,867	466,715	661,306
11	05	Sat	349,511	254,994	352,577

The distribution of weights by bin for vehicle class 5 on roadway type 1 (rural interstates) is very similar between 1999 and 2000. The large fraction of weights in bin 25 in the 1999 data for roadway type 11 (urban interstates) was largely influenced by the 1999 Indiana weight data. Figure 23 displays the fraction of class 5 vehicles from the 1999 Indiana data. Further inquiry into the 1999 Indiana weight data would be advisable before using the 1999 national weight distribution such as that shown in Figures 18a and 18b. This situation demonstrates also how a single data set added to VTRIS can affect national averages. The weight data is composed of a vehicle classification, the number of axles, and the weight on each axle. Each of these variables can potentially add erroneous readings. So one might conclude that in the Indiana data, smaller light-duty vehicles were often misidentified or mislabeled as vehicle class 5, where both class 5 vehicles and light-duty vehicles have two axles.

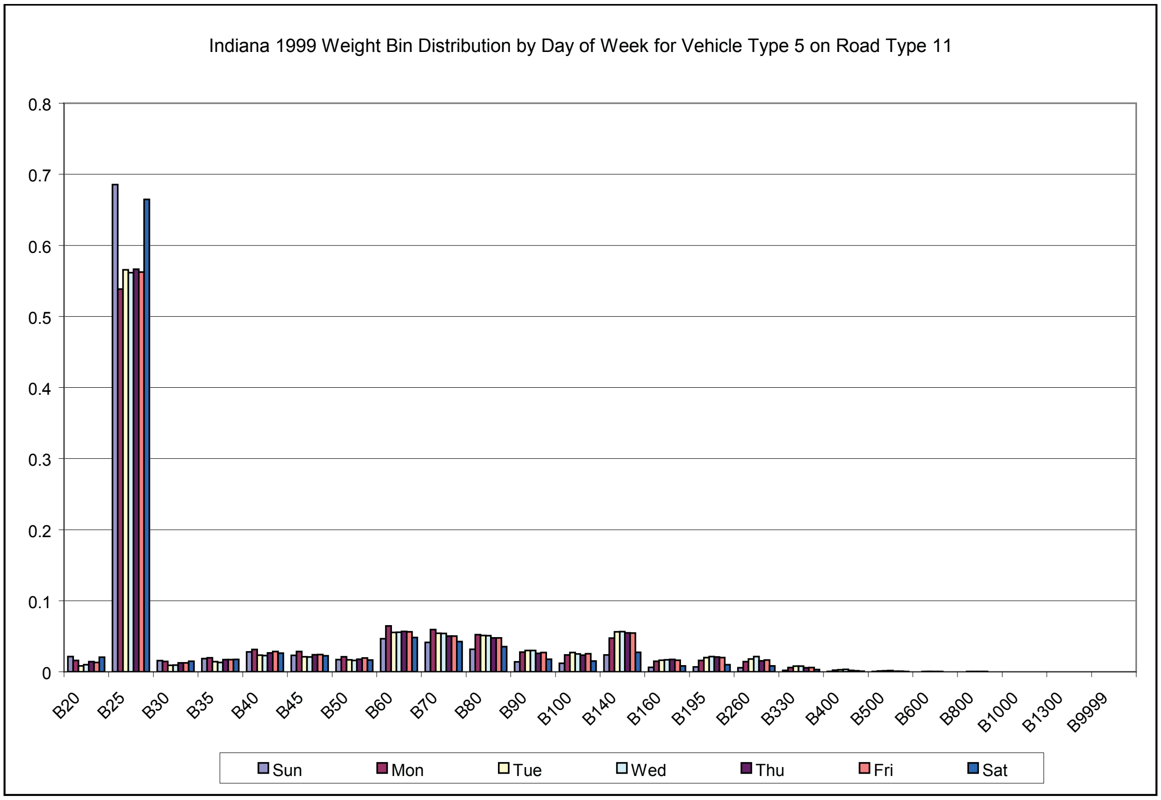

Figure 23. Fraction of class 5 vehicles on urban interstates in the 1999 Indiana weight data.

The weight bin distributions for vehicle classes 8-13 on roadway types 1 and 11 are displayed in figures 24 through 27 below. The distributions are nearly identical between 1999 and 2000. For classes 8 through 13 combined, there are often more than one million observations used in the generation of the histograms below as demonstrated in Table 12.

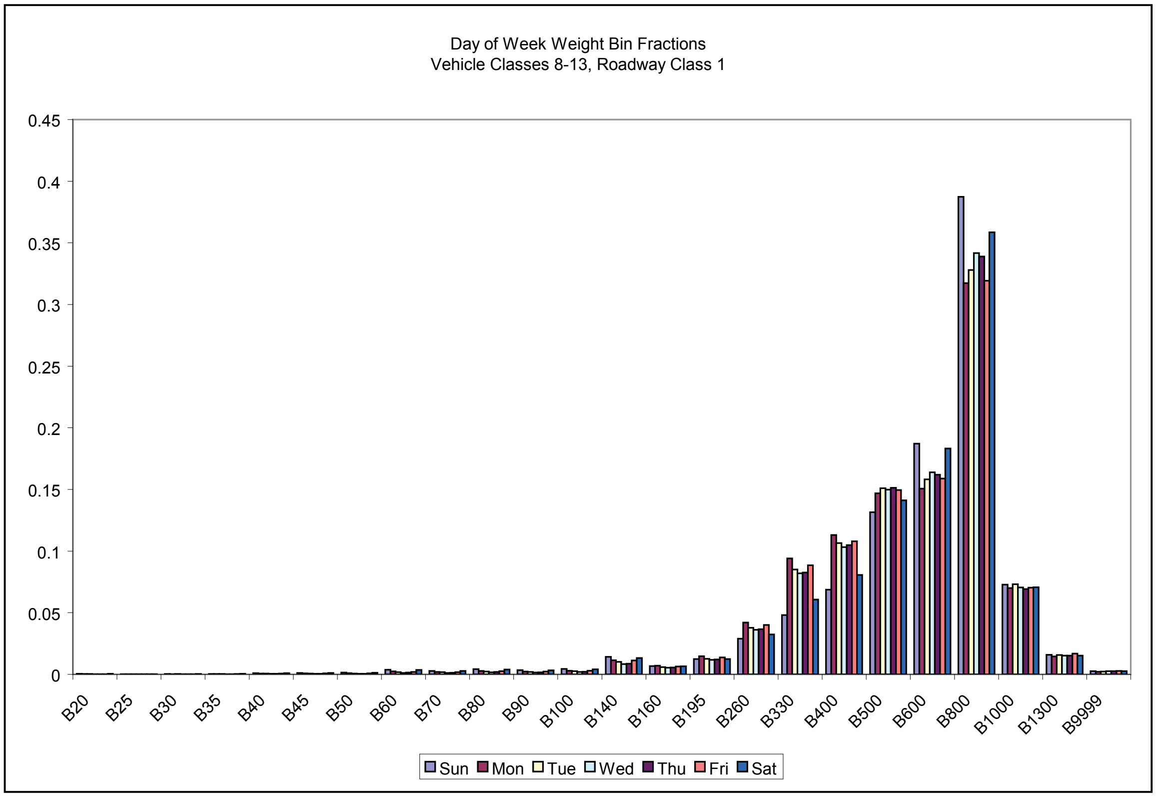

Figure 24. Day of week weight bin distribution for vehicle group (8 – 13) on road type 1 in 1999.

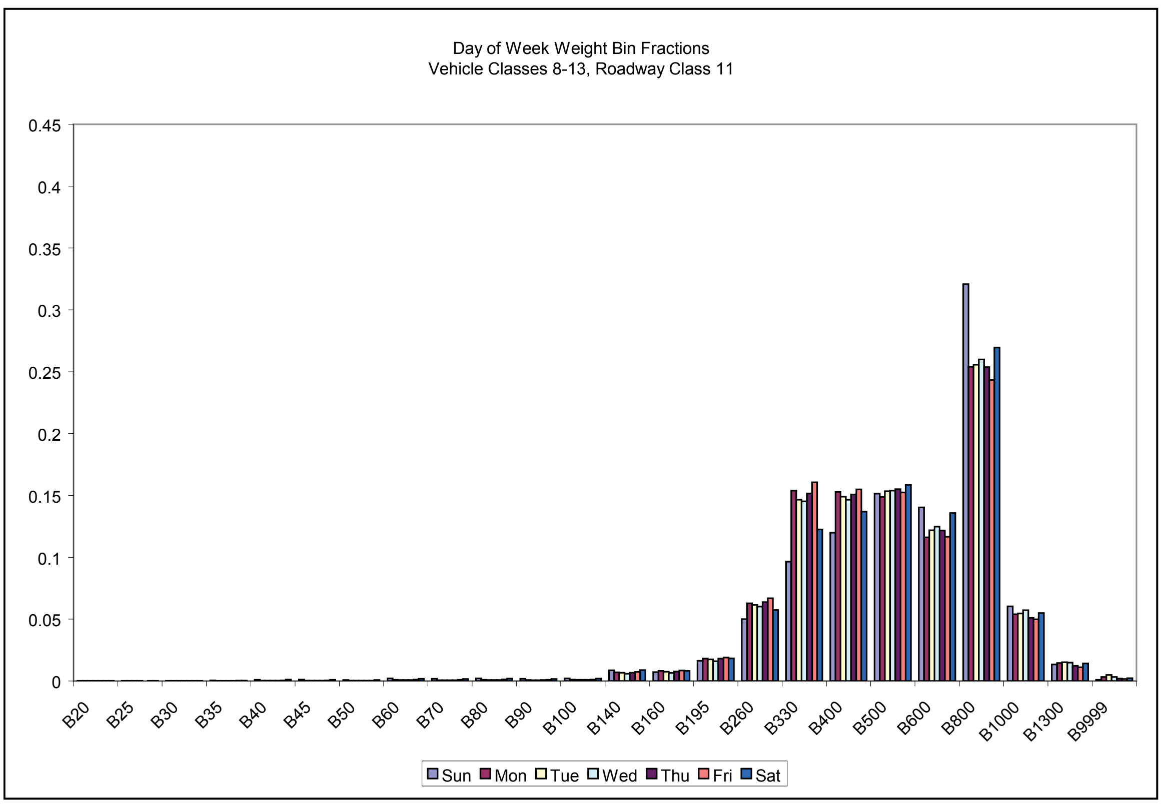

Figure 25. Day of week weight bin distribution for vehicle group (8 – 13) on road type 11 in 1999.

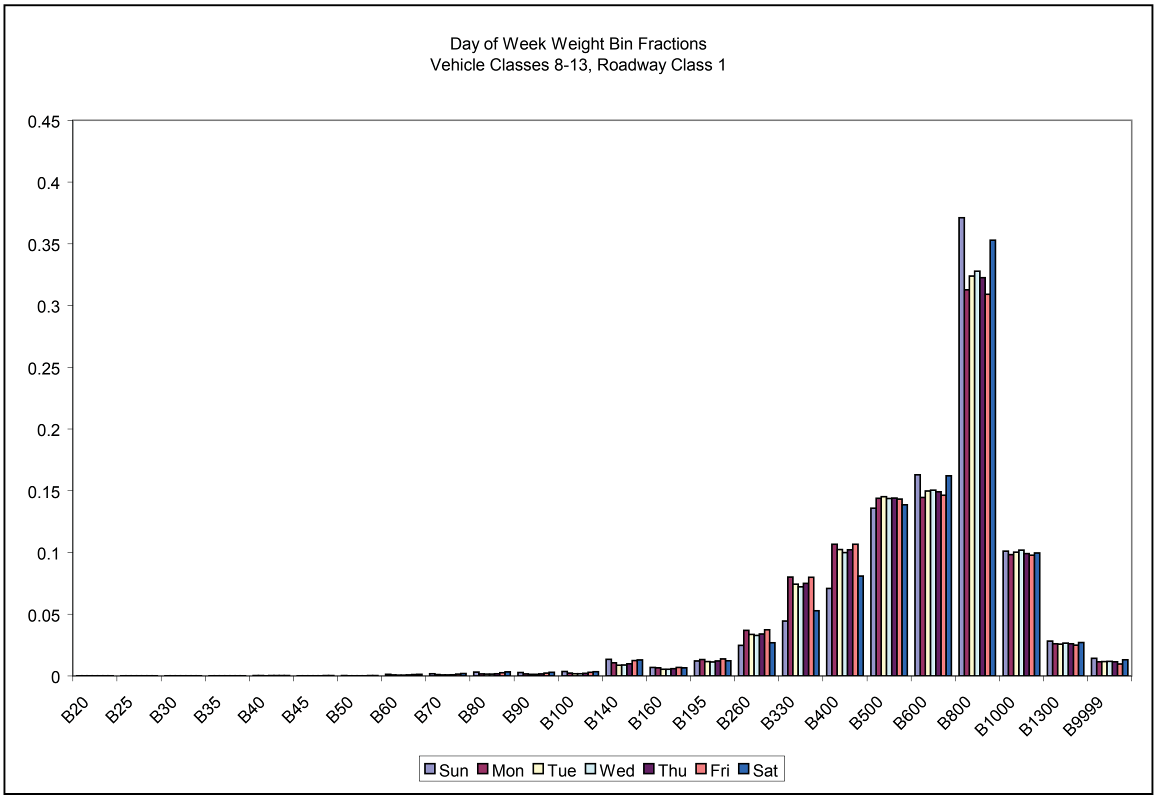

Figure 26. Day of week weight bin distribution for vehicle group (8 – 13) on road type 1 in 2000.

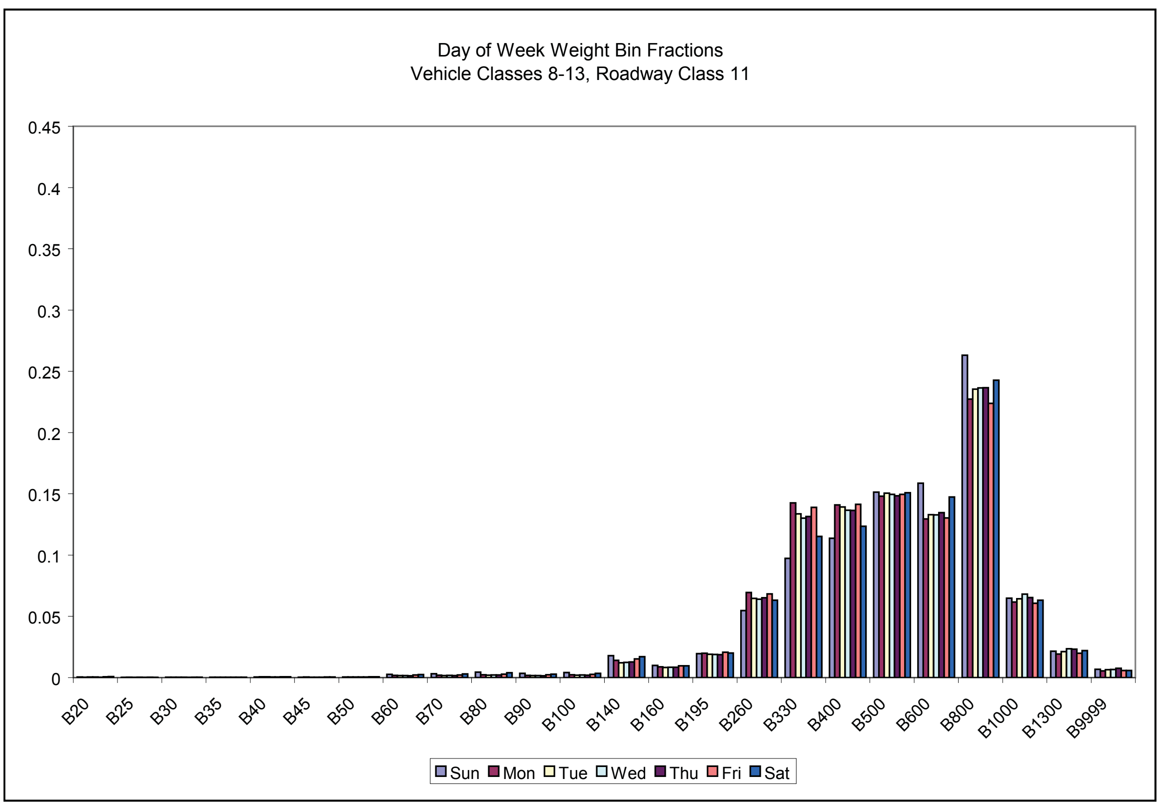

Figure 27. Day of week weight bin distribution for vehicle group (8 – 13) on road type 11 in 2000.

Table 12. Number of observations for weight distributions, vehicle classes 8-13, road types 1 and 11.

Road Type	Vehicle class	Day Of Week	No. 1999 Observations	No. 2000 Observations
01	05	Sun	1,347,601	2,598,508
01	05	Mon	1,722,437	3,530,039
01	05	Tue	2,193,374	4,338,483
01	05	Wed	2,365,475	4,522,336
01	05	Thu	2,216,493	4,339,262
01	05	Fri	1,894,417	3,795,638
01	05	Sat	1,453,452	2,820,523
11	05	Sun	425,530	547,073
11	05	Mon	1,234,483	1,358,486
11	05	Tue	1,455,748	1,570,902
11	05	Wed	1,435,950	1,623,461
11	05	Thu	1,410,331	1,631,364
11	05	Fri	1,235,550	1,499,633
11	05	Sat	569,823	680,314

Besides the day of week profiles just described, the time of day clearly affects the hourly weight bin distributions in the manner demonstrated with the average vehicle weight. Figures 28 and 29 show the effect of the time of day during the week by showing the change in distribution. The hourly weight distribution is reflected in the more easily demonstrated average weight profiles in Figures 18 and 19.

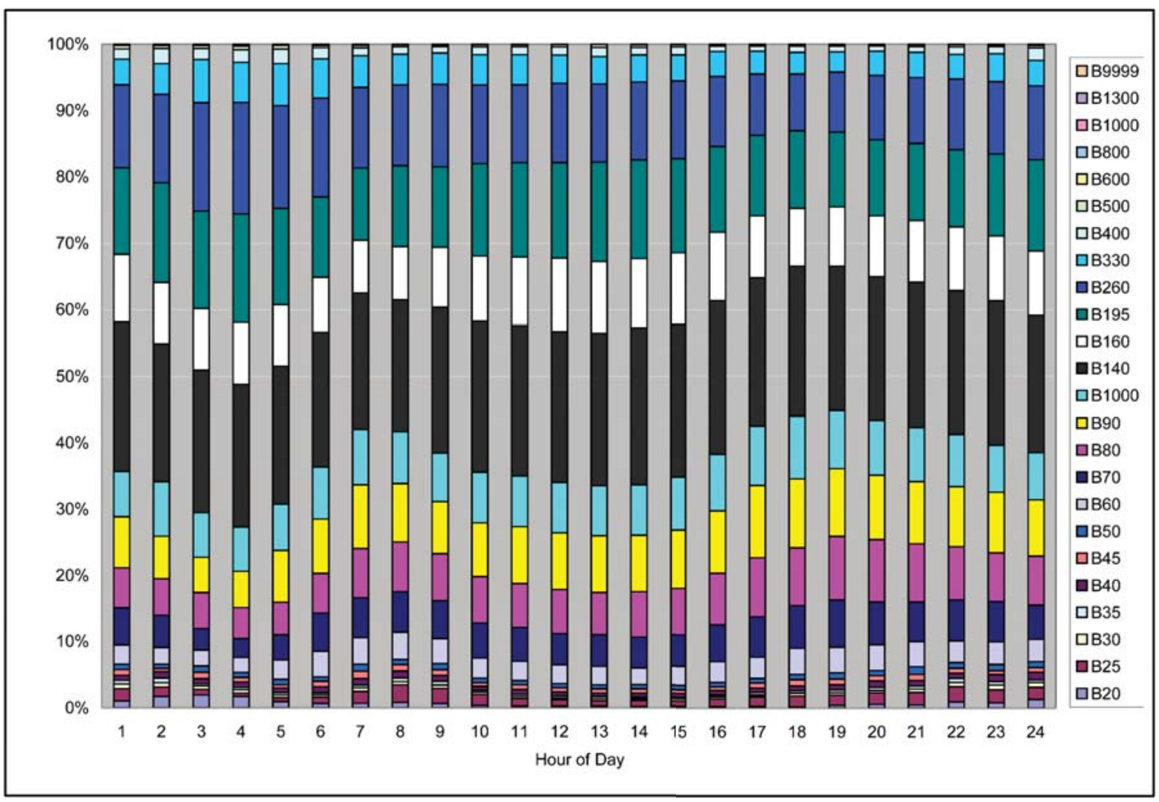

Figure 28. Vehicle 5 weight bin distribution over an average Wednesday.

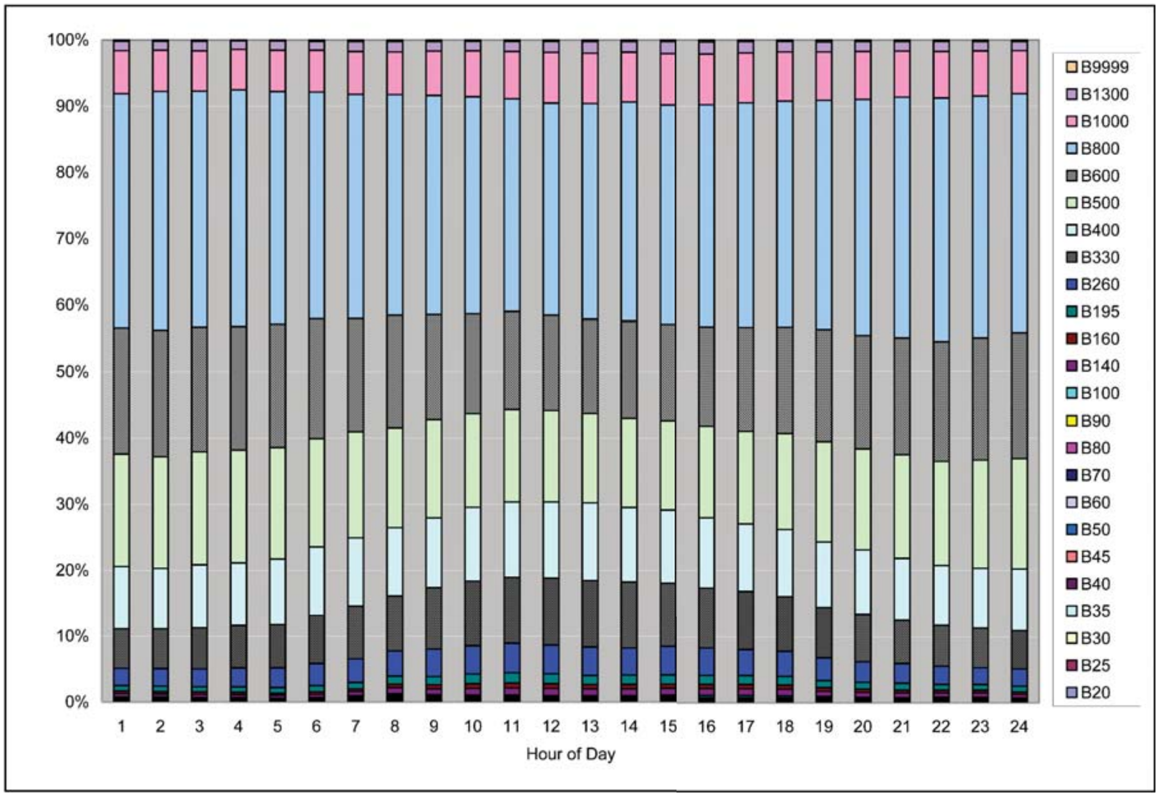

Figure 29. Vehicle group (8 – 13) weight bin distribution over an average Wednesday.

5. ANALYZE WEIGHT DISTRIBUTIONS FOR VEHICLE CLASSES 1-4

The lighter vehicle classes including buses (class 4) show a decreased potential for differences in vehicle weight primarily because the average vehicle weight is lower limiting the variability in the overall weight that individual vehicles could attain in use. The weight of these vehicles is typically higher than one might expect to find with light-duty vehicles. Vehicle class 2, so called passenger vehicles, have average weights ranging from 3,000 pounds on rural roads to 8,000 pounds on urban interstates. Vehicle class 3 has weight ranges more consistent with those of vehicle class 2 with an average weight range more typically between 6,000 and 7,000 pounds. The average weight for vehicle class 1, so called motorcycles, varies in a wide range and is usually in great excess of that typically considered reasonable for motorcycles, so the weight of vehicle class 1 was ignored in this analysis. It is possible that the FHWA method for classifying motorcycles is incorrect, at least when WIM measurements are conducted.

Regional categories could not be defined for vehicle classes 1 through 4. Not many states measured vehicle weights for vehicle classes 2 and 3, especially on urban road types. There were no consistent regional trends; states throughout the country could either be typically higher or lower without any regional grouping.

5.1 Monthly Variation

As with the heavier vehicles, there was no consistent or significant month of year trend in the average weight of vehicle classes 1-4 as shown in Figure 30. The sample sizes are provided in Table 13 for Figure 30. Vehicle class 1 had very little data in the months where data existed, no data at all for some months, and the average results are inconsistent for motorcycles (vehicle class 1). Vehicle classes 2 and 3 are considered to be primarily light-duty vehicles and have low average vehicle weights. The monthly averages were higher than generally considered for light-duty vehicles. These higher than expected vehicle weights suggest that the measurement accuracy of the weigh-in-motion stations should be investigated for lower vehicle classes.

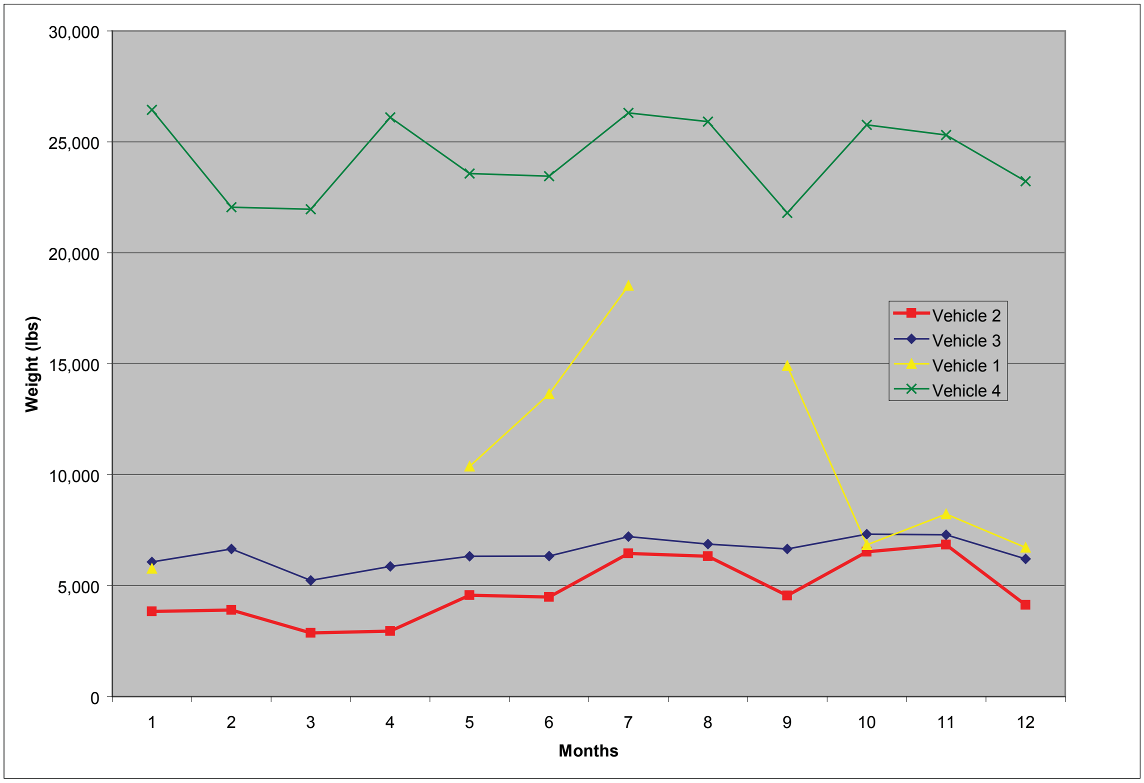

Figure 30. Average weight by month for lighter vehicle classes in 1999 on road type 1.

Table 13. Number of observations for Figure 30.

Month	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4
1	931	197,520	197,610	33,702
2	0	17,149	12,637	18,346
3	0	18,135	19,140	30,843
4	0	38,065	57,302	30,690
5	1,832	479,653	249,326	41,867
6	1,170	277,274	240,001	22,754
7	2	7,564	51,563	22,147
8	0	6,035	33,240	22,900
9	2,486	517,459	270,325	23,264
10	1	7,112	51,681	15,525
11	937	224,672	185,229	29,016
12	1,314	208,587	189,706	21,174

5.2 Daily and Hourly Variation Over an Average Week

The day of week and hour of day trends in the average weight for vehicle class 2 and 3 show no consistent trend by time of day or day of week as shown in Figures 31 and 32. On urban road types (road types 11 and higher), the average weight of vehicle class 2 is higher and more variable during the week than on weekends or on rural roads (road type 1); a trend reflected in the 2000 data as well as in the 1999 data shown in Figures 31 and 32. The high and variable weekday average values for vehicle class 2 appears in the both the 1999 and 2000 data, and are largely due to data from Connecticut. Vehicle weight data is generally sparse for the smaller vehicle classes, compared with vehicle classification or total volume counts, so often only a few States (five States contributed to Figure 31) provided weight data to VTRIS. When parsing this data by hour of each day of the week, individual state data entries can significantly affect the mean. Because the average vehicle weight for the smaller vehicles (classes 2 and 3) is low, misidentified vehicles or measurement errors can have a larger affect on the estimated mean. Results, such as that shown in Figures 31 and 32, suggest that vehicle weight data for vehicle classes 2 and 3 should be ignored or at least considered carefully given the level of uncertainty.

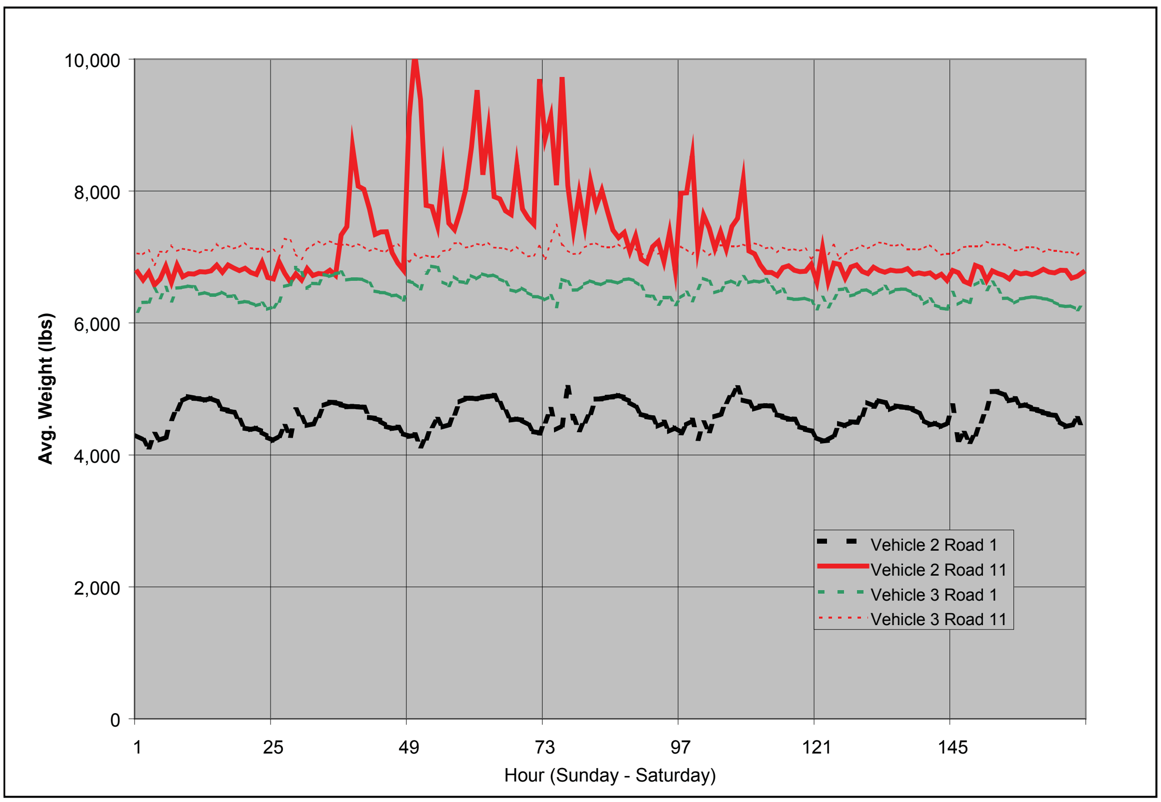

Figure 31. Light vehicles weight over a typical week in 1999.

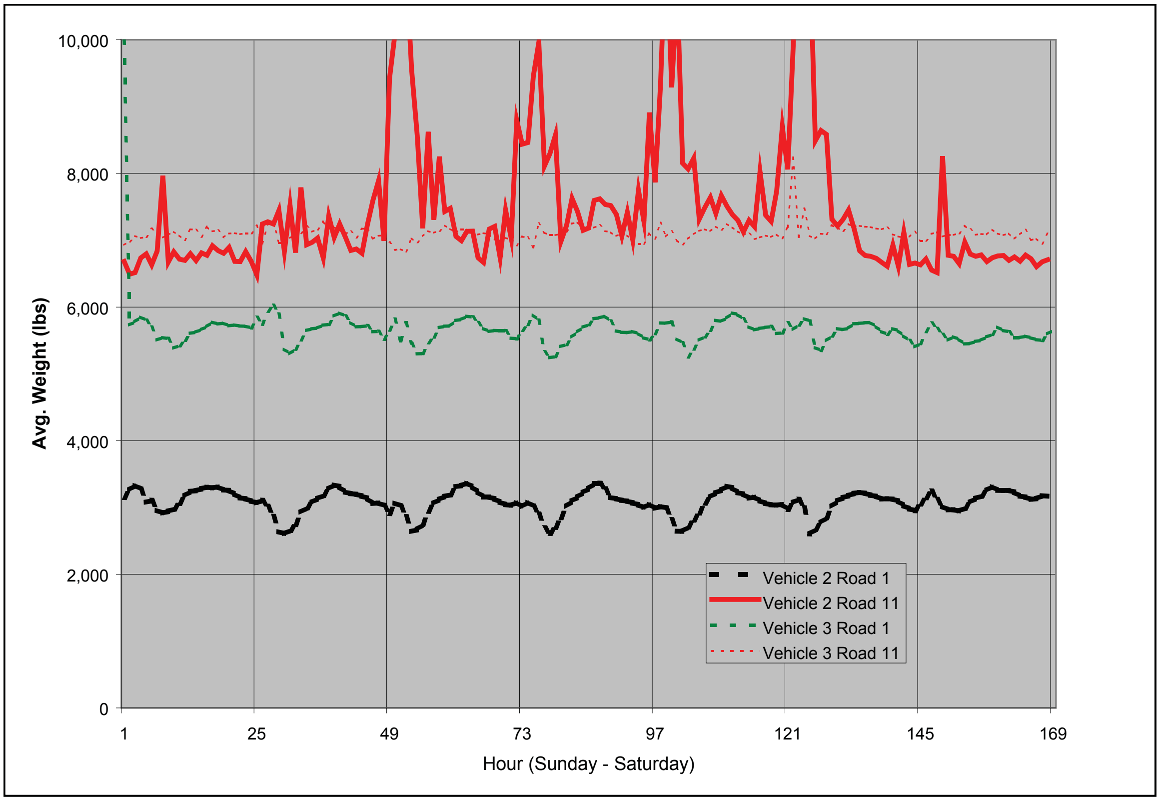

Figure 32. Light vehicles weight over a typical week in 2000.

The bus (vehicle class 4) data show a consistent trend toward higher average vehicle weights on weekends than during the week as shown for 1999 in Figure 33; a trend also observed in the 2000 data. Figure 34 shows how the day of week affects the weight distribution: on week-end days the weight distribution was shifted to higher weight bins. There is no consistent hourly trend in the vehicle weight for buses.

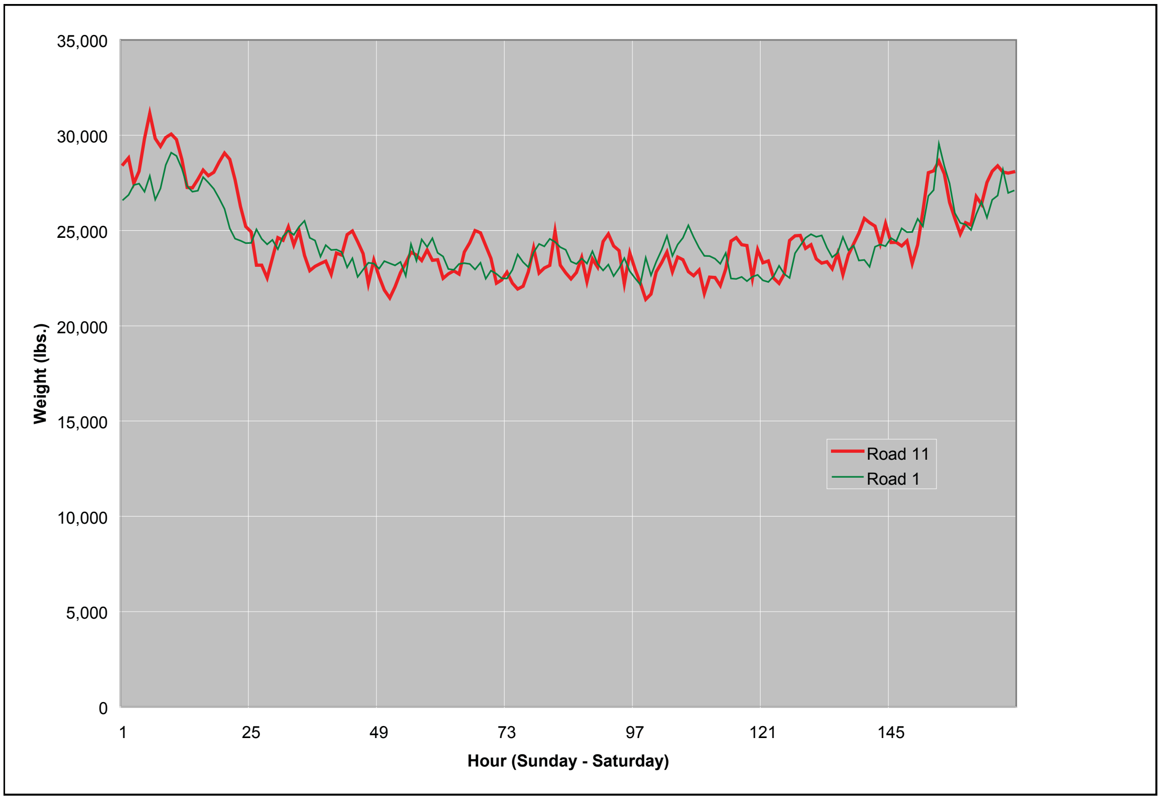

Figure 33. Bus weight over a typical week in 1999.

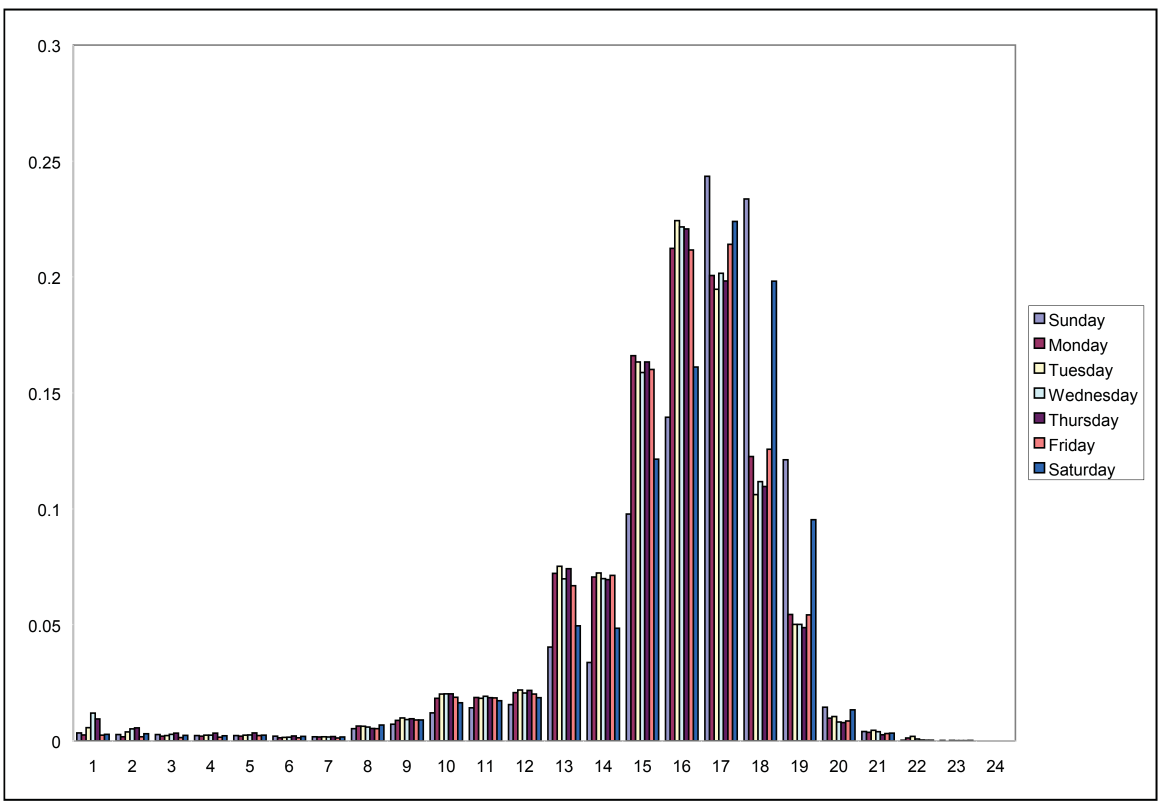

Figure 34. Bus weight bin distribution over a typical week in 1999.

6. DEVELOP NATIONAL AVERAGE WEIGHT DISTRIBUTIONS BY FHWA VEHICLE CLASSES 1-13

National average weight distribution profiles were calculated for 1999 and 2000 and were provided to EPA for further investigation. However for purposes of this report, it is too resource intensive to demonstrate and discuss average weight profiles for each vehicle class and road type. Average vehicle weights are provided in Table 14 and 15 and indicate some aspects of the national average profile in that the vehicle weight varies by road type and in-use year.

One interesting comparison is between the average weight by vehicle class on rural road types (1-9) and urban road types (11-16) roads. Vehicle classes 2 and 3 had higher average weight on urban road types than rural roads. Vehicle class 9, the most populated vehicle class within the group of vehicle classes 5 through 13, had higher average weight on rural roads compared to urban roads. Vehicle class 5, the second most populated vehicle within vehicle classes 5-13 showed no significant difference in average weight between rural and urban roads.

Table 14. Average (of the monthly averages) and 90% confidence levels (+/-) using the month-month variability of vehicle weight in 1999.

Road	Vehicle Class												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	10,624	4,790	6,504	24,328	13,080	25,124	47,797	27,011	57,053	63,825	57,141	59,244	79,102
90% CI	3,416	831	371	1,081	445	2,060	7,047	1,361	1,458	2,142	1,747	1,763	3,388
2	24,284	4,926	6,456	24,928	11,981	26,836	58,248	27,257	55,720	63,496	54,815	55,527	75,327
90% CI	3,144	652	541	829	486	1,202	2,330	1,313	1,354	2,342	2,041	1,897	3,143
6	15,804	5,961	6,966	26,460	11,376	30,672	58,498	30,093	51,983	63,848	55,055	62,794	74,405
90% CI	21,340	974	377	2,678	1,115	1,983	6,333	2,345	3,859	3,530	4,470	6,650	2,569
7		6,009	11,811	25,427	11,938	27,312	50,909	28,756	50,059	58,655	47,499	56,922	67,109
90% CI		481	7,515	3,347	2,030	2,294	7,845	3,690	6,996	7,962	3,994	21,259	9,380
8				41,998	27,450	27,865		45,562	39,019				
90% CI				68,748	20,729	13,591		5,092	27,532				
9					9,174	26,841		27,172	36,597				
90% CI					2,348	37,735		15,124	17,722				
11		8,010	7,156	24,152	11,044	26,652	60,169	29,620	51,546	62,689	53,000	58,641	77,693
90% CI		1,468	76	2,079	1,543	1,331	3,129	1,798	1,308	2,346	1,609	1,412	3,324
12		7,798	8,932	29,373	12,351	28,497	60,787	29,907	48,431	60,691	54,344	56,915	72,611
90% CI		1,077	4,004	1,019	1,198	3,055	5,287	2,299	3,140	5,403	3,268	2,655	6,779
14		6,625	9,233	23,300	13,442	30,460	63,438	32,323	53,196	62,183	54,647	62,347	86,976
90% CI		693	4,080	3,069	2,430	3,519	6,772	4,767	3,315	3,849	2,132	5,331	22,572
16		3,950	13,167	27,208	12,722	30,236	55,950	31,582	51,450	71,069	56,219	74,287	100,753
90% CI		2,180	16,637	3,122	1,755	3,517	10,981	3,642	8,565	6,494	10,125	13,802	36,512

Table 15. Average (of the monthly averages) and 90% Confidence Levels (+/-) using the month-month variability of vehicle weight in 2000.

Road	Vehicle Class												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	27,418	3,178	5,612	26,144	12,984	29,535	45,066	29,010	59,721	64,749	63,789	65,295	88,194
90% CI	3,033	236	246	2,320	434	2,912	2,972	1,728	1,140	5,841	2,046	5,652	8,597
2	12,557	4,927	6,661	24,406	13,411	29,562	56,031	29,653	55,835	63,230	55,763	57,943	78,702
90% CI	4,830	709	342	713	344	778	1,905	1,799	1,224	1,257	2,384	1,490	2,232
6		7,037	7,297	24,374	11,453	29,489	62,388	32,849	51,944	64,829	60,004	59,317	76,185
90% CI		208	347	973	624	845	2,464	2,712	3,106	3,552	5,898	4,224	2,986
7			21,936	24,099	12,669	28,161	39,924	28,891	49,720	55,550	56,285	57,087	77,611
90% CI			37,582	2,419	2,095	4,705	11,325	6,092	6,949	5,260	18,050	11,437	7,233
8				20,209	14,865	35,917		11,649	44,552				
90% CI				886	6,562	5,386		21,290	23,883				
9													
90% CI													
11	19,433	8,310	8,547	27,045	12,353	25,460	54,073	29,246	52,041	64,805	54,119	60,466	90,037
90% CI	14,349	1,832	3,229	1,667	852	1,000	3,793	1,750	3,697	3,144	5,070	4,834	9,886
12		9,191	7,090	28,985	14,498	32,030	50,005	32,903	51,244	62,767	50,454	56,752	79,858
90% CI		2,281	99	434	680	892	3,891	661	1,233	2,264	2,524	1,889	7,309
14		7,705	6,649	26,378	12,879	31,055	67,957	33,328	53,266	72,883	51,000	58,811	95,877
90% CI		5,043	702	2,384	748	3,081	11,548	4,413	6,556	11,426	6,839	7,215	21,852
16			6,940	24,148	15,731	29,829	60,454	31,662	46,298	56,544	51,487	91,701	54,555
90% CI			2,762	2,862	1,312	3,804	9,384	3,433	4,278	6,799	11,275	46,139	22,550

7. DEVELOP NATIONAL AVERAGE WEIGHT BIN DISTRIBUTIONS BY FHWA VEHICLE CLASSES 1-13

As has been discussed in this report, the vehicle weight profiles vary by roadway functional class. The weight profiles can also vary by time period, especially by day of week. However, to show the typical weight profiles, the annual average weight bin fractions for vehicle classes 2 – 13 are shown in Figures 35 – 40 for the major functional classes. The smaller functional classes (6-9 for rural and 14-16 for urban) show much more variable weight bin distributions because there were fewer sites and fewer vehicles weighed on these roadway types.

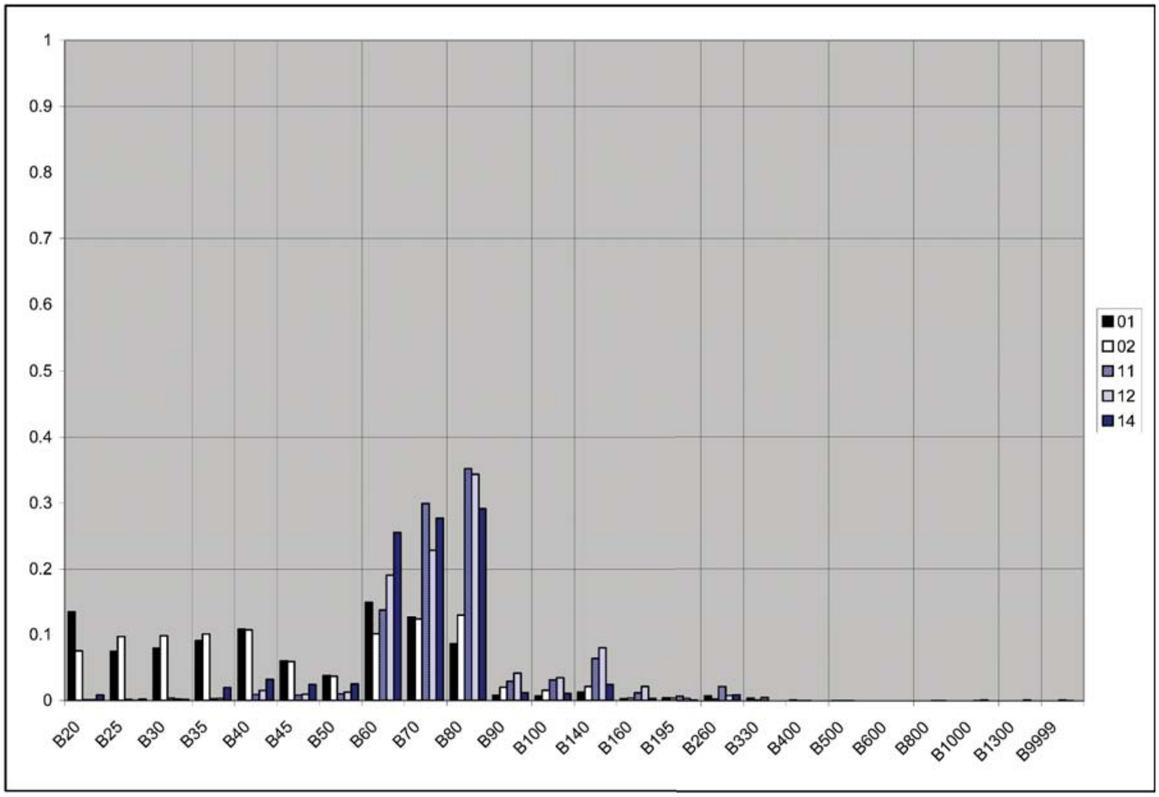

Figure 35. Vehicle 2 weight bin distribution in 1999 by functional class.

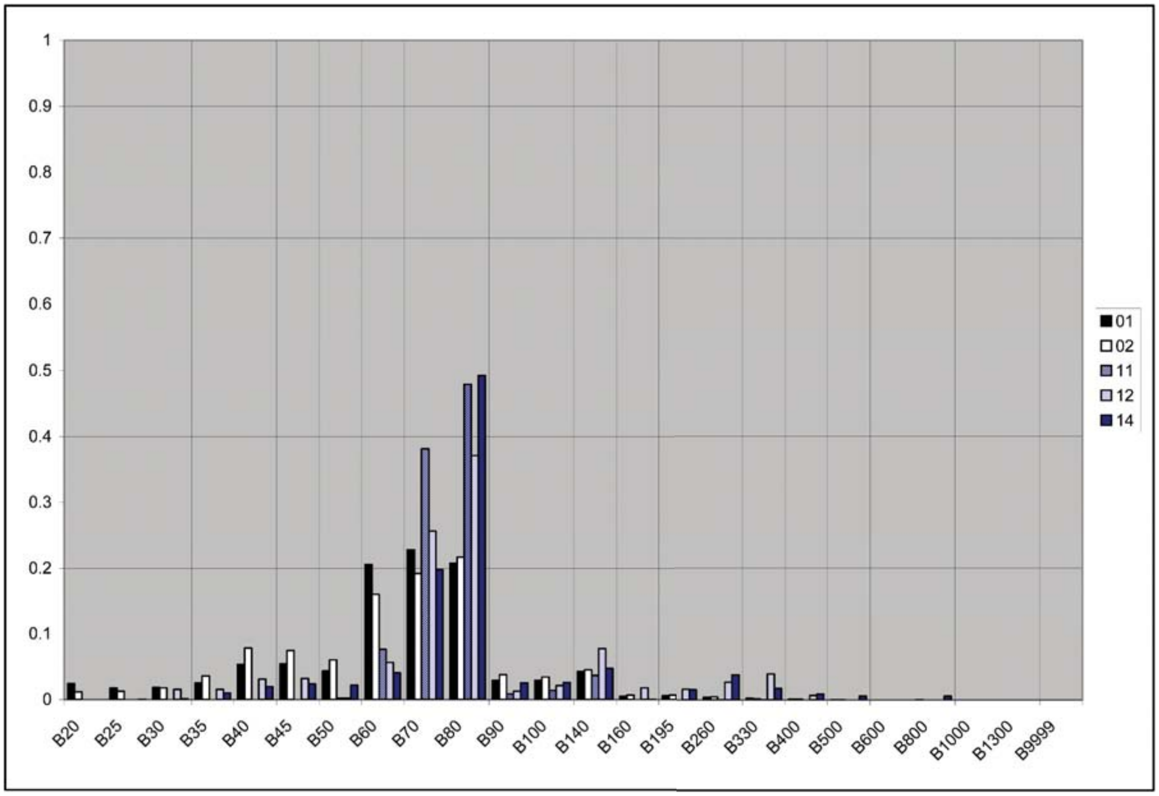

Figure 36. Vehicle 3 weight bin distribution in 1999 by functional class.

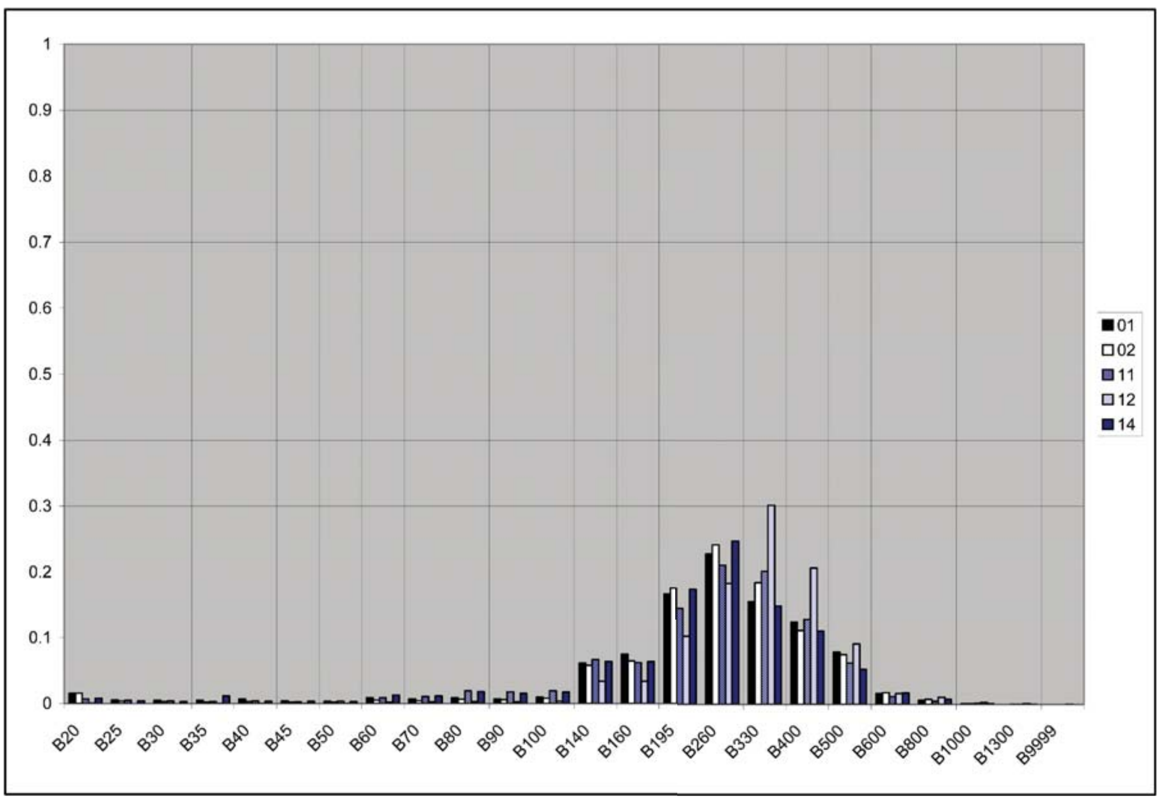

Figure 37. Vehicle 4 weight bin distribution in 1999 by functional class.

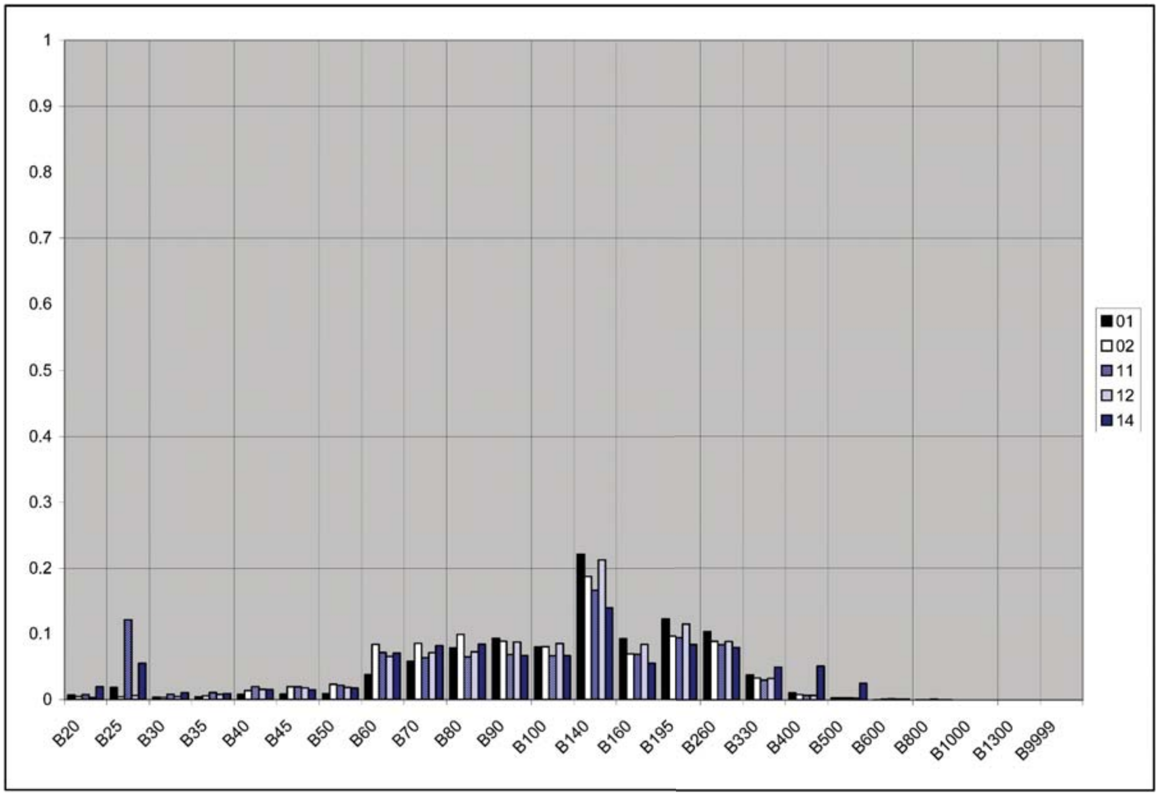

Figure 38. Vehicle 5 weight bin distribution in 1999 by functional class.

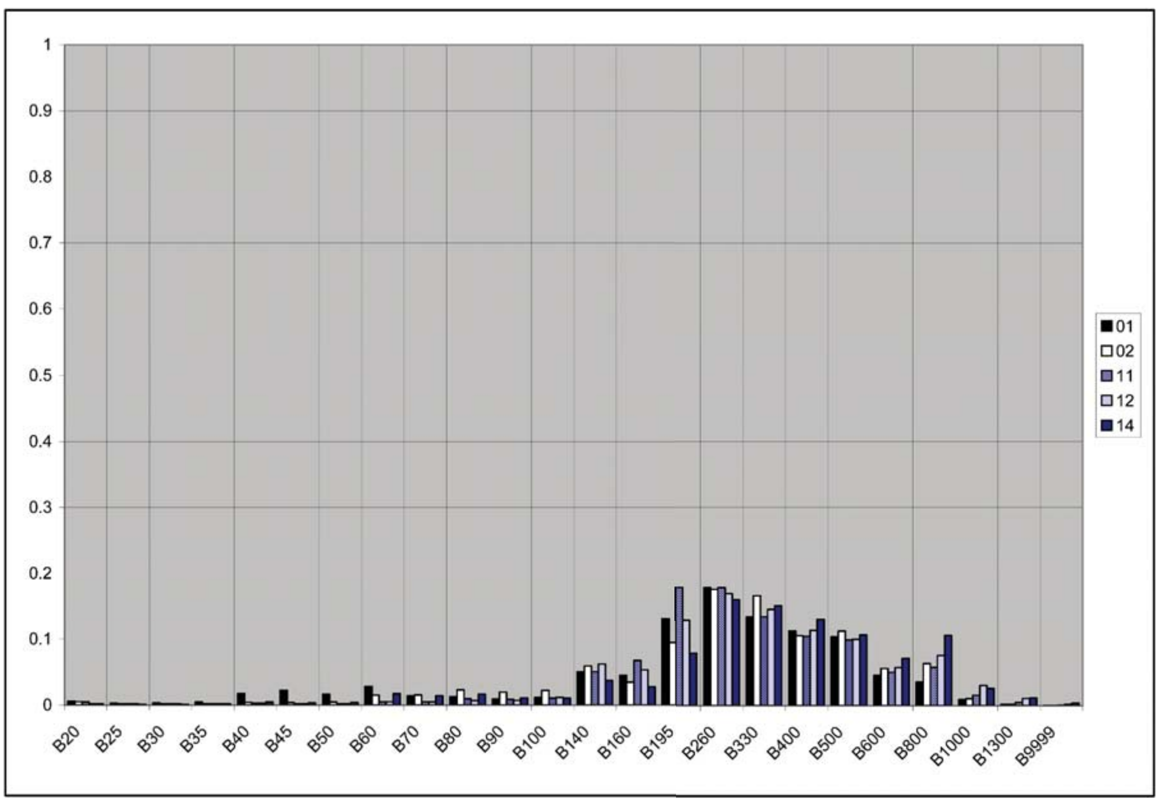

Figure 39. Vehicle 6 and 7 weight bin distribution in 1999 by functional class.

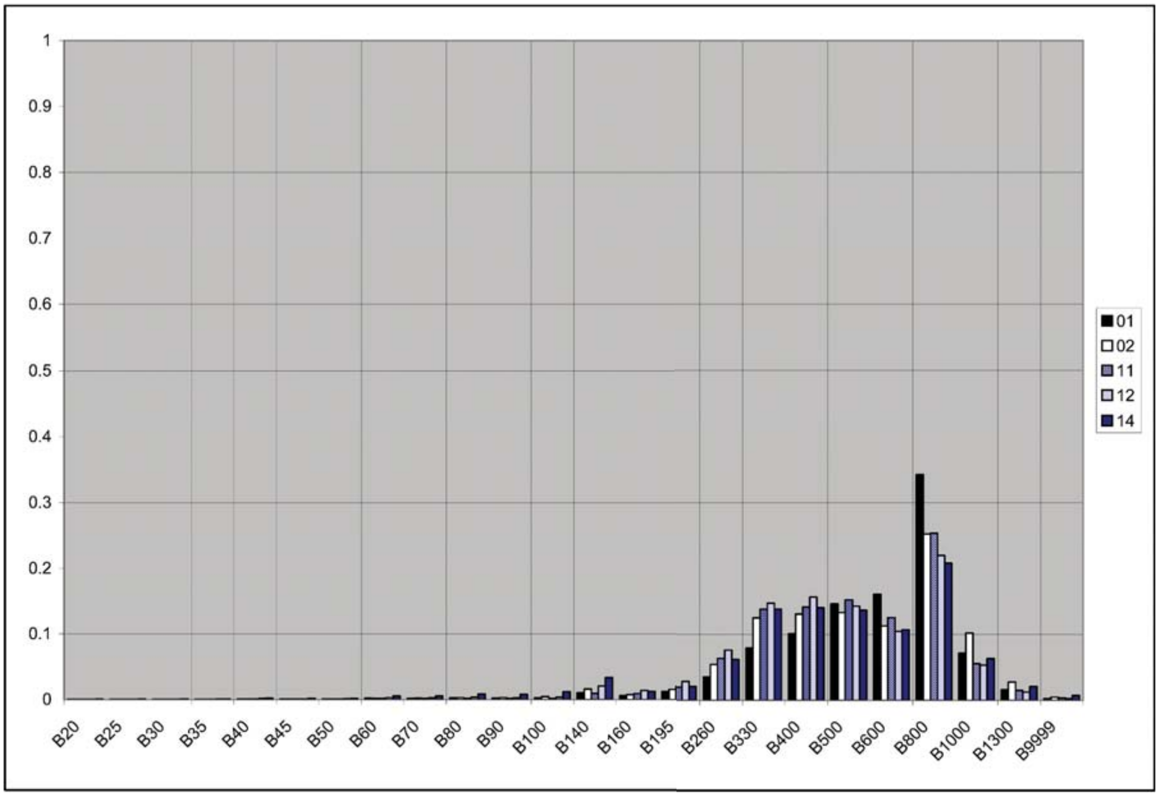

Figure 40. Vehicle 8-13 weight bin distribution in 1999 by functional class.

8. VEHICLE CLASS FRACTIONS

In developing national vehicle counts/VMT/vehicle mix fraction estimates, it was understood that some regional differences described in this report would be explicitly included in the average. As noted in Section 2, the data for the vehicle mix by type showed a clear regional trend on rural interstates but no clear trends for other roadway types. This regional trend may influence the national average calculated here depending upon which states submitted data and the number of sites in each state that were reported to VTRIS.

8.1 Monthly Variation

A sample of month-to-month variability and uncertainty in the vehicle mix is shown in Figure 41 for rural interstates in 1999 and Table 16 for all road types in 1999 and 2000. Shown by example in Figure 41, and with other road types and years, there was no clear seasonal effect on the vehicle mix. Table 16 demonstrates that the most important vehicle classes are 2 and 3 (typically associated with light-duty vehicles) and 5 (light heavy-duty), 9 (heavy heavy-duty) and 8 (heavy heavy-duty) for heavier vehicle classes.

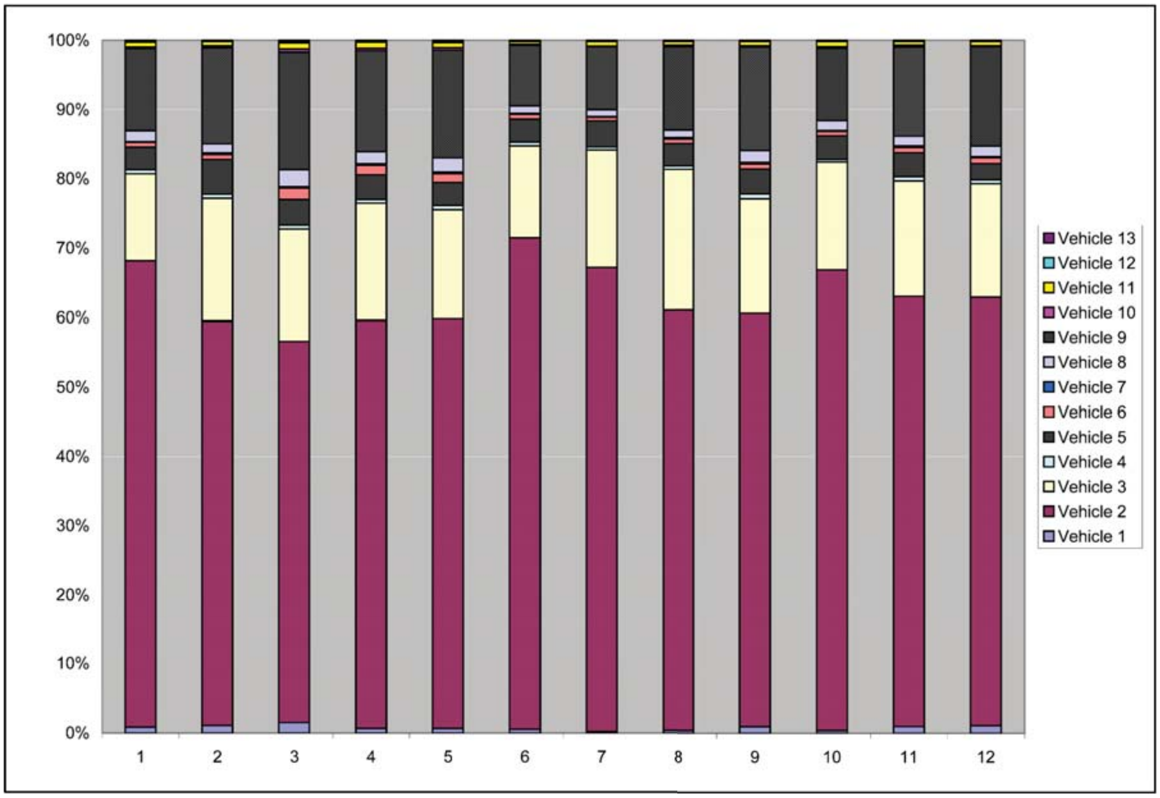

Figure 41. Month to month variability for road 1 in 1999.

Table 16. Monthly-average annual relative vehicle class counts and monthly uncertainty.

Road \ Year	Result	Vehicle												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1 – 1999	Mean	0.008	0.623	0.162	0.005	0.035	0.009	0.002	0.015	0.129	0.003	0.007	0.001	0.001
	90% CI	0.002	0.025	0.011	0.000	0.003	0.002	0.000	0.002	0.014	0.001	0.001	0.000	0.000
1 – 2000	Mean	0.005	0.592	0.158	0.007	0.026	0.014	0.001	0.022	0.156	0.004	0.007	0.002	0.003
	90% CI	0.001	0.020	0.006	0.001	0.002	0.002	0.000	0.002	0.011	0.001	0.000	0.000	0.001
2 – 1999	Mean	0.002	0.634	0.230	0.002	0.042	0.009	0.002	0.011	0.058	0.003	0.003	0.001	0.002
	90% CI	0.000	0.012	0.006	0.000	0.004	0.001	0.000	0.002	0.008	0.001	0.001	0.000	0.001
2 – 2000	Mean	0.004	0.620	0.228	0.003	0.036	0.010	0.002	0.014	0.073	0.003	0.002	0.001	0.004
	90% CI	0.001	0.006	0.004	0.000	0.003	0.000	0.000	0.001	0.004	0.000	0.000	0.000	0.002
6 – 1999	Mean	0.008	0.672	0.225	0.001	0.052	0.007	0.001	0.005	0.022	0.002	0.001	0.000	0.002
	90% CI	0.001	0.018	0.011	0.000	0.012	0.001	0.000	0.001	0.005	0.000	0.000	0.000	0.001
6 – 2000	Mean	0.007	0.677	0.231	0.001	0.037	0.008	0.001	0.007	0.027	0.002	0.001	0.000	0.002
	90% CI	0.001	0.011	0.009	0.000	0.004	0.000	0.000	0.001	0.003	0.000	0.000	0.000	0.000
7 – 1999	Mean	0.001	0.640	0.269	0.001	0.040	0.007	0.001	0.007	0.024	0.003	0.001	0.000	0.005
	90% CI	0.001	0.022	0.022	0.000	0.007	0.001	0.000	0.004	0.007	0.001	0.000	0.000	0.002
7 – 2000	Mean	0.002	0.552	0.330	0.002	0.044	0.011	0.001	0.021	0.031	0.002	0.001	0.000	0.002
	90% CI	0.001	0.021	0.012	0.001	0.003	0.002	0.000	0.006	0.006	0.001	0.000	0.000	0.001
11 – 1999	Mean	0.006	0.724	0.161	0.003	0.032	0.014	0.001	0.008	0.046	0.001	0.002	0.000	0.000
	90% CI	0.001	0.019	0.003	0.001	0.003	0.014	0.000	0.001	0.006	0.000	0.000	0.000	0.000
11 – 2000	Mean	0.007	0.716	0.167	0.003	0.029	0.008	0.001	0.011	0.054	0.001	0.002	0.000	0.000
	90% CI	0.002	0.016	0.010	0.000	0.002	0.001	0.000	0.001	0.005	0.000	0.000	0.000	0.000
12 – 1999	Mean	0.007	0.744	0.168	0.002	0.038	0.005	0.002	0.005	0.027	0.001	0.001	0.000	0.000
	90% CI	0.002	0.014	0.007	0.000	0.003	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
12 – 2000	Mean	0.007	0.769	0.162	0.004	0.023	0.005	0.001	0.005	0.023	0.000	0.001	0.000	0.000
	90% CI	0.002	0.013	0.011	0.001	0.003	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
14 – 1999	Mean	0.014	0.702	0.211	0.003	0.038	0.008	0.001	0.005	0.017	0.000	0.000	0.000	0.000
	90% CI	0.003	0.027	0.016	0.001	0.008	0.002	0.000	0.001	0.004	0.000	0.000	0.000	0.000
14 – 2000	Mean	0.006	0.702	0.209	0.003	0.053	0.007	0.001	0.005	0.014	0.001	0.000	0.000	0.000
	90% CI	0.002	0.014	0.011	0.000	0.009	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
16 – 1999	Mean	0.003	0.725	0.176	0.002	0.055	0.010	0.002	0.009	0.013	0.002	0.001	0.000	0.002
	90% CI	0.001	0.051	0.019	0.001	0.040	0.006	0.002	0.004	0.003	0.001	0.000	0.000	0.001
16 – 2000	Mean	0.007	0.728	0.172	0.003	0.052	0.008	0.000	0.013	0.015	0.000	0.001	0.000	0.000
	90% CI	0.002	0.032	0.024	0.001	0.021	0.001	0.000	0.002	0.003	0.000	0.000	0.000	0.000

8.2 Hourly Variation Over an Average Week

The vehicle class counts show clear differences by hour of day and day of week, especially distinguishing between weekdays and weekend days. Figures 42 and 43 show the hourly change in the vehicle mix throughout the average weekly activity.

In these figures, it can be seen that Sunday (first day of week), Saturday, and weekdays are clearly different from one another by comparing the fraction of vehicle 9 (in bold green) and Vehicle 8 (bold blue). Differences between each weekday are less clear, but indicate that each weekday could also be considered a unique day.

The hourly change in vehicle mix is more dramatic with an overnight and secondary mid-day peak in the mix of heavier heavy-duty vehicles (primarily vehicle classes 8, 9, and 11) higher than the average daily fraction.

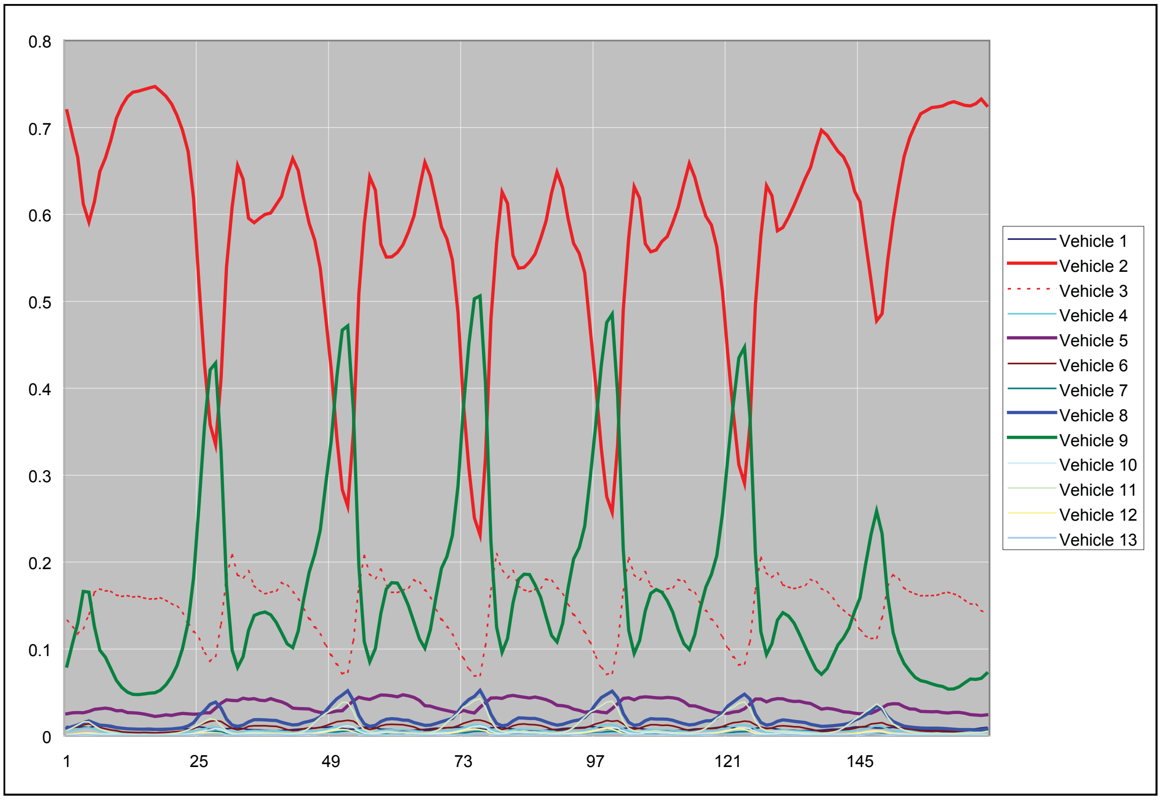

Figure 42. 1999 Hourly average-week vehicle fractions on road type 1, rural interstates.

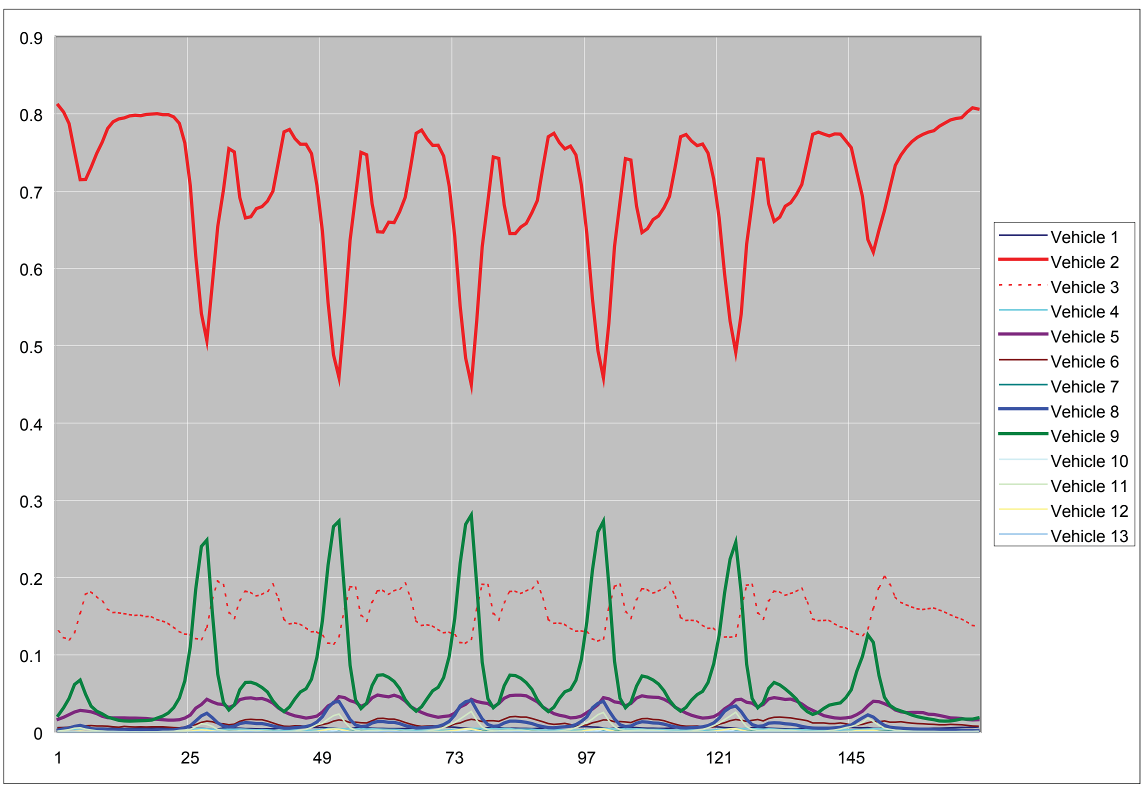

Figure 43. 1999 Hourly average-week vehicle fractions on road type 11, urban interstates.

9. TRAFFIC VOLUME TRENDS

The Traffic Volume Trends data for 2000 were ported into MySQL and summary data were provided to EPA in Access® files. The data for 1999 were not available. A sample of the 2000 results for rural and urban road types is shown in Figures 44 and 45. The TVT data results shown in these graphs provide a consistent understanding of the typical hourly traffic profiles. As the road types move to lower traffic volumes, the hourly profile maintains a similar shape but lower in magnitude.

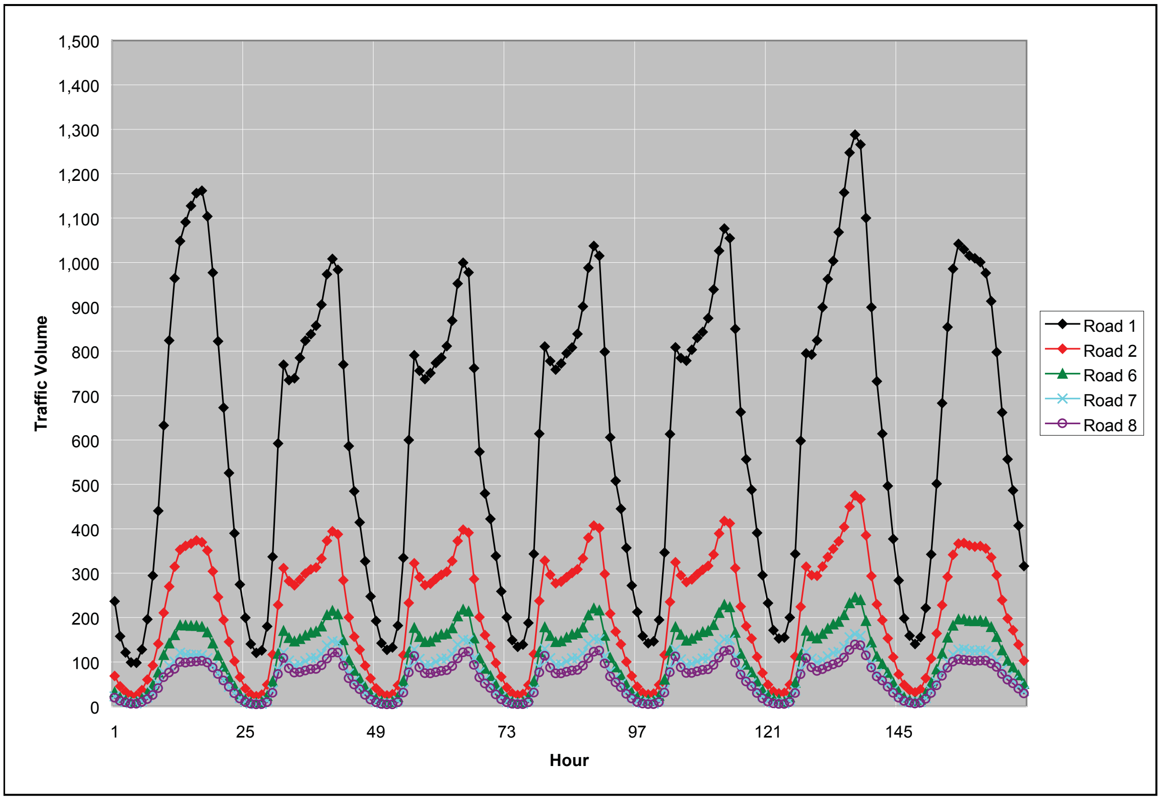

Figure 44. Typical national average weekly total traffic volume for rural roads.

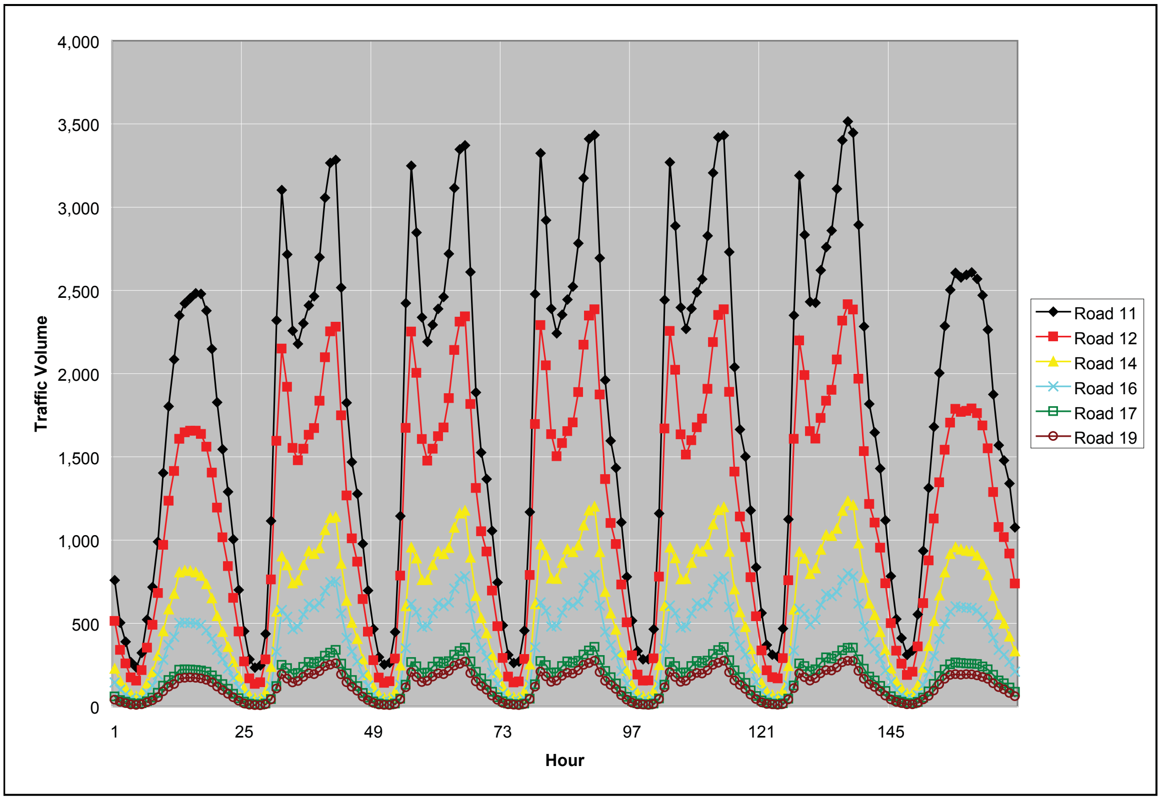

Figure 45. Typical national average weekly total traffic volume for urban roads.

As with the vehicle class count data, the total volume counts were averaged at individual sites before being averaged across sites. The steps followed in processing the class count data were the same as the VTRIS vehicle class counts data:

1. All counts across lanes in the same roadway direction were totaled. Different directions at site were treated separately.
2. All counts (either total volume or count for each vehicle class) were averaged for each site-direction pair by hour, day of week (i.e., Sunday through Saturday), month, and roadway classification. This means that at most five values were averaged together, corresponding to the total number of days in a week during one month. In other words, all Monday counts during January for hour 10 were averaged together at each site-direction pair.
3. The hourly class counts were averaged across the sites. These averages were calculated by roadway function class, month, day of week, and hour of the day.

EPA requested that temporal profiles be provided for four aggregate road types in addition to the more numerous types shown in Figures 44 and 45. These aggregate temporal profiles are provided in Appendix C.

In addition, Appendix D provides an analysis of the regional variability of the TVT total volume temporal profiles and a comparison of the temporal trends between the TVT and VTRIS data. A regional pattern of the temporal profiles could not be found in general, however individual States had significant differences for some road types and temporal profiles. The VTRIS total volume counts exhibited similar trends to the TVT profiles indicating that VTRIS vehicle mix could be used in concert with TVT total volume estimates.

10. CONCLUSIONS AND RECOMMENDATIONS

This work demonstrates that the VTRIS and TVT data can be imported into standard database programming tools that can be used to generate averages and typical temporal or regional profiles useful for emissions modeling. The summary results presented in this report can inform EPA of vehicle characteristics, weight and class fractions of the in-use fleet.

The results of this work were provided with this report as a series of database and Excel summary files, as it was impossible to present all the summary results in a reasonable length report. The summaries presented in this report were selected to provide EPA a flavor of the results. The more important conclusions of this work are:

- There were no clear regions that could be defined with similar vehicle weight profiles, but there were indications of a regional effect on the vehicle fleet mix. state specific summaries were produced to further investigate regional effects on both vehicle weight distributions and vehicle mix.

- Temporal profiles of weight or weight distribution indicate that month of year had little effect, while the day of week and in some cases the hour of day had a noticeable effect on the average vehicle weight and weight distribution. The temporal profile of vehicle mix was more dramatic showing clear diurnal and weekly profiles especially of the larger heavy-duty vehicle fractions. The temporal profiles of the vehicle mix will have an effect on modeled emissions because heavy-duty vehicles typically emit NOx and PM emissions at much higher rates than light-duty vehicles, so overall emission estimates will be sensitive to these temporal profiles of the vehicle mix.

- The road type, especially urban or rural, has an effect on all elements described in this report. The road type where vehicle weight was measured can affect the average weight for some vehicle classes, but the overall and temporal profiles of the vehicle mix and total traffic volume were more clearly affected by the road type measured. Heavy-duty vehicle mix tends to be highest with rural road types and higher traffic volume roadways. The total traffic volume profiles were more sensitive to time of day on higher traffic volume roadways.

- Vehicle weights for the smaller vehicle classes, 2 and 3, seem unreasonably high and may need to be ignored. It is unclear whether the vehicle weight measurements for the lighter vehicles were affected by the detection limits of the measurement method or had been calibrated only for the higher weights of heavy-duty vehicles. In either case the lighter vehicles had average weight readings of up to twice the gross vehicle weight rating for the vehicles supposedly measured.

- The results in this work suggest that vehicle grouping be reinvestigated or that no groupings be made maintaining as much specificity as is provided in the FHWA vehicle classifications. Vehicle classes 6 and 8 had similar average vehicle weights while vehicle class 7 was more typical of vehicle classes 9 – 13. Therefore the typically used vehicle groupings of (8 – 13) and (5 – 7) were not consistent with the vehicle classes found.

There are several potential areas for future work. While for the most part the data from 1999 and 2000 provided a consistent understanding of the regional and temporal profiles, additional years of VTRIS data might be evaluated to provide a more robust understanding of typical weight and vehicle mix profiles. From analysis of traffic data that ENVIRON has performed for several states, we know that states do not always submit all their data to VTRIS, so additional data can be gathered directly from the state agencies, especially for states not included in VTRIS to fill in missing regions.

VTRIS and TVT are part of the Heavy Vehicle Travel Information System (HVTIS), which is a data collection system authorized by the Office of Management and Budget (OMB). States must have traffic monitoring systems, and FHWA requests a copy of some of their data reducing the added burden when submitting data to providing it in the requested format. The traffic data received is only from state DOTs and not county or municipal transportation departments. As has been demonstrated and explained in this report, missing data is the primary cause for variability and discontinuous trends, and there are various reasons why a state may have missing data including equipment malfunction, budget limits, or unwillingness to submit it to VTRIS. The Weigh-In-Motion (WIM) systems have the most problems and states often struggle to keep them operating, especially when the systems have endured the harsh environment of the roadway after a few years. FHWA encourages the states to edit data before submitting to VTRIS or TVT, so that they are comfortable with publishing the data. Both TVT and VTRIS entry systems perform basic data edits. However, individual data entries by station or other delineation may be peculiar compared with national, state, or metropolitan aggregates. These outliers may be unique situations and influence the average while being valid data. Outlier identification and review were performed to the extent possible within the scope of the current work, although additional work on such data anomalies is recommended.

Another area relevant for current modeling is to better cross-reference the FHWA and MOBILE vehicle classes. The vehicle classification data presented in this report provide field verification of national averages and better delineation of vehicle travel patterns by road type and region. These results have potential importance in current emissions work both for overall road type mix and temporal profiles. The results of this study point out many of the failings of current cross-referencing methods described in Appendix B.

REFERENCES

EPA. (2004), personal communication with Dave Brzezinski, U.S. Environmental Protection Agency, September, 2004, modeling tool to estimate national average VMT mix by in-use month and year.

EPA. (2003), personal communication from Megan Beardsley, U.S. Environmental Protection Agency, September 2003.

Gillman, Ralph. (2005), Acting Chief, Travel Monitoring and Surveys Division Federal Highway Administration, personal communication, September 29, 2005.

TCEQ. (2004), Houston-Galveston State Implementation Plan. [TTI (2003), “2000 On-Road Mobile Source Episode-Specific Emission Inventories for the Houston/Galveston Ozone Nonattainment Area, prepared for the Texas Council on Environmental Quality by the Texas Transportation Institute, August, 2003.]

Yoon, S., Zhang, P., Pearson, J.R., Guensler, R.L., and Rodgers, M.O. (2004). “A Heavy-Duty Vehicle Visual Classification Scheme: Heavy-Duty Vehicle Reclassification Method for Mobile Source Emissions Inventory Development,” Presentation at the 2004 AWMA.

APPENDIX A – QUALITY ASSURANCE/QUALITY

CONTROL EVALUATION AND REVIEW

A-1. PROJECT OBJECTIVES, ORGANIZATION, AND RESPONSIBILITIES

A-1.1 Purpose of Study

Heavy-duty vehicles have been seen as contributing a large fraction of emissions from on-road vehicles and are coming under more intense scrutiny because light-duty emissions have been controlled to a greater extent than heavy-duty vehicle emissions. A heavy-duty vehicle can produce 10 to 100 times the emissions (of NO_X and PM emissions especially) of a light-duty vehicle. Thus, heavy-duty vehicle activity needs to be better characterized. Key uncertainties with the use of MOBILE6 regarding heavy-duty vehicle emissions include the fraction of heavy-duty vehicles on all types of roadways at all times of day. In addition, there may regional variability in both the fraction of different vehicle classes and the vehicle weights within each class.

With the MEASURE[1] model and the developing MOVES[2] model (eventual replacement to MOBILE[3]), greater emphasis is given to physical parameters affecting the engine loads and therefore the emissions from individual vehicles. One primary factor affecting the engine load is the vehicle weight, so the weight of the vehicle on the road is needed to estimate the in-use emissions of given vehicles. Because the effect of vehicle weight may be nonlinear for certain types of driving, the weight distribution of vehicles is useful knowledge to incorporate into emission estimates.

Databases collected by the Federal Highway Administration (FHWA) include vehicle count and classification from the Highway Performance Monitoring System (HPMS) which was automated traffic recorders (ATR) used to produce the Travel Volume Trends (TVT) reports. Other data sets hold the results of data collection from weigh-in-motion (WIM) sensors, and other data sources (visual observation, weigh stations, and other special projects) maintained by the FHWA and compiled in the Vehicle Travel Information System (VTRIS).

This report investigates and evaluates these databases to assist in the development of improved emissions estimates of heavy-duty vehicles. The goal of the project was therefore to produce estimates of the ratio of heavy-duty vehicles to all vehicle traffic, and weight distributions

[1]MEASURE = Mobile Emissions Assessment System for Urban and Regional Evaluation. Model. This model is a prototype GIS-based modal emissions model.

[2]MOVES = Mobile Vehicle Emissions Estimator, next generation mobile source emissions model. The model will be used for State Implementation Plan emission inventories and will replace the current MOBILE model.

[3]MOBILE = Current mobile source emissions model used for State Implementation Plan emission inventories.

for heavy-duty vehicles according to the time of day, day of week, and other temporal variables as well as investigating regional differences.

A-1.2 Project Objectives

The objectives of this project were to:

A. Generate detailed weight distributions of FHWA classes 1-13 individually

B. Develop regional aggregations of data.

C. Analyze the regional variability in weight distributions by road type.

D. Analyze the temporal variability in the weight distributions by road type.

E. Develop national average weight distributions for FHWA classes 1-13 individually for each road type.

F. Develop national average temporal distributions for FHWA classes 1-13 individually for each road type.

G. Develop VMT fractions for the FHWA classes, especially groups 1 thru 4 individually, 5-7 as a group, and 8-13 as a group. These fractions will be by month, day of week, and hourly.

H. Report the results of uncertainty analysis on A through G above.

I. Evaluate the Traffic Volume Trends dataset for the most appropriate platform for its incorporation into the analysis for task G above.

National or state total vehicle miles traveled (VMT) estimates have historically been provided by the Federal Highway Administration (FHWA) as annual or average daily totals or other similar general estimates for all vehicle classes together. In order to properly use these estimates to estimate emissions for air quality planning, temporal adjustments and the vehicle class fractional mix must be determined. The TVT data were used to provide the temporal adjustments of the total (all vehicle classes summed together) VMT because TVT data has been used by FHWA to provide the VMT estimates. The vehicle mix was determined using the VTRIS data. In addition, VTRIS also provides vehicle weight data useful as input data for future estimation tools that EPA is developing.

The TVT and VTRIS databases include vehicle counts (by class and weight in VTRIS) for a number of sites across the country defined by roadway type and provided by month, day, and hour. These two databases do not consist of identical sites, so the temporal distribution of the total VMT was determined separately from the temporal variability in the vehicle mix or vehicle weight distribution. Roadway functional classes (type of roadway such as interstate, arterial, collector, etc. and either rural or urban) are standard FHWA road type designations and were used to associate the temporal trends of total VMT and the vehicle mix and weight estimates.

Several statistical procedures were used to estimate uncertainties in the final aggregate national estimates of vehicle weight distributions and vehicle class fractions (Objective H.). Statistical hypothesis testing procedures are also available for evaluating the statistical significance of regional and temporal differences in these distributions. Uncertainties in individual class or weight fraction estimates obtained from aggregated data (for example, national estimates of the Class 5 vehicle travel fraction) were obtained by treating the data as binomial and computing the standard error of the sample estimate of the binomial probability. This process was repeated for each vehicle class of interest. In addition, significance tests were applied to determine if vehicle class or weight distributions differ by facility type or by time of day (or day of week). These significance tests were based on the chi-square statistic computed from contingency tables of vehicle counts such as tables of counts by vehicle class and hour of day.

The results of this study were provided along with the accompanying uncertainty analysis in files along with the final report. The databases used in the study are large and have been provided on a hard drive to which the final report, results, and uncertainty files can be added. The summary files primarily provided in Access® database tables were also large, but provided aggregate results by the spatial and temporal delineations requested in the work assignments.

A-1.3 Secondary Data Required by the Project

The secondary data used in this project was all the available data contained in the Federal Highway Administration's (FHWA) Vehicle Travel Information System (VTRIS) dataset for the years 1999 and 2000. This data was previously evaluated for its usefulness and analyzed in Phase I of this work. This work assignment extended the analysis of the 1999 and 2000 VTRIS data and provided national and state average activity with the combined datasets.

The other dataset was the Traffic Volume Trends (TVT), also maintained by FHWA. The TVT data was used to generate estimates of VMT fractions under item (G) in section 1.2 above.

A-1.4 Approach for Evaluating Project Objectives

In Phase I of this work, the raw 1999 and 2000 VTRIS was incorporated into two Microsoft SQL Server databases (one containing the 1999 VTRIS data, the other for the 2000 VTRIS Data). Algorithms (discussed at length under "QA Procedures" below) were developed for reducing the dataset to include only those data deemed appropriate for this analysis. Starting from these “cleaned” versions of the datasets, the analyses of elements (A) through (H) of the project objective were conducted.

The Traffic Volume Trends (TVT) data has been examined. Only monthly summaries of the 1999 TVT data was available, so only the 2000 TVT data was used. For the 2000 data, a QA procedure that FHWA applies to this type of data and detailed in Section 3.1 was followed. There were additional restrictions required that were placed on the 2000 TVT data clearly documented in this appendix. Because only one year’s worth of data was available for TVT, specific emphasis was placed on evaluating whether sufficient data was available to provide aggregate results that could be widely applied.

A-2. SOURCES OF SECONDARY DATA

A-2.1 Sources of Secondary Data Used

There are two datasets used in this project, namely the VTRIS and TVT datasets, both compiled and maintained by FHWA.

VTRIS and TVT are part of the Heavy Vehicle Travel Information System (HVTIS), which is a data collection system authorized by OMB. States must have traffic monitoring systems, and FHWA asks for a copy of some of their data in the Traffic Monitoring Guide (TMG) format. The traffic data is only from state DOTs.

The automatic traffic recorders (ATR) that generate data for TVT and the automatic vehicle classifiers (AVC) and weigh-in-motion (WIM) systems that generate data for VTRIS are usually at different locations. Since traffic volume is also an output of AVC, AVC sites provide traffic volume to the TVT database as well. FHWA is beginning the process of merging TVT and VTRIS software into the new TMAS (Travel Monitoring Analysis System) and more AVC sites and data are expected in the future, so there will be greater overlap between VTRIS and TVT databases (Ralph Gillman, FHWA, 2005).

States often have missing entries, and there are various reasons for this. Individual detectors may not be working, communications with detectors may have broken down, their data processing software may not be working correctly, they may be in the process of changing data processing software or operating systems, they may have difficulty providing data in TMG format, they may be short on staff, or they may be late, etc. The WIM systems have the most problems and states often struggle to keep them operating, especially when the systems have endured the harsh environment of the roadway a few years.

FHWA encourages the states to edit their data before submitting it to VTRIS or TVT, so that they are comfortable with publishing the data. Both TVT and VTRIS entry systems perform basic data edits. However, individual data entries by station or other delineation may be peculiar compared with national, state, or metropolitan aggregates. These outliers may be unique situations and influence the average while be valid data. Such outlier identification and review were beyond the scope of the current work, however the data aggregations performed in this study identified suspect data.

A-2.2 Rationale for Selecting Data Sources

The VTRIS dataset was selected for this analysis because of its size and content. There were roughly 30 states with data in VTRIS for 1999 and 2000 with hourly vehicle classification data from numerous sites within each state, so it is a large dataset. The VTRIS dataset also contains weigh-in-motion data, which consists of the vehicle weights of all vehicles passing over a roadway for a period of time. This weight data was used to help determine the distributions of vehicle weights, in particular, the distributions of vehicle weights for heavy-duty classes. In addition to the weigh-in-motion data, VTRIS contains class count data by hour of the day (usually collected using automatic traffic counters). The class count data was used to generate temporal profiles for all the FHWA classes.

The TVT dataset was selected to provide estimates of vehicle miles traveled. When combined with the class count data, it is possible to estimate VMT by vehicle class, hour of day, and roadway type.

A-3. QUALITY OF SECONDARY DATA

A-3.1 Quality Requirements of Secondary Data

FHWA has published guidance that describes requirements for data collection for the two sets of secondary data used in this work: Vehicle Travel Information System (VTRIS) and the Travel Volume Trends (TVT). For VTRIS, FHWA requires that State Departments of Transportation follow the Traffic Monitoring Guide (FHWA–PL-01-021, http://www.fhwa.dot.gov/ohim/tmguide/index.htm) for which requirements for collecting class count information is detailed in Section 4 and vehicle weight information in Section 5. This guide includes a lengthy description of the data collection requirements including data collection equipment, site selection, sampling periods, and other data handling procedures used in the compilation of this data set. As the data is input into the VTRIS system, FHWA also describes in a manual (http://www.fhwa.dot.gov/ohim/ohimvtis.htm) the requirements of data and how the data is handled by the VTRIS system. Likewise the TVT data is a compilation of the Highway Performance Monitoring System (HPMS) and must follow the HPMS Field Manual (http://www.fhwa.dot.gov/ohim/hpmsmanl/hpms.htm). This guidance has detailed descriptions of the site selection, sampling procedures, data collection and verification, reporting and data handling.

Under this work, additional quality assurance checks were applied to the data to find and eliminate spurious data. The additional quality assurance requirements of the VTRIS data were determined during Phase I of this work. They are listed briefly below:

- All site identification fields were required to have a match in the detailed site information table so that the observation could be properly placed.
- For the vehicle class count data, a record was not used if the percent of unknown vehicles (classes 14 and 15) contained more than 2% of the observed counts for that hour.
- For the vehicle class counts, only days with all 24 hours measured were included.
- For the vehicle class counts data, data was only used if all lanes in a direction were measured to reduce bias by heavier vehicles tending to travel in the right most lanes.
- For the weight data, if the sum of the axle weights differed from the total vehicle weight by more than 5%, the data was thrown out.

As part of this work, for the TVT data, the QA requirements were further refined during the course of investigating the database structure and performing the uncertainty analysis. These requirements include those implemented by FHWA, which are as follows:

- For each month, a station must have at least one valid day of observations for each day of the week. If there is a day of the week with no valid observations for that month, that station's observations are dropped for that month.

- Records with more than seven consecutive hours of zero traffic volumes are dropped.

- All days must have 24 hours of valid volume counts to be considered valid.

- An hourly volume count of zero is considered invalid if an adjacent hour has a count greater than 50.

A-3.2 QA Procedures

The quality assurance requirements and procedures of the VTRIS and TVT data were developed under Phases I and II of this work. Only the "clean" VTRIS and TVT data were used in subsequent phases of the work. The methods for "cleaning" the VTRIS data are described below.

A-3.2.1 VTRIS Data

The Vehicle Travel Information System (VTRIS) is a database management system written in FoxPro 2.6a for Windows. It is maintained by the FHWA to house vehicle travel characteristic data. It is designed to import, edit, and summarize data.

All the VTRIS data analyzed in this project are those that were already imported into the VTRIS system. As part of this work effort, we exported all the VTRIS data out of VTRIS and into two Microsoft SQL Server databases (one for the year 1999 and one for 2000).

The VTRIS data we analyzed had already undergone some quality assurance checks upon data import into VTRIS. The ASCII files that were loaded in to VTRIS were validated by the VTRIS program as follows :

1. Determination of the record's type according to FHWA formats set for coding of STATION, CLASSIFICATION and WEIGHT data. The data type, record length, and other record parameters were also checked.
2. Validation of single fields within a record to ensure that they hold a valid field value or are within a specific range of values. In addition, cross-validation within a single

record between two or more fields was done to ensure that data fields were not contradicting each other.

3. Checks for duplicates and consistency between the records that are being loaded into the same table. This mostly concerns STATION and CLASSIFICATION data since there should not be duplicate records with the same key value. For WEIGHT data it is not a validation issue, but rather a matter of data maintenance since the specified key may identify an unlimited number of records. This corresponds to the fact that the table contains one record per truck measured.

4. Cross-validation between the fields of the new records and the records from the VTRIS table to prevent duplicates and support referential integrity between different VTRIS tables as well as consistency within a single table. The integrity requires that the CLASSIFICATION and WEIGHT data checks against station data to make sure that the key is valid (e.g. Station-Direction-Lane exist).

The VTRIS User's Manual further lists error levels upon import of the data:

1. **Junk** - those records that are detected at the earliest stage of validation and result in the record being put into the JUNK file. No further validation is possible for these records until some manual editing is done.
2. **Fatal** - those records that cannot be admitted "as is" even if User would like them to. For those errors, an appropriate correction through the ERROR table Browse/Edit facility is required. Those are typically errors in the key fields and other very significant fields that would violate consistency and referential integrity.
3. **Caution** - those errors that can be fixed or can be flagged by User as acceptable and put into the VTRIS tables "as is". If User accepts and flags them, an appropriate Flag Code will be placed into a VTRIS table along with the record.

Records that are classified by VTRIS as "junk" or "fatal" are automatically rejected by VTRIS. This means that there were no "junk" or "fatal" records in the data that we exported for this project.

The data flags were not exported by VTRIS. This means that data assigned a "caution" flag were included in our analysis. In order to capture some of these records that VTRIS would have flagged, ENVIRON duplicated some of the error checking in the VTRIS program using the default data ranges and error margins in VTRIS.

What follows below is a discussion of the quality assurance methods, including the removal of data due to criteria developed during this work. The calculations performed and the QA/QC decisions were programmed in Microsoft SQL, and the text for these scripts was provided at the end of phase I and phase II with the ".sql" extension.

Vehicle Class Counts

The first step in processing the vehicle class counts data was to remove bad data. A bad record was one for which one of the unknown vehicle classes (14 or 15) contained more than 2% of the observed counts for that hour. This criterion was set based on the default VTRIS program configuration.

Records were eliminated where the site identification in the class counts data had no match in the site table making it impossible to place the data into a state and county or identify the roadway type. The site table field labeled “Method of Vehicle Classification” included codes to identify two types of automatic identification and one type labeled “Human Observation.” The records taken by human observation were eliminated to avoid the inclusion of subjective data into the final data set.

The next step was to find all stations and days for which all lanes in a direction were measured, and all 24 hours were observed for each of the lanes. This QA/QC criterion was to eliminate records where only partial data was available for a road type. For road types with multiple lanes, there may be significant differences in vehicle types between these lanes such as where heavy-duty vehicles may be required to preferentially use the right most lanes on freeways. Also, daytime or other partial diurnal measurements were taken possibly biasing the hour-of-day estimates and making it unable to be scaled for relative day-of-week activity.

A check of the vehicle class counts against VTRIS default maximums and minimums was explicitly not performed because EPA did not want to eliminate values that would have qualified as outliers, but that might be entirely accurate.

Initially we proposed to use only data where all 7 days of the week were measured. But this criterion would have eliminated most of the data available. The intention of the vehicle class counts data was to provide estimates of the vehicle class activity by one vehicle class relative to another rather than the total vehicle counts between days.

The number of class count records in the analysis was reduced from 3,130,642 to 824,112 (or 34,338 complete days) in 1999, from 4,070,127 to 1,468,200 (or 61,175 complete days) in 2000. For all the remaining data, the class counts were summed across all lanes in a given direction, and then they were averaged for different combinations of state FIPs, roadway function class, county FIPs, month, hour, and day of week. For the day of week, 1 = Sunday, 7 = Saturday.

<u>Vehicle Weights</u>

Upon importing the weight data, bad data was removed and stored in tables with the suffix "_bad." These records were ones for which the sum of the axle weights differed by more than 5% from the total vehicle weight. This criteria was not part of the VTRIS program, but was implemented on our part to ensure data integrity. As with the vehicle class counts tables, records were eliminated where the site identification in the weight data had no match in the site table, making it impossible to place the data into the state and county or identify the roadway type. There were 50,559,506 weight records for the 1999 dataset, and 1,197,410 were dropped. There were 69,910,356 weight records for the 2000 dataset, and 3,029,156 were dropped.

A-3.2.2 Travel Volume Trends (TVT) Data

The data we received was 2000 TVT data in the standard format prescribed by the "Traffic Monitoring Guide" published by the FHWA at:

http://www.fhwa.dot.gov/ohim/tmguide/tmg6.htm

The quality assurance we implemented was that recommended by FHWA staff as follows:

- For each month, a station must have at least one valid day of observations for each day of the week. If there is a day of the week with no valid observations for that month, that station's observations are dropped for that month.
- Records with more than seven consecutive hours of zero traffic volumes are dropped.
- All days must have 24 hours of valid volume counts to be considered valid.
- An hourly volume count of zero is considered invalid if an adjacent hour has a count greater than 50.

Out of 1,926,976 records, less than 1% of records were dropped. The remaining number of records analyzed was 1,922,822 (where one record contained all 24 hours of observations). After summing the volumes across all lanes in one direction, there were 1,872,708 days of observations.

A-3.3 Data Representativeness

Data representativeness was defined for this work to determine the data coverage, in terms of the number of states represented by the road types. Five major road types were responsible for 99% of the VMT (according to the FHWA Highway Statistics publication, http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm. Though the proportion of VMT by road type varies by local metropolitan and state analysis methods where other road types may responsible for more VMT), so the analysis of the data coverage was described for these major road types to simplify the presentation. For both vehicle mix (the fraction of vehicles by class) and weight (for the heavy-duty vehicle types), the data was sampled from states and road types covering approximately 50% of the national VMT.

Table A-1. TVT data coverage by state and important facility types.

State	Rural Interstates 2000	Rural Arterial 2000	Urban Interstates 2000	Urban Other Freeways 2000	Urban Arterial 2000
Alaska	1	1	1	0	1
Alabama	1	1	1	0	1
Arkansas	1	1	1	1	1
Arizona	0	0	0	0	0
California	1	1	1	1	1
Colorado	0	0	0	0	0
Connecticut	1	1	1	1	1
District Of Columbia	0	0	0	0	0
Delaware	0	0	0	0	0
Florida	1	1	1	1	1
Georgia	1	1	1	1	1
Hawaii	0	1	1	1	1
Iowa	1	1	1	0	1
Idaho	1	1	1	0	1
Illinois	1	1	1	0	1
Indiana	1	1	1	1	1
Kansas	1	1	1	1	1
Kentucky	1	1	1	1	1
Louisiana	1	1	1	0	1
Massachusetts	1	1	1	1	1
Maryland	0	0	0	0	0
Maine	0	0	0	0	0
Michigan	1	1	1	1	1
Minnesota	1	1	1	1	1
Missouri	1	1	1	1	1
Mississippi	1	1	1	1	1
Montana	1	1	1	0	1
North Carolina	1	1	1	1	1
North Dakota	1	1	1	0	1
Nebraska	1	1	1	0	1
New Hampshire	1	1	1	1	1
New Jersey	1	1	1	1	1
New Mexico	1	1	1	0	1
Nevada	1	1	1	1	1
New York	1	1	1	1	1
Ohio	1	1	1	1	1
Oklahoma	1	1	1	0	0
Oregon	1	1	1	1	1
Pennsylvania	1	1	1	1	1
Rhode Island	1	1	1	1	1
South Carolina	1	1	1	0	1
South Dakota	1	1	1	0	1

State	Rural Interstates 2000	Rural Arterial 2000	Urban Interstates 2000	Urban Other Freeways 2000	Urban Arterial 2000
Tennessee	1	1	1	0	1
Texas	1	1	1	1	1
Utah	1	1	1	0	1
Virginia	1	1	1	1	1
Vermont	1	1	1	1	1
Washington	1	1	1	1	1
Wisconsin	1	1	1	1	1
West Virginia	1	1	1	1	1
Wyoming	1	1	1	0	1
VTRIS VMT Data Coverage by Facility*	93%	94%	94%	89%	93%
National VMT by Facility*	22%	18%	32%	13%	13%

* The VMT by state and facility were provided by FHWA Highway Statistics (http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm) for 2000.
1 = Data present.
0 = Data absent.

The data coverage with the VTRIS data included only some states as shown in Tables A-2 and A-3. Little regional variability beyond that for rural interstates was described in the main report, so the lack of data from the states not represented would not be expected to bias the national average results much. For instance, the eastern seaboard states could be considered a region with lower truck traffic for rural interstate roads as described in Section 2 of the report because the states are located outside of the main freight corridors. The mid-Atlantic states of Maryland, Delaware, and Virginia and the north Atlantic states of New York, Massachusettes, Maine and New Hampshire were entirely missing from the database, but these states comprise 13% of the national VMT and only 10% of the rural interstate VMT. So while there is a potential that the missing data in the VTRIS 1999 and 2000 database may bias the national averages, any bias would be relatively minor.

Table A-2. VTRIS data coverage for vehicle mix by state and important facility types.

State Name	Rural Interstate		Rural Arterial		Urban Interstates		Urban Other Freeways		Urban Arterial	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Alaska	0	0	0	0	0	0	0	0	0	0
Alabama	0	0	0	0	0	0	0	0	0	0
Arkansas	1	1	1	1	1	1	1	1	1	1
Arizona	0	0	0	0	0	0	0	0	0	0
California	1	1	1	1	1	1	1	1	0	0
Colorado	0	0	0	1	0	0	0	1	0	0
Connecticut	0	0	1	1	0	1	0	0	0	1
District Of Columbia	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
Florida	1	0	1	0	1	0	1	0	1	0
Georgia	0	1	0	1	0	0	0	1	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Iowa	1	1	1	1	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0
Illinois	0	0	0	0	0	0	0	0	0	0
Indiana	0	0	0	0	0	0	0	0	0	0
Kansas	1	1	1	1	1	1	0	1	1	1
Kentucky	1	0	1	0	1	0	1	0	1	0
Louisiana	0	1	1	1	0	0	0	0	1	1
Massachusetts	0	0	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	0	0	0	0	0	0
Maine	0	0	1	0	0	0	0	0	0	0
Michigan	1	1	1	1	1	0	0	0	1	0
Minnesota	0	0	0	0	0	0	0	0	0	0
Missouri	0	1	0	1	0	1	0	1	0	1
Mississippi	1	1	1	1	1	0	0	0	1	1
Montana	0	1	0	1	0	0	0	0	0	0
North Carolina	1	0	1	1	0	0	0	0	0	0
North Dakota	0	0	0	0	0	0	0	0	0	0
Nebraska	0	0	1	0	0	0	0	0	1	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	1	1	1	1	1	1	1	1	1	1
New Mexico	0	1	0	0	0	0	0	0	0	0
Nevada	0	0	1	1	0	0	0	0	1	0
New York	0	0	0	0	0	0	0	0	0	0
Ohio	1	0	0	1	0	1	1	1	0	0
Oklahoma	0	1	1	1	0	1	0	1	0	1
Oregon	0	0	0	0	0	0	0	0	0	0
Pennsylvania	1	1	1	1	0	0	0	0	1	1
Rhode Island	1	1	1	1	1	1	1	1	0	0
South Carolina	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	1	1	0	0	0	0	0	0

State Name	Rural Interstate		Rural Arterial		Urban Interstates		Urban Other Freeways		Urban Arterial	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Tennessee	0	0	0	0	0	0	0	0	0	0
Texas	0	0	0	0	0	0	0	0	0	0
Utah	0	0	0	0	0	0	0	0	0	0
Virginia	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Washington	1	0	1	1	1	1	1	0	0	1
Wisconsin	1	1	1	1	1	1	0	0	1	1
West Virginia	0	0	0	1	0	0	0	1	0	0
Wyoming	1	1	1	1	1	0	0	0	0	0
VTRIS VMT Data Coverage by Facility*	52%		62%		46%		50%		34%	
National VMT by Facility*	22%		18%		32%		13%		13%	

* The VMT by state and facility were provided by FHWA Highway Statistics (http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm) for 2000.

1 = Data present.

0 = Data absent.

Table A-3. VTRIS data coverage for vehicle weight by state and important facility types.

State Name	Rural Interstate		Rural Arterial		Urban Interstates		Urban Other Freeways		Urban Arterial	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Alaska	0	0	0	0	0	0	0	0	0	0
Alabama	0	0	0	0	0	0	0	0	0	0
Arkansas	1	1	1	1	1	1	1	1	1	1
Arizona	0	0	0	0	0	0	0	0	0	0
California	1	1	1	1	1	1	1	1	0	0
Colorado	0	0	0	1	0	1	0	1	0	0
Connecticut	1	1	1	1	1	1	1	1	1	1
District Of Columbia	0	0	0	0	0	0	0	0	0	0
Delaware	0	0	0	0	0	0	0	0	0	0
Florida	1	0	1	0	1	0	1	0	1	0
Georgia	0	0	0	0	0	0	0	1	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0
Iowa	1	1	1	1	0	0	0	0	0	0
Idaho	1	1	1	1	0	0	0	0	0	0
Illinois	0	0	0	0	0	0	0	0	0	0
Indiana	1	1	1	1	1	1	0	0	1	0
Kansas	1	1	1	1	1	1	1	1	1	1
Kentucky	1	0	1	0	1	0	1	0	1	0
Louisiana	0	1	1	1	0	0	0	0	1	0
Massachusetts	0	0	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	0	0	0	0	0	0

State Name	Rural Interstate		Rural Arterial		Urban Interstates		Urban Other Freeways		Urban Arterial	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Maine	0	0	1	0	0	0	0	0	0	0
Michigan	1	1	1	1	1	0	0	0	1	0
Minnesota	1	0	1	0	1	0	0	0	0	0
Missouri	1	1	1	0	1	1	0	0	0	0
Mississippi	1	1	1	1	1	0	0	0	1	1
Montana	0	1	0	1	0	0	0	0	0	0
North Carolina	1	1	1	1	0	0	0	0	0	1
North Dakota	0	0	0	0	0	0	0	0	0	0
Nebraska	1	0	1	0	1	0	0	0	1	0
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	1	1	1	1	1	1	1	1	1	1
New Mexico	1	1	1	0	0	0	0	0	0	0
Nevada	1	1	1	1	1	0	1	0	1	0
New York	0	0	0	0	0	0	0	0	0	0
Ohio	1	0	0	0	1	0	0	0	0	0
Oklahoma	0	0	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	0	0	0	0	0	0
Pennsylvania	1	1	1	1	0	0	0	0	1	1
Rhode Island	1	1	1	1	1	1	1	1	0	0
South Carolina	1	1	1	0	0	0	1	1	1	0
South Dakota	1	1	1	1	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0	0	0	0	0
Texas	1	1	1	1	0	0	0	0	0	0
Utah	0	1	0	0	0	0	0	0	0	0
Virginia	1	0	1	0	1	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Washington	1	1	1	1	1	1	1	1	0	1
Wisconsin	1	1	1	1	0	1	0	1	1	1
West Virginia	0	0	0	1	0	0	0	1	0	0
Wyoming	1	1	1	1	1	1	0	0	0	0
VTRIS VMT Data Coverage by Facility*	69%		73%		53%		48%		37%	
National VMT by Facility*	22%		18%		32%		13%		13%	

* The VMT by state and facility were provided by FHWA Highway Statistics (http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm) for 2000.

1 = Data present.

0 = Data absent.

A-3.4 Data Sample Sizes

The following tables display the number of complete sampling days by site for each of the three datasets; the VTRIS vehicle classification, VTRIS weight-in-motion, and TVT total volume data. Note that for the VTRIS and TVT volume data, all lanes in each direction are summed together and each direction is counted separately in the TVT and VTRIS number of observations below.

Table A-4. Number of VTRIS weigh-in-motion observations by state.

State	1999 Observations	2000 Observations
AR	5,911,103	17,421,478
CA	10,519,290	7,320,284
CO	0	2,986,607
CT	240,640	207,286
FL	281,598	0
GA	0	1,753
IA	1,508,979	12,987,453
ID	10,290,043	4,793,371
IN	3,404,073	5,745,172
KS	21,746	32,927
KY	1,054,358	0
LA	24,236	53,391
MD	3,738	10,543
ME	5,997	0
MI	96,392	543,081
MN	652,758	0
MO	25,879	508,349
MS	1,120,899	639,944
MT	0	3,012,214
NC	902,050	446,567
NE	59,922	0
NJ	2,267,252	2,094,257
NM	2,760,347	161,306
NV	129,418	5,327
OH	3,603,002	0
PA	115,180	347,318
RI	257,360	261,191
SC	84,216	41,696
SD	435,198	878,554
TX	229,985	134,674
UT	0	72,611
VA	165,814	0
WA	2,434,354	2,124,689

State	1999 Observations	2000 Observations
WI	504,084	3,934,765
WV	0	4,945
WY	252,185	109,447
Total	49,362,096	66,881,200

Table A-5. Number of VTRIS vehicle classification observation days by site-direction in each state.

State	1999 Observation Days	2000 Observation Days
AR	4,179	16,390
CA	888	467
CO	0	2,253
CT	6	9
FL	356	0
GA	0	6
IA	259	4,523
KS	39	62
KY	104	0
LA	16	26
ME	32	0
MI	15	137
MO	0	892
MS	752	486
MT	0	7,353
NC	97	28
NE	17	0
NJ	16,879	15,674
NM	0	50
NV	532	2
OH	776	690
OK	2	417
PA	148	209
RI	259	231
SD	966	1,436
WA	6,545	7,225
WI	1,165	2,148
WV	0	6
WY	306	455
Total	34,338	61,175

Table A-6. Number of 2000 TVT observation days (site-directions counted separately) in each state.

State	2000 Observation Days
AK	48,676
AL	54,687
AR	29,044
CA	20,868
CT	23,458
FL	95,177
GA	36,877
HI	5,990
IA	91,494
ID	98,820
IL	22,310
IN	18,918
KS	61,708
KY	39,081
LA	1,422
MA	18,466
MI	77,359
MN	102,401
MO	14,161
MS	29,386
MT	20,797
NC	44,438
ND	25,936
NE	30,337
NH	35,656
NJ	48,247
NM	34,804
NV	27,640
NY	48,041
OH	58,060
OK	5,708
OR	65,253
PA	43,661
RI	8,085
SC	13,671
SD	26,803
TN	4,841
TX	94,645
UT	44,085
VA	120,784
VT	23,268
WA	25,667
WI	67,472
WV	20,011
WY	44,495
Total	1,872,708

A-4. DATA REPORTING, DATA REDUCTION, AND DATA VALIDATION

A-4.1 Data Reduction Procedures

The data reduction procedures used for the VTRIS data are described in detail in section (3) above. The SQL scripts used to reduce the data were delivered to EPA. The programming scripts written for the purpose of eliminating and processing data were also delivered to EPA.

A-4.2 Data Validation Procedures

The data validation used by FHWA in preparing the database is the primary validation of the raw data. When reducing this data to useful summary data, additional quality checks were used and documented in Section 3 of this appendix. Final comparisons across temporal and geographic definitions provided additional understanding of the data and provided a validation of the summaries produced. The comparison summaries demonstrated outliers that deserve additional analysis and validation.

APPENDIX B - CROSS REFERENCE METHOD TO CONVERT FHWA VEHICLE

CLASSES TO MOBILE VEHICLE TYPES

B-1. INTRODUCTION

Heavy-duty vehicles are believed to generate a large fraction of emissions from on-road vehicles and are coming under more intense scrutiny because light-duty emissions have been controlled to a greater extent than heavy-duty vehicle emissions. A heavy-duty vehicle can produce 10 to 100 times the emissions (of NO_X and PM emissions especially) because heavy-duty engines emit at a higher rate per unit of power than light-duty engines, and the vehicles themselves weigh more requiring greater engine loads. Key uncertainties with the use of MOBILE6 regarding heavy-duty vehicle emissions include the fraction of heavy-duty vehicles on all types of roadways at all times of day. In addition, there may be regional variability in both the fraction of different vehicle classes and the vehicle weights within each class.

Heavy-duty vehicle activity needs to be better characterized in terms of the fraction of vehicles on the road. One key uncertainty with the use of the current MOBILE6 model and future versions of on-road emission estimates is the unknown fraction of heavy-duty vehicles on all types of roadways at all times of day.

Traffic count data can be collected using a number of electronic devices. These can be road tubes, loops, or weigh-in-motion (WIM) technology. Traffic counting devices can be either portable or permanent. Some of the devices can measure time of day, vehicle speed, axle weight, total weight, distance between axles, and total length, and then determine a fairly reliable vehicle classification. Some devices are only able to collect an estimated total vehicle count (where the vehicle count is estimated to be the number of axle hits divided by two). For the purposes of determining temporal distributions by vehicle class, an estimate of vehicle classification is necessary. The vehicle mix by class is critical to understanding emissions, especially for NOx and particulate emission because the emission rates for these pollutants from heavy-duty vehicles are orders of magnitude higher than those from light-duty vehicles.

The site characteristics of the data are also required for this analysis. The roadway type, number of lanes measured, and the total number of lanes in that direction must be indicated. In particular, it is important that all lanes in a direction are measured. This is necessary to avoid any bias that could be introduced from the fact that heavy-duty trucks tend to travel in the right lanes.

The vehicle count data consists of loop counter and pneumatic (tube counters). Typically there are approximately 20 to 50 counters per state, primarily for multi-lane interstate and highway links. For each site, the site characteristics required for the analysis include roadway functional classification, county, number of lanes, and number of lanes measured.

The data provide vehicle classifications in FHWA standard class format, which are different from those in MOBILE6. These classifications are listed in Table B-1 and clearly distinguish light-duty passenger vehicles from other vehicles. However, the vehicle classifications do not exactly match the MOBILE vehicle groupings. Historically, FHWA vehicle classifications are by the number and configuration of axels for a given vehicle. EPA vehicle classifications are by engine size. Thererfore, a cross-walk is necessary between the FHWA vehicle classifications and the MOBILE6 classifications.

Table B-1. FHWA vehicle classifications.

FHWA Class	Description
1	Motorcycle
2	Passenger cars
3	Other 2-axle, 4-tire single unit vehicles
4	Buses
5	2-axle, 6-tire single-unit vehicles
6	3-axle, 6-tire single-unit vehicles
7	4+ axle single-unit vehicles
8	4 or less axle combination vehicles
9	5-axle combination vehicles
10	6+ axle combination vehicles
11	5-axle multi-trailer vehicles
12	6-axle multi-trailer vehicles
13	7+ axle multi-trailer vehicles
14	Unclassified
15	Unclassifiable

The vehicle mix is provided by the FHWA roadway functional class as listed in Table B-2, though vehicle classification counters are usually sited on busy roadways so many of the road types less traveled do not have data.

Table B-2. FHWA roadway functional classifications.

Code	Classification Description RURAL
1	Principal Arterial – Interstate
2	Principal Arterial – Other
6	Minor Arterial
7	Major Collector
8	Minor Collector
9	Local System
URBAN	
11	Principal Arterial – Interstate
12	Principal Arterial – Other Freeways or Expressways
14	Principal Arterial – Other
16	Minor Arterial
17	Collector
19	Local System

B-2. CROSS REFERENCE FROM FHWA TO MOBILE VEHICLE CLASSIFICATION

There are three methods available to cross-reference the vehicle counts by FHWA classification to the EPA classification scheme. The first was a joint effort by EPA and FHWA to produce estimates for the EPA Trends report, and the second is a recent research effort. The EPA method was used for this work because it has been vetted, but the other method is described here for future reference.

EPA (2003) provided ENVIRON estimates of the crosswalk between the FHWA truck classifications and the MOBILE6 vehicle types used in the NEI emission inventory development; these are shown in Table B-3. The crosswalk for FHWA vehicle classes #2 and #3 was assumed in this work to be the default light-duty mix as shown in Table 3 rather than an explicit result of an EPA analysis. The vehicle counts can be aggregated to MOBILE5 or MOBILE6 groupings. The reported vehicle class estimates by FHWA class was converted using both the EPA default for light-duty and EPA crosswalk for heavy-duty vehicles to produce estimates by specific MOBILE6 vehicle classes. If MOBILE5 formats are needed, then the MOBILE6 vehicle classifications can be aggregated into the MOBILE5 groupings. It is not possible to determine the diesel and gasoline fraction from the road counters, so either state registration or national averages (such as provided in the MOBILE6 model) are used to apportion the vehicles by fuel type.

Table B-3. FHWA and MOBILE6 crosswalk estimates for heavier vehicles. (EPA, 2003).

MOBILE Weight Ratings\FHWA Types	Passenger Car FHWA #2[1]	Other 2-axle 4-tire, FHWA #3	Single-Unit Trucks, FHWA #5-7	Combination Trucks, FHWA #8-13
LDV	52.3%	98.3% (0.524% Class 2b)	0%	0%
6,000 lbs or less LDT1 & LDT2	35.4%		24%	0%
6001 – 10,000[2] LDT3, LDT4, Class 2b	12.3% (1% Class 2b)		21%	0.77%
10,001 – 14,000 Class 3	0	0.44	12	0.61
14,001 –16,000 Class 4	0	0.14	5.0	0.65
19,500 Class 5	0	0.13	4.8	0.64
26,000 Class 6	0	0.24	12	3.3
33,000 Class 7	0	0.12	6.8	3.7
60,000 Class 8a	0	0.05	11	28
> 60,000 Class 8b	0	0.006	2.5	62

[1] – Default 2002 light-duty vehicle VMT distribution (EPA, 2004).
[2] – 8% were estimated to be Class 2b, GVWR (8,500 – 10,000 lbs) heavy-duty vehicles and of those 24% diesel.

The definition in Table B-3, however, is not sufficient to map the vehicle identification to vehicle class in either MOBILE6 or MOBILE5. In order to map the vehicle classification into MOBILE6 groups, the default vehicle mix can be used to apportion between LDGT1 and LDGT2 or between LDGT3 and LDGT4. Another problem with the method described in Table 3 is that it uses the default vehicle mix for FHWA Class 2, but the better defined method for FHWA Class 3 would over allocate the vehicle counts to LDT and under allocate to LDV. The suggested remedy is that light-duty portion of FHWA Class 3 be combined with FHWA Class 2 prior to redistributing using the default light-duty allocation shown in Table B-3. The crosswalk for converting FHWA vehicle classes into MOBILE6 vehicle classes is described in Table B-4.

Table B-4. Default 2002 VMT mix by the MOBILE6 16 vehicle classes and crosswalk calculation method from FHWA vehicle classes.

MOBILE6 16 Vehicle Classes	Diesel Fraction*	Vehicle Mix	Calculation Method
LDV	0.0016	0.459	0.523 x FHWA Vehicle Class 2 + 0.983 x 0.523 FHWA Vehicle Class 3
LDT1	0.0007	0.072	0.082 x FHWA Vehicle Class 2 + 0.983 x 0.082 FHWA Vehicle Class 3
LDT2	0.0007	0.238	0.272 x FHWA Vehicle Class 2 + 0.983 x 0.272 FHWA Vehicle Class 3
LDT3	0.0138	0.074	0.078 x FHWA Vehicle Class 2 + 0.983 x 0.084 FHWA Vehicle Class 3
LDT4	0.0138	0.034	0.036 x FHWA Vehicle Class 2 + 0.983 x 0.039 FHWA Vehicle Class 3
HDV2B	0.2414	0.038	0.0099 x FHWA Vehicle Class 2 + 0.0052 x FHWA Class 3 + See Table B-3 for other FHWA Classes
HDV3	0.7264	0.004	See Table B-3
HDV4	0.8307	0.003	See Table B-3
HDV5	0.4906	0.002	See Table B-3
HDV6	0.7075	0.008	See Table B-3
HDV7	0.8882	0.010	See Table B-3
HDV8A	0.9996	0.011	See Table B-3
HDV8B	1.0000	0.038	See Table B-3
HDBS	0.7500	0.002	FHWA Vehicle Class 4 & Fraction of Vehicle Mix of HDBS and HDBT
HDBT	1.0000	0.001	FHWA Vehicle Class 4 & Fraction of Vehicle Mix of HDBS and HDBT
MC	0.0000	0.006	FHWA Vehicle Class 1

*Default registration distribution x Default diesel fraction summed over all model years. Diesel fraction from MOBILE6 defaults.

The diesel fraction is used to convert the 16 vehicle categories to the 32 vehicle categories used in MOBILE6 before combining categories to group the MOBILE5 vehicle categories as shown in Table B-5. This conversion is performed if the user needs to run MOBILE5 instead of or in addition to MOBILE6.

Table B-5. Converting MOBILE6 vehicle types to MOBILE5 vehicle types – diesel fractions.

MOBILE5 Vehicle Classes	Calculated from MOBILE6
LDGV	LDV – LDDV
LDGT1	(1-Diesel fraction) x LDT1 + (1-Diesel Fraction) x LDT2
LDGT2	(1-Diesel fraction) x LDT3 + (1-Diesel Fraction) x LDT4
HDGV	(1-Diesel fraction) x HDV2b + (1-Diesel Fraction) x HDV3 + (1-Diesel fraction) x HDT4 + (1-Diesel Fraction) x HDV5 + (1-Diesel fraction) x HDV6 + (1-Diesel Fraction) x HDV7 +(1-Diesel fraction) x HDV8A + (1-Diesel Fraction) x HDV8B + (1-Diesel fraction) x HDBS
LDDV	Diesel Fraction x LDV
LDDT	SUM (LDT1, LDT2, LDT3, LDT4) – LDGT1 – LDGT2
HDDV	SUM (HDV All, Buses All) – HDGV
MC	MC

A sample of the results is shown in Figure B-1 and demonstrates the higher fractions of heavy-duty vehicle traffic overnight as well as distinguishing the day of week activity.

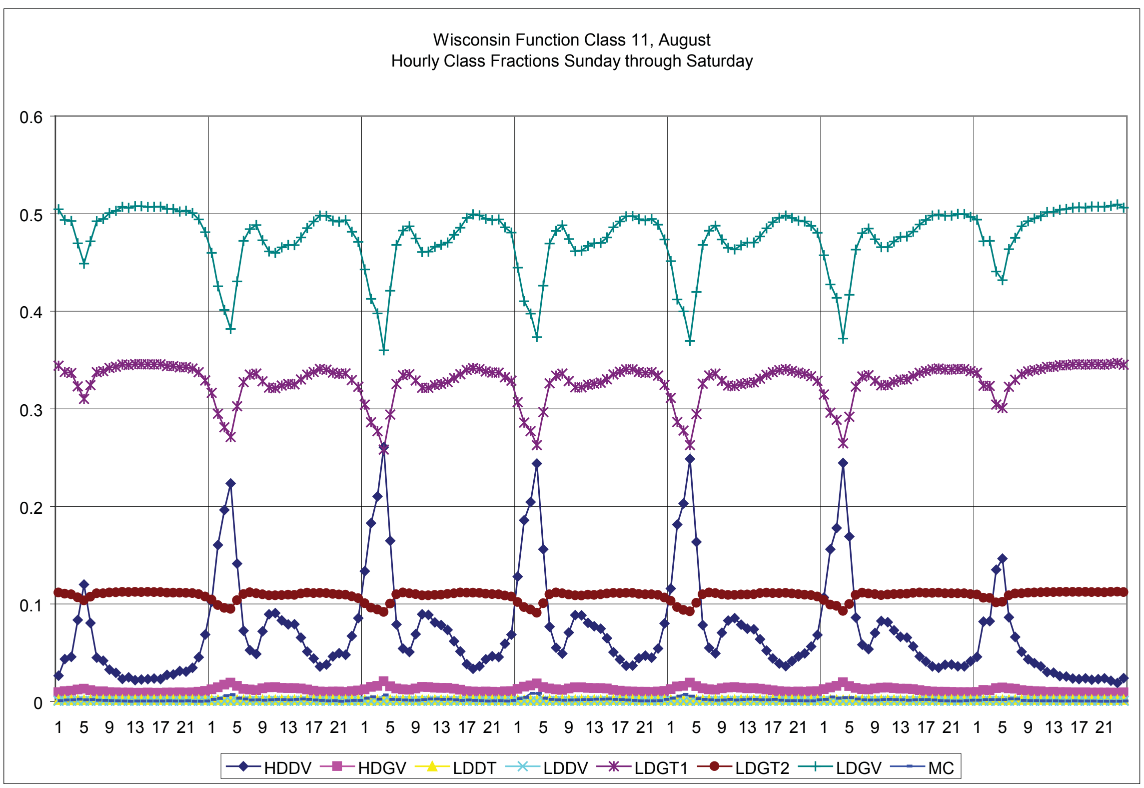

Figure B-1. Vehicle fractional mix over a week for urban interstates in Wisconsin.

Overall the vehicle mix results are consistent with the national average for light-duty/heavy-duty as shown in Table B-6. Without a complete understanding of the total VMT for each roadway type within a given region, it is difficult to determine if the regional average is similar to the national average. The fraction of heavy-duty vehicles is highest on interstates and freeways, and it is typically lower on roads less traveled. Rural interstates have higher heavy-duty vehicle fractions than urban interstates. One concern about the cross-reference method used in this work is that heavy-duty diesel vehicles are a larger portion of the heavy-duty fleet than the national average, at the expense of heavy-duty gasoline vehicles. In essence, the method may be biased towards heavy-duty diesel vehicles and thus produce values that underrepresent heavy-duty gasoline vehicles.

Table B-6. Raw average annual vehicle mix estimates.

RoadType	Data	HDDV	HDGV	LDDT	LDDV	LDGT1	LDGT2	LDGV	MC
1	WI	0.167	0.013	0.002	0.001	0.293	0.098	0.424	0.003
	IL	0.210	0.014	0.001	0.001	0.276	0.093	0.399	0.006
	MI	0.162	0.013	0.002	0.001	0.296	0.099	0.427	0.001
	MN	0.103	0.013	0.002	0.001	0.316	0.107	0.455	0.004
2	WI	0.100	0.013	0.002	0.001	0.318	0.107	0.458	0.002
	IL	0.055	0.011	0.002	0.001	0.334	0.110	0.485	0.002
	MI	0.085	0.012	0.002	0.001	0.324	0.109	0.467	0.001
	MN	0.063	0.012	0.002	0.001	0.330	0.111	0.477	0.004
6	WI	0.077	0.013	0.002	0.001	0.326	0.110	0.469	0.002
	IL	0.032	0.009	0.002	0.001	0.341	0.111	0.499	0.005
	MI	0.029	0.011	0.002	0.001	0.343	0.114	0.499	0.001
	MN								
7	WI	0.037	0.012	0.002	0.001	0.341	0.114	0.492	0.002
	IL	0.098	0.016	0.002	0.001	0.319	0.111	0.452	0.002
	MI								
	MN								
11	WI	0.069	0.012	0.002	0.001	0.329	0.109	0.478	0.002
	IL	0.112	0.012	0.002	0.001	0.313	0.104	0.454	0.003
	MI	0.074	0.012	0.002	0.001	0.328	0.109	0.475	0.000
	MN								
12	WI	0.059	0.011	0.002	0.001	0.332	0.110	0.483	0.002
	IL								
	MI	0.059	0.011	0.002	0.001	0.333	0.110	0.484	0.000
	MN								
14	WI	0.047	0.011	0.002	0.001	0.337	0.111	0.489	0.003
	IL	0.031	0.010	0.002	0.001	0.342	0.112	0.498	0.004
	MI	0.024	0.010	0.002	0.001	0.345	0.114	0.502	0.002
	MN								
16	WI	0.032	0.010	0.002	0.001	0.341	0.112	0.498	0.004
	IL	0.046	0.012	0.002	0.001	0.337	0.111	0.489	0.004
	MI								
	MN								
17	WI								
	IL	0.018	0.010	0.002	0.001	0.347	0.112	0.509	0.001
	MI								
	MN								
EPA Average		0.082	0.036	0.002	0.001	0.310	0.107	0.458	0.006

The method described in this work to cross reference the FHWA classification into MOBILE vehicle categories is a relatively novel technique, though the state of Texas is currently using a similar method developed by TTI (2003) (and the description of their method is described here) to adjust their emission inventories in the Houston-Galveston SIP (TCEQ, 2004). ENVIRON worked with EPA to develop this cross-reference method, however EPA may consider further development of this method to reconcile the field measurement results with those derived from registration, diaries, and surveys.

B-2.1 ALTERNATIVE METHODS FOR CROSS REFERENCE

At least two alternative methods have been suggested to cross reference FHWA categories with MOBILE classes of vehicle types. Georgia Institute of Technology and Texas Transportation Institute (TTI) have each proposed a method to cross reference vehicle count information from automatic traffic recorder data to MOBILE vehicle classifications.

B-2.2 GEORGIA TECH INSTITUTE METHOD

One alternative method has been forwarded by researchers in the Atlanta area (Yoon, et al., 2004) and is shown in Table B-7. There are two reasons why this method was not used for this work: it has not been vetted, and the FHWA class #8 is distinguished into 3 and 4 axle categories, which is not provided in the data set. In addition, the EPA method would still be required to map the FHWA class #3 results in the MOBILE classes. The FHWA #5 group needs to be divided into several GVWR classifications presumably from registration or historic manufacturers sales data making the cross-reference difficult without additional information.

Table B-7. FHWA and MOBILE6 crosswalk estimates for heavier vehicles. (Yoon et al., 2004).

FHWA Types \ MOBILE Weight Ratings	MOBILE (Class 2b – 7) GVWR (8,500 – 33,000) lbs*	MOBILE (Class 8a) GVWR (33,000 – 60,000)	MOBILE (Class 8b) GVWR (>60,000 lbs.)
#5	100%	0%	0%
#6 & #8 (3-axle)	0%	100%	0%
#7, #8 (4-axle), #9-13	0%	0%	100%

* Uncertain fraction of FHWA #3 into GVWR 8,500 – 10,000 lbs, Class 2b heavy-duty vehicles.

B-2.3 TTI Method of VMT Mix

Another alternative method has been used by TTI (TCEQ, 2004) for constructing alternative VMT mix profiles for Texas on-road emission inventories. What follows is the TTI documentation describing the method quoted from the Texas SIP (TCEQ, 2004). The method relies on regionally specific registration data for Texas and Houston-Galveston so cannot be used for national average cross-reference method.

"For the 2000 estimate, 1997 - 2000 TxDOT vehicle classification data were used. The eight-county area data were aggregated. TxDOT classification counts classify vehicles into the standard FHWA vehicle classifications (based on vehicle length/number of axles) using best practice vehicle classification count methods."

[ENVIRON Note: The TTI classification follows the FHWA definition with the elimination of unknown and unclassified vehicles and presumably the merging of motorcycles with passenger vehicles. The tables have been renumbered to follow the document format. Table B-8 is a table of the TTI definition and the inferred FHWA class definition.]

Table B-8. TTI vehicle identifiers.

FHWA Class	TTI DEFINITION	Description
1		Motorcycles
2	C	Passenger vehicles
3	P	Two-axle, four-tire single-unit trucks
4	B	Buses
5	SU2	Six-tire, two-axle single-unit vehicles
6	SU3	Three-axle single-unit vehicles
7	SU4	Four or more axle single-unit vehicles
8	SE4	Three or four axle single-trailer vehicles
9	SE5	Five-axle single-trailer vehicles
10	SE6	Six-axle multi-trailer vehicles
11	SD5	Five or less axle multi-trailer vehicles
12	SD6	Six-axle multi-trailer vehicles
13	SD7	Seven or more axle multi-trailer vehicles

EPA and MOBILE use a different vehicle classification scheme than the FHWA categories. The 28 EPA vehicle categories are defined as a function of gross vehicle weight rating (GVWR) and fuel type (see Table B-9). The FHWA axle/vehicle length-based classification categories must be converted into 28 MOBILE GVWR/fuel type based categories.

The FHWA vehicle classification counts were first aggregated into three intermediate groups:

Passenger Vehicles (PV)	C + P;
Heavy-Duty Vehicles (HDV)	SU2 + SU3 + SU4 + SE4; and
HDDV8b (HDX)	SE5 + SE6 + SD5 + SD6 + SD7.

This is followed by a second intermediate allocation that separates light-duty vehicles (LDV) into PVs and light-duty trucks (LDT) based on TxDOT registration data:

LDV	0.695 × PV (by county, 2002 Harris registration data shown); and
LDT	0.305 × PV (by county, 2002 Harris registration data shown).

A third intermediate allocation further separates LDTs into LDT1 and HLDT (note that LDT1 is itself intermediate and is further divided into LDGT1 and LDDT.):

LDT1	0.813 × LDT (by county, 2002 Harris registration data shown); and
HLDT	0.187 × LDT (by county, 2002 Harris registration data shown).

Next, the remaining FHWA categories are disaggregated into EPA vehicle groups, as shown. Note that TxDOT vehicle classification count procedures do not distinguish between gasoline and diesel LDTs. Consequently, MOBILE defaults for the year of interest are used. As before, actual TxDOT vehicle registration data are used to separate gasoline from diesel heavy-duty trucks. Note also that motorcycles are not counted separately and are included as a default (subtracted from LDGV):

LDGV	0.9989987 × LDV (MOBILE6 default for 2007 shown);
LDDV	0.0010013 × LDV (MOBILE6 default for 2007 shown);
LLDT	0.9947975 × LDT1 (MOBILE6 default for 2007 shown);
LDDT	0.0052025 × LDT1 (MOBILE6 default for 2007 shown);
HDGV	0.358 × HDV (by county, 2002 Harris County registration data shown);
HDDV	0.642 × HDV (by county, 2002 Harris County registration data shown);
MC	0.001 of total (subtracted from LDGV).

This converts the FHWA axle count-based categories into GVWR categories. This part of the conversion procedure is summarized schematically in Table 10. Starting with the TxDOT vehicle classification data, these data themselves provide sufficient information to complete the first step in the conversion process, the allocation of vehicles into PVs, HDVs, HDDV8bs, and buses (B). Steps 2 and 3 further allocate these categories using TxDOT registration data. Finally, Step 4 allocates light-duty vehicles by fuel type using EPA MOBILE diesel fractions and motorcycles are separated from light-duty gasoline vehicles using a nominal constant.

The MOBILE6 28-category typology is a subset of this typology. A combination of EPA MOBILE6 defaults and area vehicle registration data are used to expand these intermediate categories.

For the 28-category EPA scheme, HDVs — HDGV and HDDV — are separated into eight and seven categories respectively. HDDV8b vehicles are counted directly. The 15 HDV categories are separated from total HDV, which have been separated by fuel type using TxDOT registration data by county. Each HDV category (HDGV and HDDV) is then divided into sub-categories based on TxDOT area vehicle registration data. Buses are treated separately.

The 28-category EPA scheme also further divides the two LDT categories based in part on assumed loading. The previous LDGT1 and LDGT2 categories (previously defined as GVWR < 6,000 and GVWR > 6,000 to 8,500, respectively) are separated into subcategories in terms of adjusted loaded vehicle weight (ALVW). ALVW is the average of vehicle curb weight and GVWR. Thus, two new intermediate categories are introduced. These are light light-duty trucks (LLDT) and heavy light-duty trucks (HLDT), which are defined as:

- LLDT - any light-duty truck rated through 6,000 pounds GVWR, and
- HLDT - any light-duty truck rated greater than 6,000 pounds GVWR.

These two new intermediate categories are then used to define the four LDT categories using EPA MOBILE6 defaults for the year of interest. The four LDT categories are:

- LDGT1 -light light-duty trucks through 3,750 pounds loaded vehicle weight (LVW);
- LDGT2 - light light-duty trucks greater than 3,750 pounds LVW;
- LDGT3 - heavy light-duty trucks to 5,750 pounds ALVW; and
- LDGT4 - heavy light-duty trucks greater than 5,750 pounds ALVW.

Similarly, the LDDT category is sub-divided into two categories based on GVWR (less than or equal to 6,000 GVWR and 6,000 to 8,500 GVWR). This is accomplished using EPA MOBILE6 default values for the year of interest.

Finally the three bus categories are separated from the TxDOT classification counts bus category using EPA MOBILE6 default values. (Under MOBILE6 the HDV category does not include buses.)

For historical VMT mix estimates, the MOBILE6 default values consistent with the historical year are used. No other adjustments are made to alter the count data and conversion procedure to accommodate historical years. Table 11 shows the VMT mix estimation procedure summary followed by explanatory notes. For this analysis, VMT mix estimates were developed for application with three functional classification groups (see Table 31 in Emissions Calculations section) [not shown here] and four time-of-day periods (See Table 5 [not shown here]).

This procedure is performed as described for weekdays. TxDOT vehicle classification data are only collected for weekdays (Monday through Thursday), consequently other data is used to estimate VMT mix for Fridays, Saturdays, and Sundays. The procedure used to estimate Friday, Saturday, and Sunday VMT mix relies on vehicle classification data collected over several years in urban areas. The ratio of weekday VMT mix to Friday, Saturday, and Sunday VMT mix is applied to the weekday VMT mix to produce region specific Friday, Saturday and Sunday VMT mix. (No seasonal changes are assumed).

Table B-9. EPA Vehicle Types - 28 Categories.

Category	Description	GVWR
LDGV	Light-duty gasoline vehicle	< 6,000
LDGT1	Light-duty gasoline truck	< 6,000
LDGT2	Light-duty gasoline truck	< 6,000
LDGT3	Light-duty gasoline truck	6,001 - 8,500
LDGT4	Light-duty gasoline truck	6,001 - 8,500
HDGV2b	Heavy-duty gasoline vehicle	8,501 - 10,000
HDGV3	Heavy-duty gasoline vehicle	10,001 - 14,000
HDGV4	Heavy-duty gasoline vehicle	14,001 - 16,000
HDGV5	Heavy-duty gasoline vehicle	16,001 - 19,500
HDGV6	Heavy-duty gasoline vehicle	19,501 - 26,000
HDGV7	Heavy-duty gasoline vehicle	26,001 - 33,000
HDGV8a	Heavy-duty gasoline vehicle	33,001 - 60,000
HDGV8b	Heavy-duty gasoline vehicle	> 60,000
HDGB	Heavy-duty gasoline bus	all
LDDV	Light-duty diesel vehicle	< 6,000
LDDT12	Light-duty diesel truck	< 6,000
LDDT34	Light-duty diesel truck	6,001 - 8,500
HDDV2b	Heavy-duty diesel vehicle	8,501 - 10,000
HDDV3	Heavy-duty diesel vehicle	10,001 - 14,000
HDDV4	Heavy-duty diesel vehicle	14,001 - 16,000
HDDV5	Heavy-duty diesel vehicle	16,001 - 19,500
HDDV6	Heavy-duty diesel vehicle	19,501 - 26,000
HDDV7	Heavy-duty diesel vehicle	26,001 - 33,000
HDDV8a	Heavy-duty diesel vehicle	33,001 - 60,000
HDDV8b	Heavy-duty diesel vehicle	> 60,000
HDDBS	Heavy-duty diesel school bus	all
HDDBT	Heavy-duty diesel transit bus	all
MC	Motorcycle	all

Table B-10. Initial Vehicle Classification Conversion Procedure.

<table>
<tr><th>Start</th><th>Step 1</th><th>Step 2</th><th>Step 3</th><th>Step 4</th></tr>
<tr><td rowspan="12">Total Vehicles</td><td rowspan="8">PV</td><td rowspan="3">LDV</td><td rowspan="2">LDGV</td><td>MC</td></tr>
<tr><td>LDGV</td></tr>
<tr><td colspan="2">LDDV</td></tr>
<tr><td rowspan="5">LDT</td><td rowspan="2">LDDT</td><td>LLDT</td></tr>
<tr><td>LDDT</td></tr>
<tr><td rowspan="2">LDGT</td><td>LDGT 1 & 2</td></tr>
<tr><td>LDGT 3 & 4</td></tr>
<tr><td colspan="2">HLDT</td></tr>
<tr><td rowspan="2">HDV</td><td colspan="3">HDGV</td></tr>
<tr><td colspan="3">HDDV</td></tr>
<tr><td colspan="4">HDDV8b</td></tr>
<tr><td colspan="4">Buses</td></tr>
</table>

Table B-11. VMT Mix Estimation Procedure Summary.

EPA-8	EPA-28	Conversion
LDGV	LDGV	0.9990 × LDV
LDGT1	LDGT1	0.2310 × LLDT
	LDGT2	0.7690 × LLDT
LDGT2	LDGT3	0.6850 × HLDT
	LDGT4	0.3150 × HLDT
HDGV	HDGV2b	0.519 × HDGV
	HDGV3	0.194 × HDGV
	HDGV4	0.094 × HDGV
	HDGV5	0.034 × HDGV
	HDGV6	0.091 × HDGV
	HDGV7	0.032 × HDGV
	HDGV8a	0.032 × HDGV
	HDGV8b	0.004 × HDGV
	HDGB	0.0931 × B
LDDV	LDDV	0.0010 × LDV
LDDT	LDDT12	0.0337 × LDDT
	LDDT34	0.9663 × LDDT
HDDV	HDDV2b	0.278 × HDDV
	HDDV3	0.134 × HDDV
	HDDV4	0.081 × HDDV
	HDDV5	0.053 × HDDV
	HDDV6	0.168 × HDDV
	HDDV7	0.102 × HDDV
	HDDV8a	0.184 × HDDV
	HDDV8b	HDX
	HDDBT	0.3239 × B
	HDDBS	0.5830 × B
MC	MC	MC

Notes to VMT Mix Estimation Procedure Summary

Intermediate category factors and sources:

LDV	0.695 × PV (by county, 2002 Harris County registration data shown)
LDT	0.305 × PV (by county, 2002 Harris County registration data shown)
LDT1	0.813 × LDT (by county, 2002 Harris County registration data shown)
HLDT	0.187 × LDT (by county, 2002 Harris County registration data shown)
LLDT	0.9948 × LDT1 (EPA MOBILE6 default, 2007 shown)
LDDT	0.0052 × LDT1 (EPA MOBILE6 default, 2007 shown)
HDV	SU2+SU3+SU4+SE3+SE4
HDX	SE5+SE6+SD5+SD6+SD7
HDGV	0.358 × HDV (by county, 2002 Harris County registration data shown)
HDDV	0.642 × HDV (by county, 2002 Harris County registration data shown)

Category conversion factors and sources:

LDGV	0.9990 × LDV (EPA MOBILE6 default, 2007 shown)
LDGT1	0.2310 × LLDT (EPA MOBILE6 default, 2007 shown)
LDGT2	0.7690 × LLDT (EPA MOBILE6 default, 2007 shown)
LDGT3	0.6850 × HLDT (EPA MOBILE6 default, 2007 shown)
LDGT4	0.3150 × HLDT (EPA MOBILE6 default, 2007 shown)
HDGV2a	0.519 × HDGV (HGAC area registration data)
HDGV3	0.194 × HDGV (HGAC area registration data)
HDGV4	0.094 × HDGV (HGAC area registration data)
HDGV5	0.034 × HDGV (HGAC area registration data)
HDGV6	0.091 × HDGV (HGAC area registration data)
HDGV7	0.032 × HDGV (HGAC area registration data)
HDGV8a	0.032 × HDGV (HGAC area registration data)
HDGV8b	0.004 × HDGV (HGAC area registration data)
HDGB	0.0931 × B (EPA MOBILE6 default, 2007 shown)
LDDV	0.0010 × LDV (EPA MOBILE6 default, 2007 shown)
LDDT12	0.0337 × LDDT (EPA MOBILE6 default, 2007 shown)
LDDT34	0.9663 × LDDT (EPA MOBILE6 default, 2007 shown)
HDDV2b	0.278 × HDDV (HGAC area registration data)
HDDV3	0.134 × HDDV (HGAC area registration data)
HDDV4	0.081 × HDDV (HGAC area registration data)
HDDV5	0.053 × HDDV (HGAC area registration data)
HDDV6	0.168 × HDDV (HGAC area registration data)
HDDV7	0.102 × HDDV (HGAC area registration data)
HDDV8a	0.184 × HDDV (HGAC area registration data)
HDDV8b	HDX (TxDOT classification counts)
HDDBT	0.3239 × B (EPA MOBILE6 default, 2007 shown)
HDDBS	0.5830 × B (EPA MOBILE6 default, 2007 shown)
MC	MC (default subtracted from LDGV, no conversion)”

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APPENDIX C - NATIONAL AVERAGE TEMPORAL PROFILES FOR FOUR ROAD TYPES

C-1. INTRODUCTION

This appendix was prepared to satisfy a request by EPA to provide summary temporal profiles grouped into four road types. The groupings combine several different road types that each have unique profiles and different sample sizes, so the groupings could include sampling bias by the selection of the sites by the local and state transportation departments.

The results here provide state and national temporal aggregations requested by road type or also called roadway functional classification. The EPA work assignment requested national and state temporal profiles by month, day of week, and time of average day of total vehicle travel from the Traffic Volume Trends (TVT) data and by vehicle type using the Vehicle Travel Information System (VTRIS). The temporal profiles requested were to be reclassified into the four road types described in Table C-1.

Table C-1. FHWA roadway functional classification (types) in TVT and VTRIS.

Code	Classification Description RURAL
1	Principal Arterial – Interstate
2	Principal Arterial – Other
6	Minor Arterial
7	Major Collector
8	Minor Collector
9	Local System
URBAN	
11	Principal Arterial – Interstate
12	Principal Arterial – Other Freeways or Expressways
14	Principal Arterial – Other
16	Minor Arterial
17	Collector
19	Local System

The vehicle types that are reported in VTRIS are shown in Table C-2. The most prevalent vehicle types in the database are vehicle 2 and 3, which are primarily light-duty vehicles. Other significant vehicle types are vehicle type 9 (18 wheel line-haul trucks), and vehicle type 5 (typical of local delivery trucks). The remainder of the vehicles types represent typically 3% or less of the traffic volume except on rural interstates where other truck types are found in higher numbers.

Table C-2. FHWA Vehicle classifications.

FHWA Class	VTRIS Vehicle Type
1	Motorcycle
2	Passenger cars
3	Other 2-axle, 4-tire single unit vehicles
4	Buses
5	2-axle, 6-tire single-unit vehicles
6	3-axle, 6-tire single-unit vehicles
7	4+ axle single-unit vehicles
8	4 or less axle combination vehicles
9	5-axle combination vehicles
10	6+ axle combination vehicles
11	5-axle multi-trailer vehicles
12	6-axle multi-trailer vehicles
13	7+ axle multi-trailer vehicles
14	Unclassified
15	Unclassifiable

ENVIRON analyzed Traffic Volume Trends (TVT) data to provide national average and individual state temporal profiles by both the FHWA and the reclassified road types described in Table C-1. The 2000 TVT data represented several states and a number of sample sites as shown in Table C-3. For national and state EPA-requested road type groupings (described in Table C-1 and outlined in alternating white and light gray background in Table C-3), the vehicle counts and number of sample sites were summed to determine average vehicle counts per site (where opposite directions at a site were treated as separate sites). So the importance of each road type in a group was determined by the number of sampling sites regardless of the relative miles of roadway or vehicle miles traveled (VMT) on each roadway type. To avoid a possible day of week bias, data for a site month was dropped if not all seven days were measured at that site during that month. The national average volumes were then calculated as the average of the state average volumes.

Table C-3. FHWA roadway functional classification (types) in TVT.

FHWA Code	FHWA Classification Description	EPA MOVES Group	States Represented	Sites
1	Principal Arterial – Interstate	RLA	44	964
2	Principal Arterial – Other	RO	45	1646
6	Minor Arterial	RO	44	927
7	Major Collector	RO	42	564
8	Minor Collector	RO	13	57
9	Local System	RO	11	45
11	Principal Arterial – Interstate	ULA	45	913
12	Principal Arterial – Other Freeways or Expressways	ULA	29	354
14	Principal Arterial – Other	UO	44	901
16	Minor Arterial	UO	39	390
17	Collector	UO	24	132
19	Local System	UO	8	44

National temporal allocations by road type grouping were prepared for this work assignment. Figures 1, 2, and 3 show the monthly, day of week, and time of day average temporal allocations. The trends for the monthly vehicle counts shown in Figure 1 incorporate to some extent the year-to-year growth in VMT and therefore increase from the beginning of the year to the end perturbed by a seasonal trend. The trend for day of week activity shows higher activity during the week peaking on Friday, with Saturday and Sunday traffic much lower. The time of day activity show the typical diurnal mid-day traffic increase with the urban commuting period. The national average volumes generated from the TVT data in figures 1 through 3 are calculated as the average of the state averages, following the same procedures as outlined in Appendix D. For these averages, the sample size corresponds to the number of states represented.

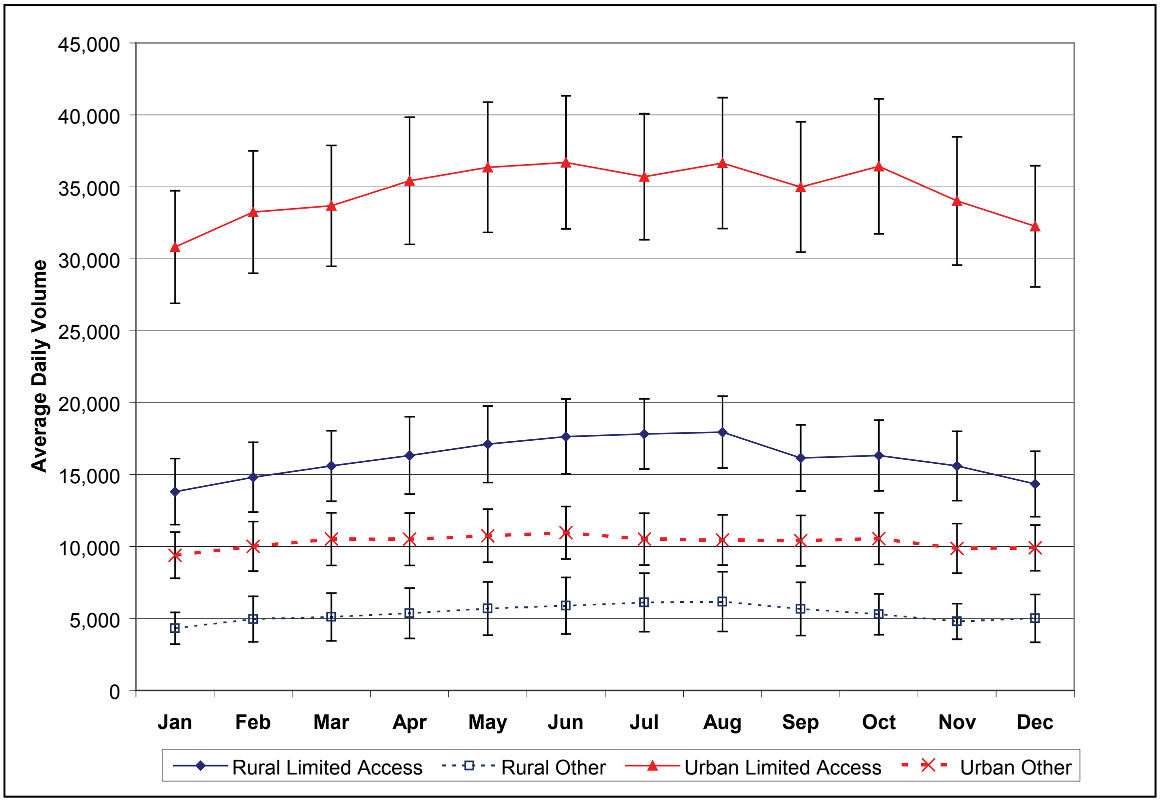

Figure C-1. National average daily volumes by month with 90% confidence intervals.

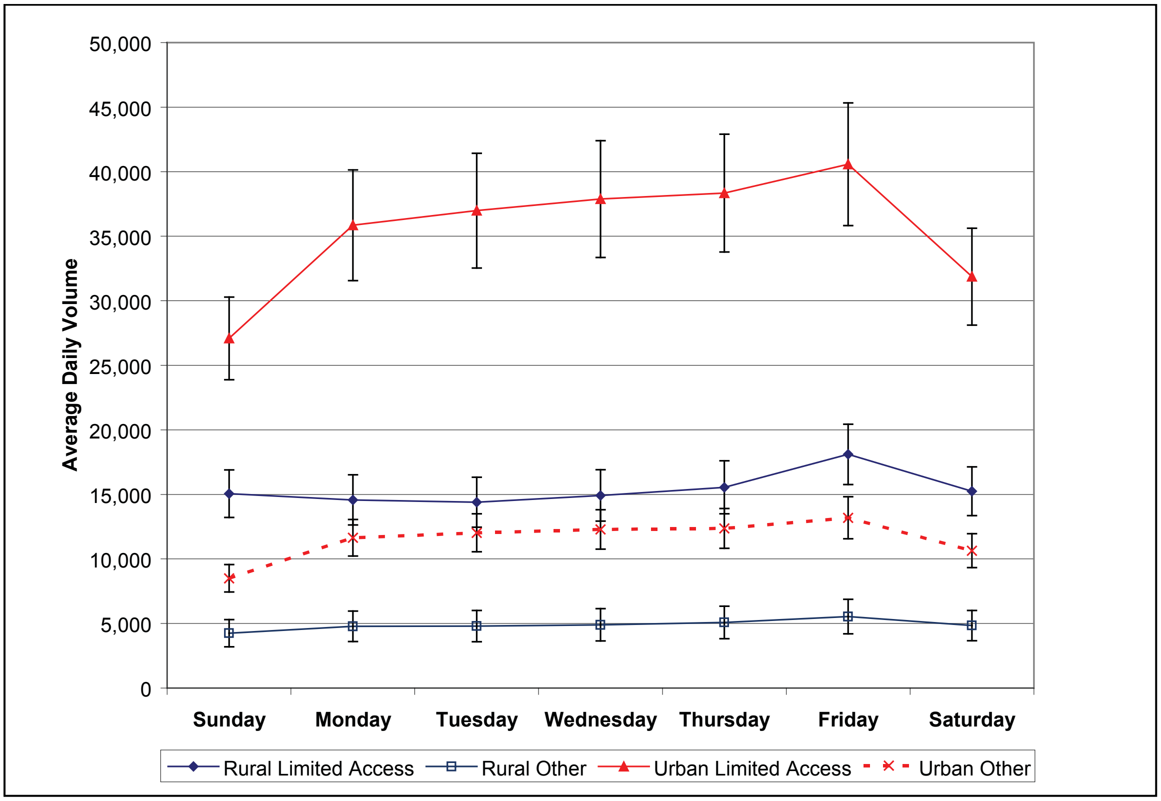

Figure C-2. National average daily volumes by day of week with 90% confidence intervals.

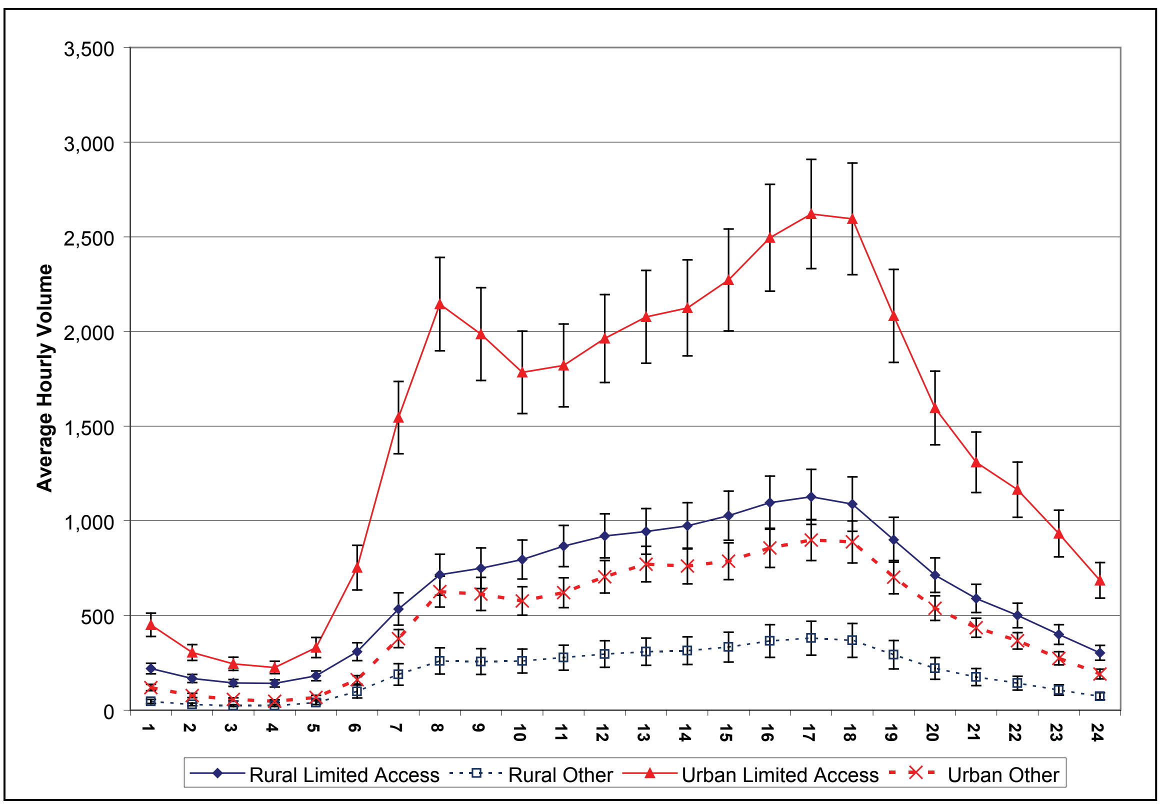

Figure C-3. National average hourly volumes with 90% confidence intervals.

For the VTRIS data analysis of vehicle classifications, the 1999 and 2000 databases were merged to generate the aggregate average profiles.

Monthly temporal profiles for the four EPA groups of road types were developed to provide an understanding of the likely results. The results shown in Figure 4 demonstrate the month-to-month variability in the results for rural interstates. Vehicle type 2 (so called passenger cars) shows high travel fractions for the month of July on both rural road types and urban limited access, and high variability from month to month. Vehicle type 3 also shows variability from month to month with July results higher for rural and urban limited access road types. Other vehicle types show less variability in count magnitude, however similar relative (percentage) variability. The average volumes calculated from the VTRIS data presented in Figures 4 through 16 were calculated directly from the site-values instead of from the average of state averages. Thus, the confidence intervals are small because of the large sample size though state to state variability remains high.

The number of vehicle counts varies more than the relative vehicle fractions of the total because of the site selection and especially the relative number of sites at higher or lower volume roadways. So the vehicle mix fractions shown in Figure C-5 do not vary as much as the total counts of each vehicle types as shown in Figure C-4. Even the dramatic July peak in Vehicle 2 and 3 traffic counts is much less apparent when observing the vehicle fleet fractions.

Similarly variable vehicle counts for other roadway types are provided in Figures C-6 – C-8, and also show more variability than the fleet fractions as the total volume counts vary from month to month. This suggests that the fleet fractions are a valid result, and can be used to represent the temporally averaged vehicle mix.

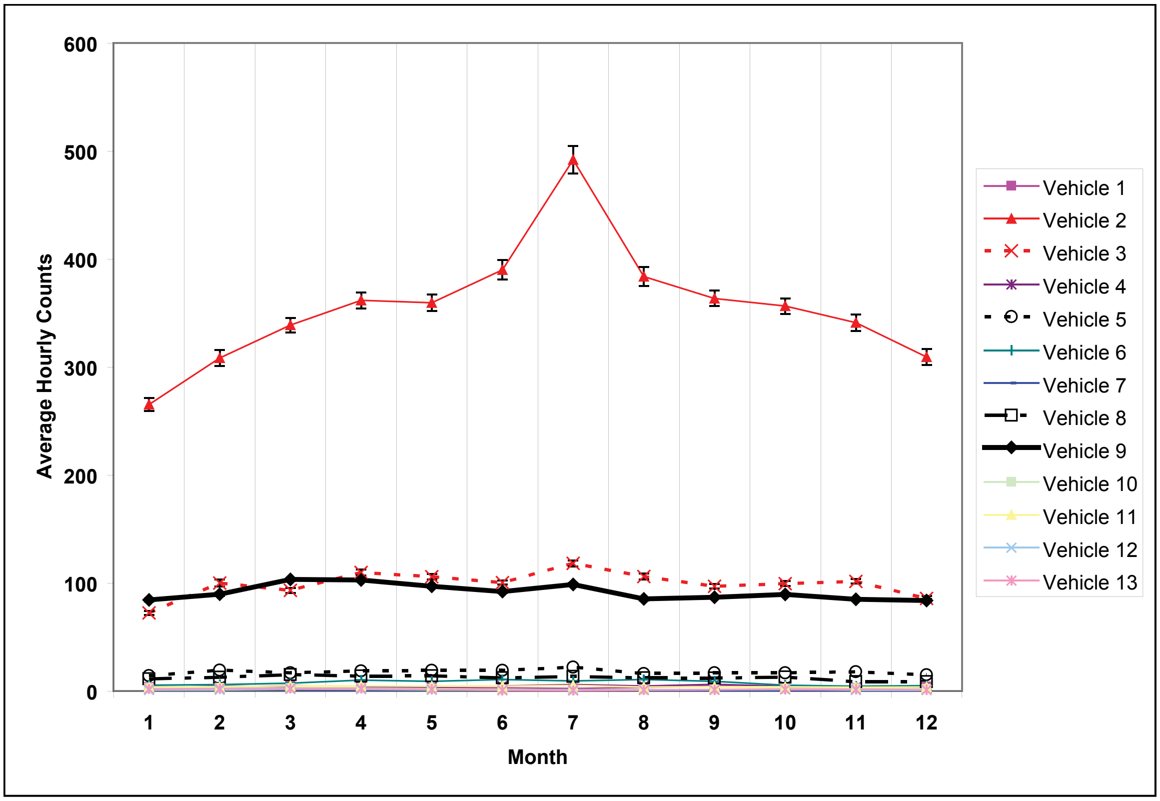

Figure C-4. National average monthly vehicle counts per site for rural limited access roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

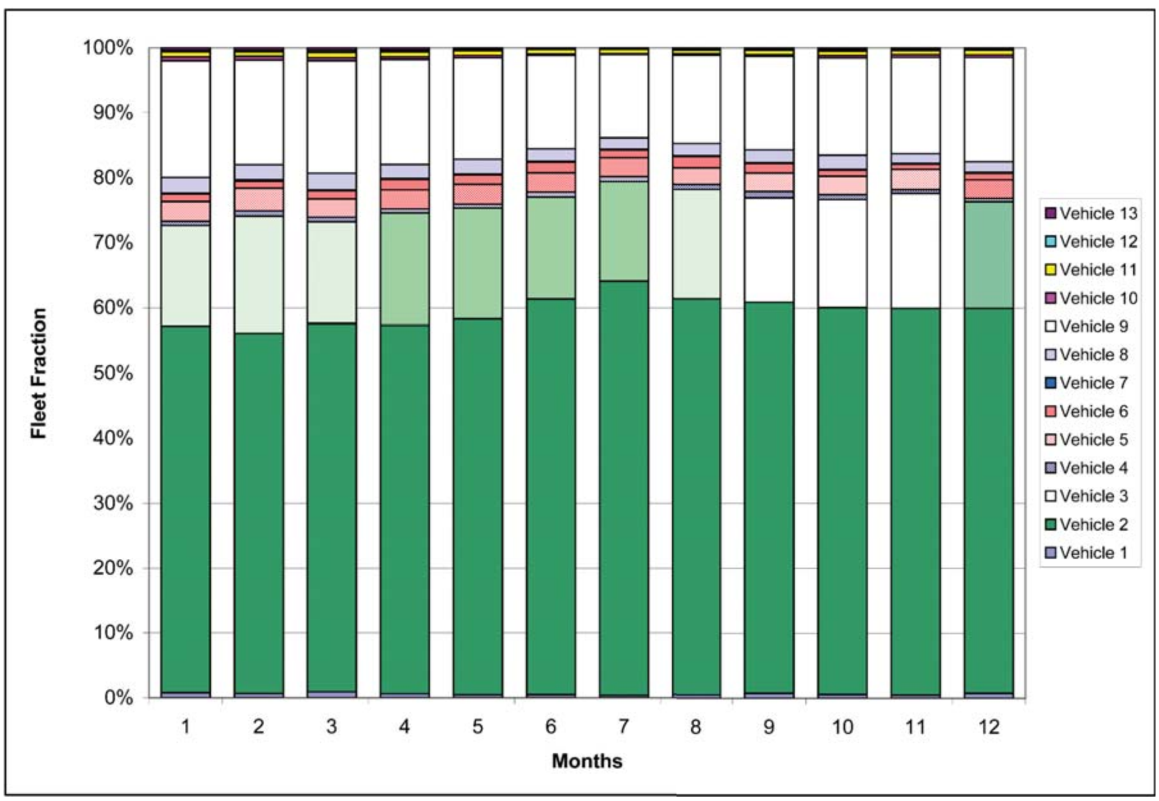

Figure C-5. National average monthly vehicle fleet fractions for rural limited access roads.

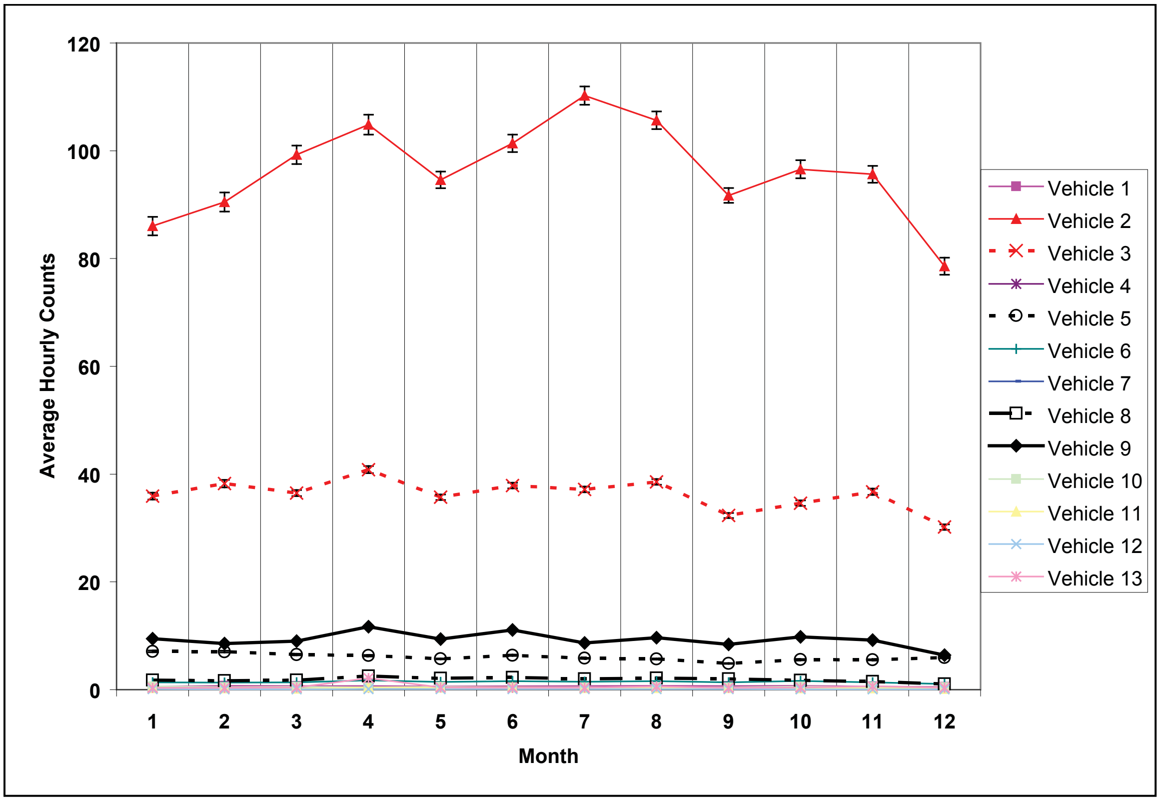

Figure C-6. National average monthly vehicle counts per site for rural other roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

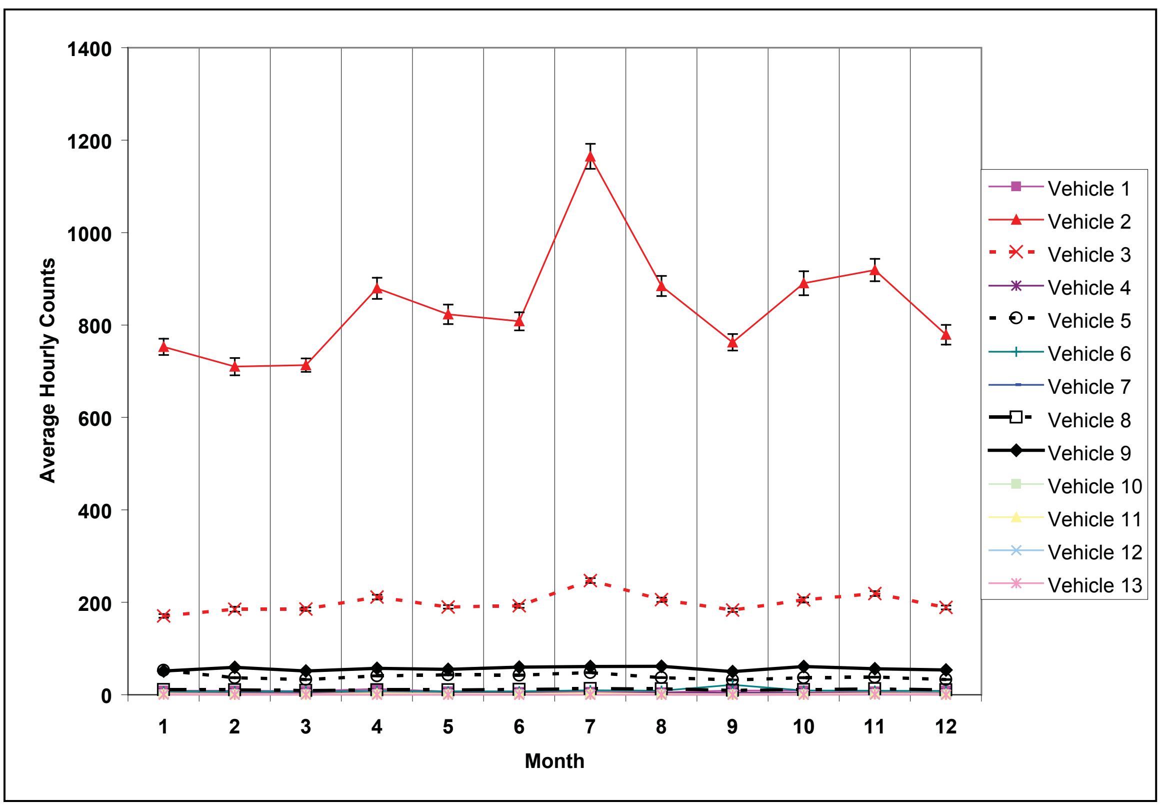

Figure C-7. National average monthly vehicle counts per site for urban limited access roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

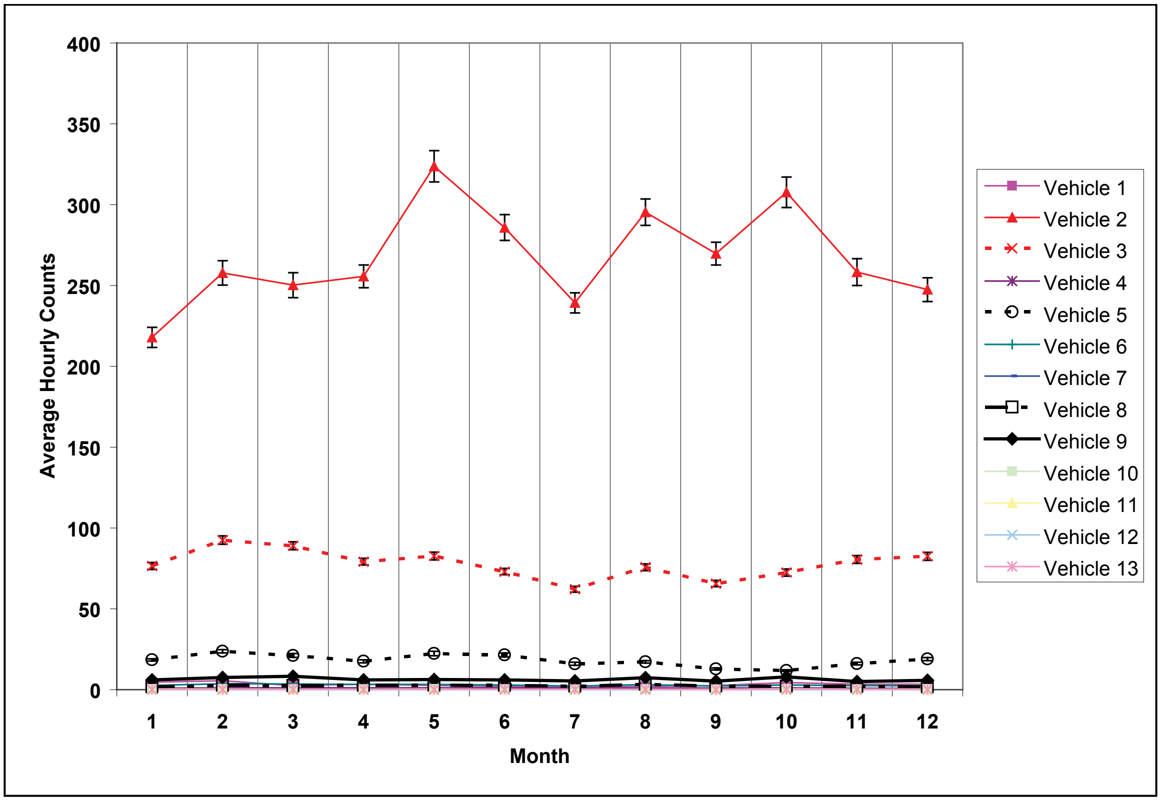

Figure C-8. National average monthly vehicle counts per site for urban other roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

The day of week and time of day summary estimates are shown in the Figures C-9 to C-16. The general trends follow those of the monthly averages where the trucks (primarily vehicle types 5 and 9) show higher activity on rural limited access and lower activity on urban other road types. The trucks also show less diurnal and weekday variability compared with the light-duty vehicles (vehicle types 2 and 3) where Friday travel and morning and afternoon peak travel times are evident. Trucks show little deviation from one weekday to another and regular diurnal profiles without rush hour peaks.

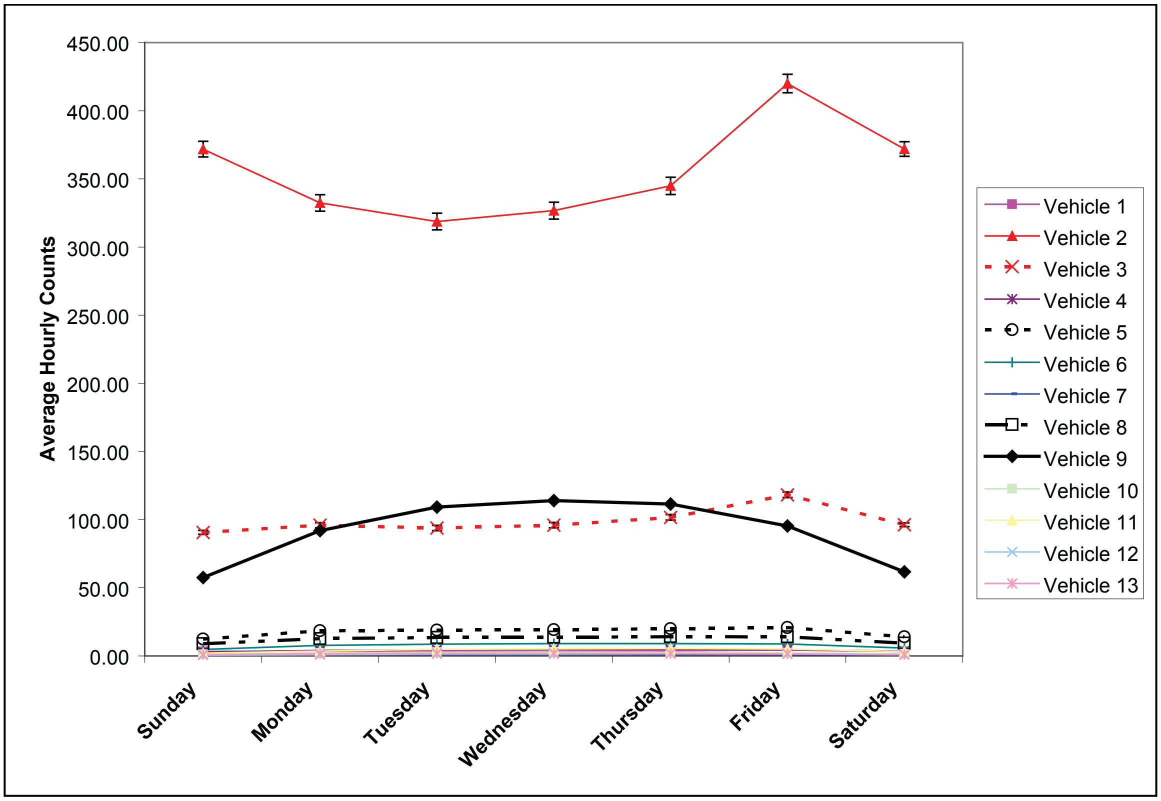

Figure C-9. National average day of week vehicle counts per site for rural limited access roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

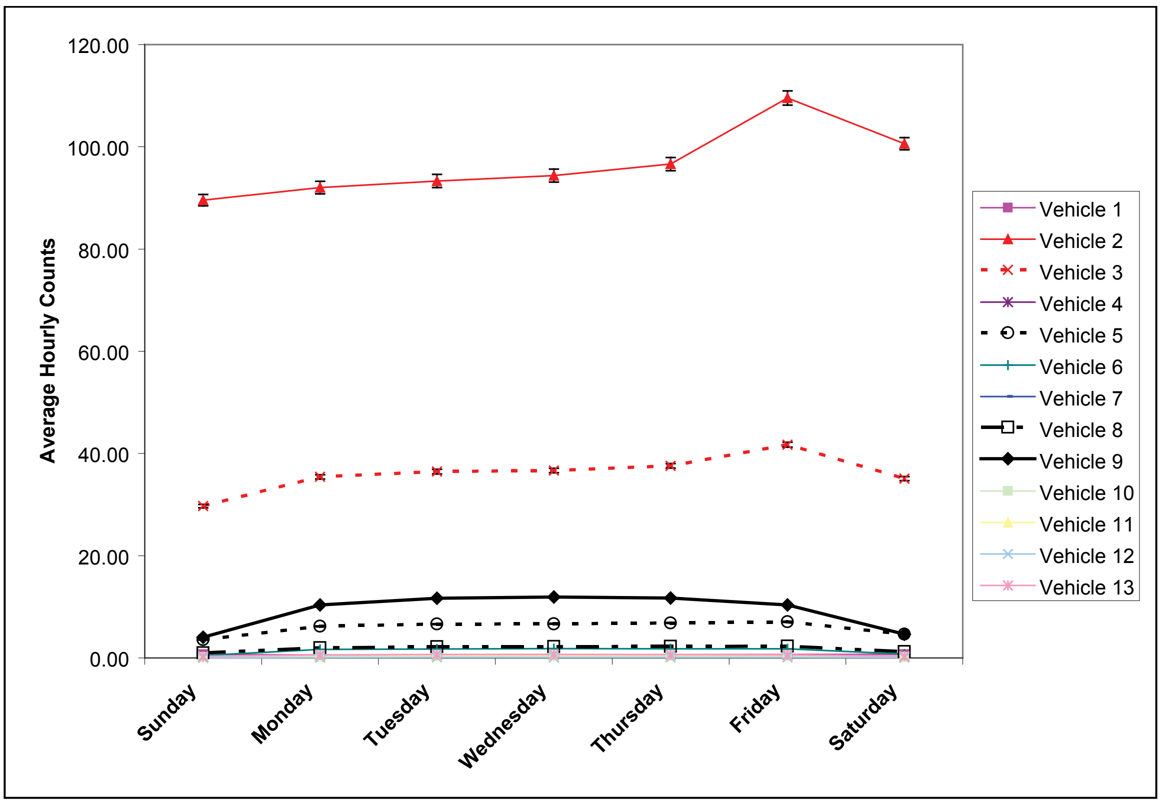

Figure C-10. National average day of week vehicle counts per site for rural other roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

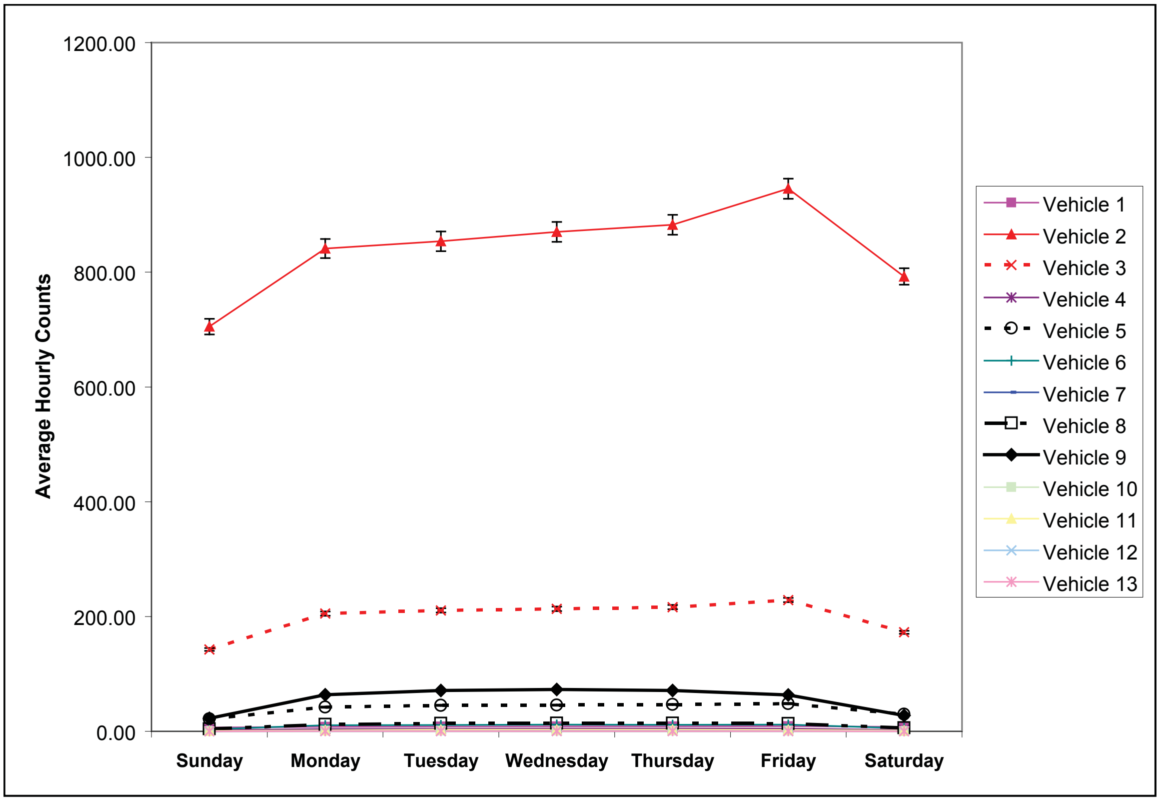

Figure C-11. National average day of week vehicle counts per site for urban limited access roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

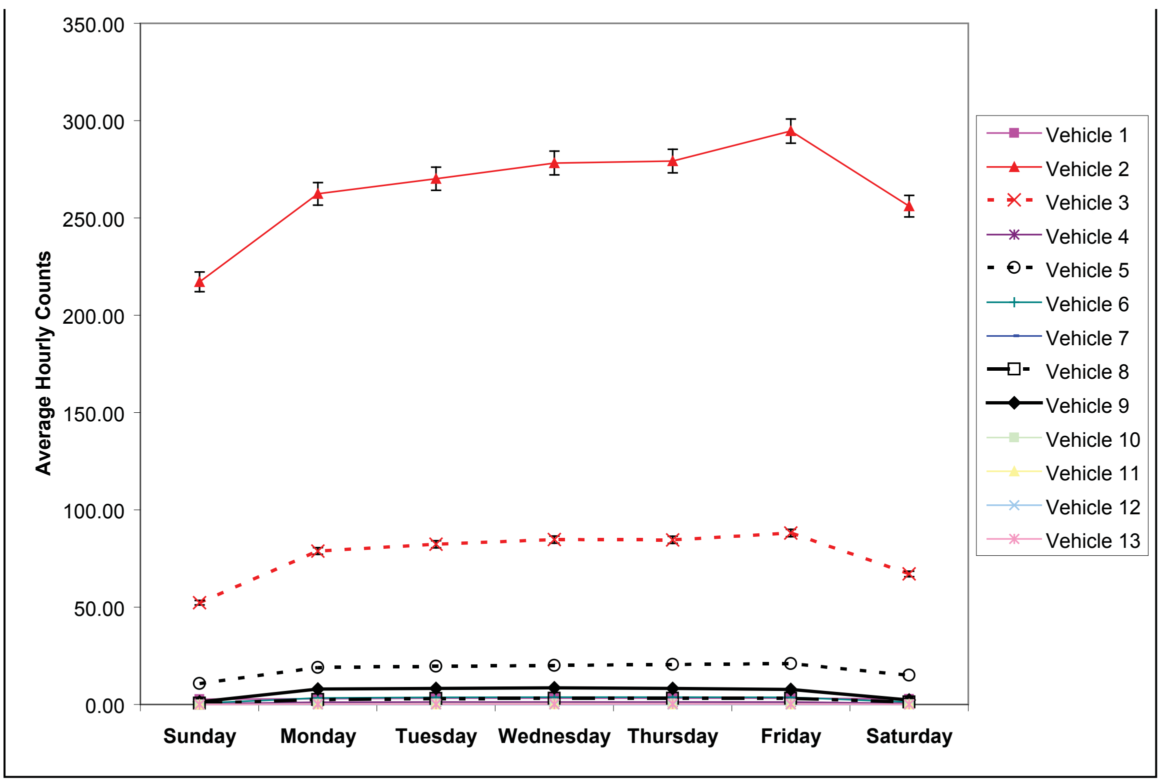

Figure C-12. National average day of week vehicle counts per site for urban other roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

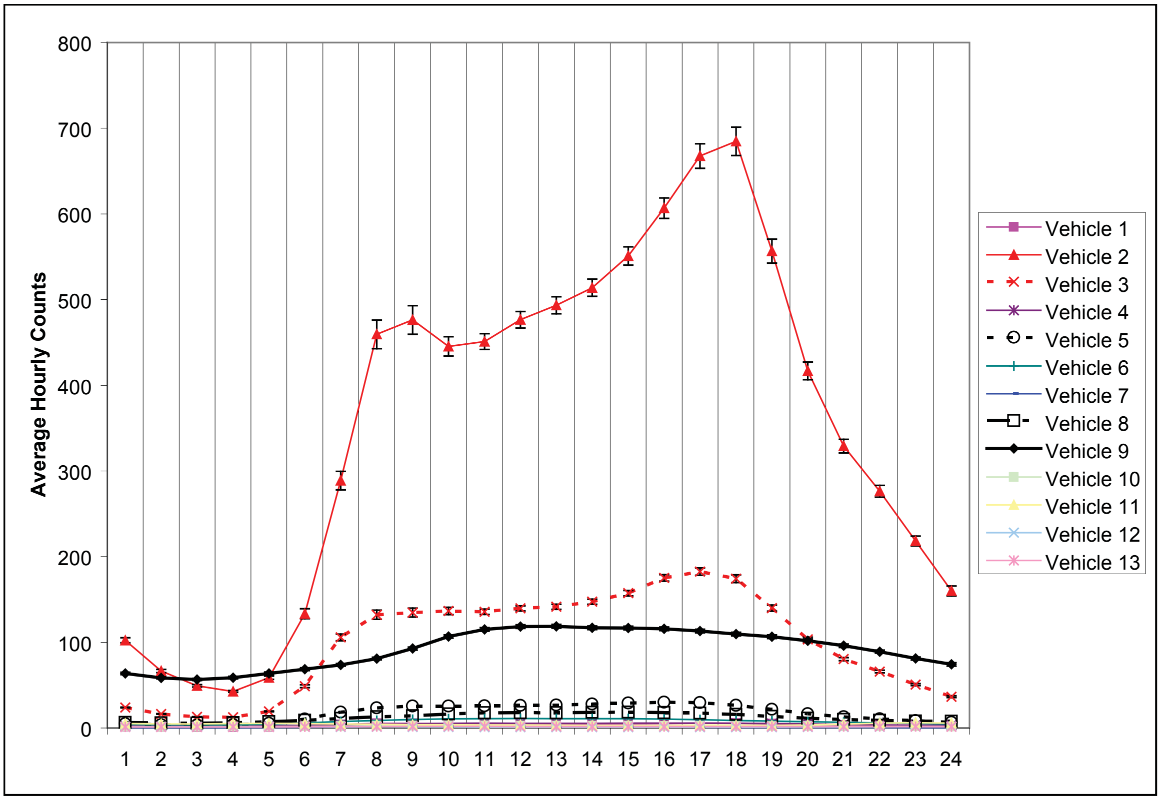

Figure C-13. National average time of day vehicle counts per site for rural limited access roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

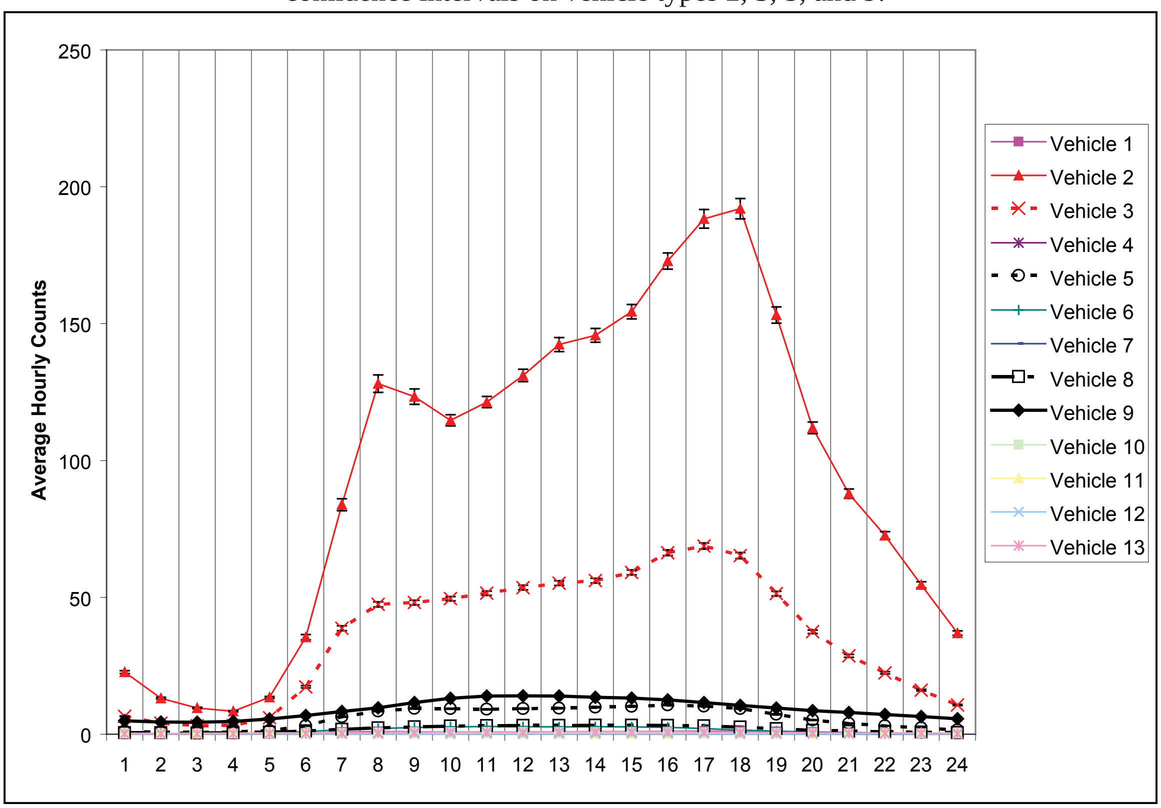

Figure C-14. National average time of day vehicle counts per site for rural other roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

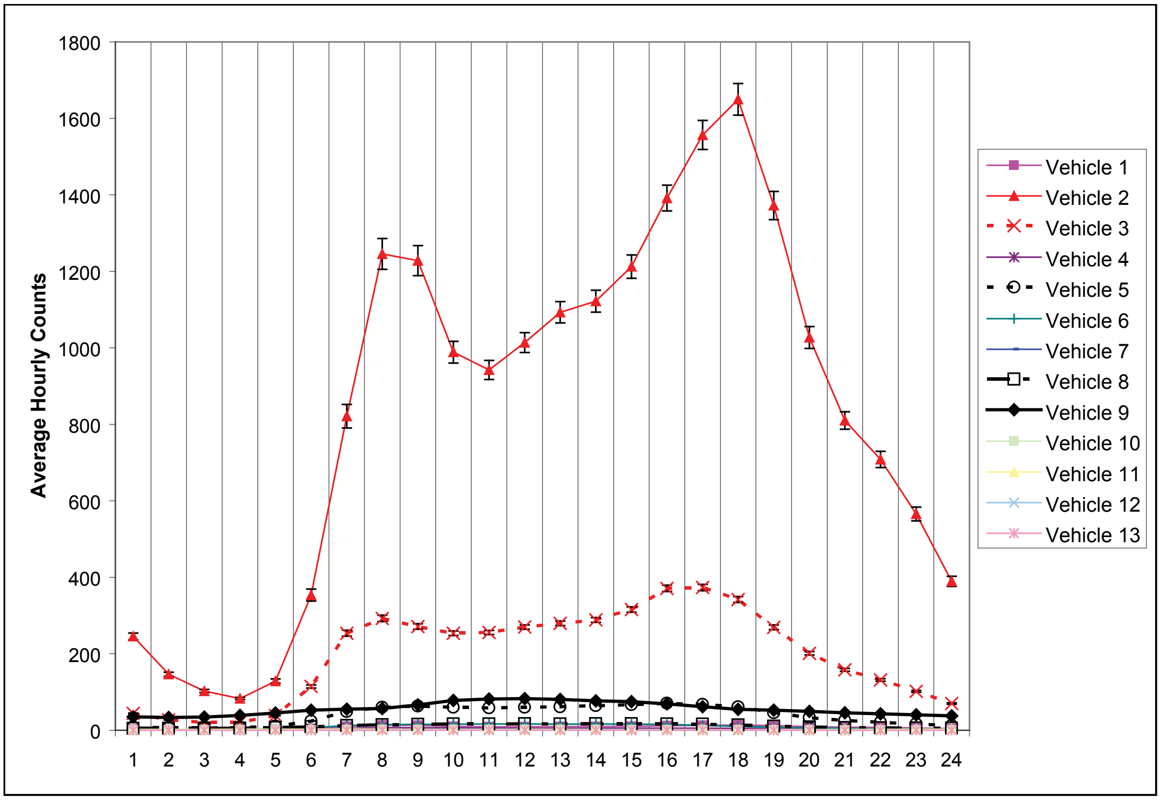

Figure C-15. National average time of day vehicle counts per site for urban limited access roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

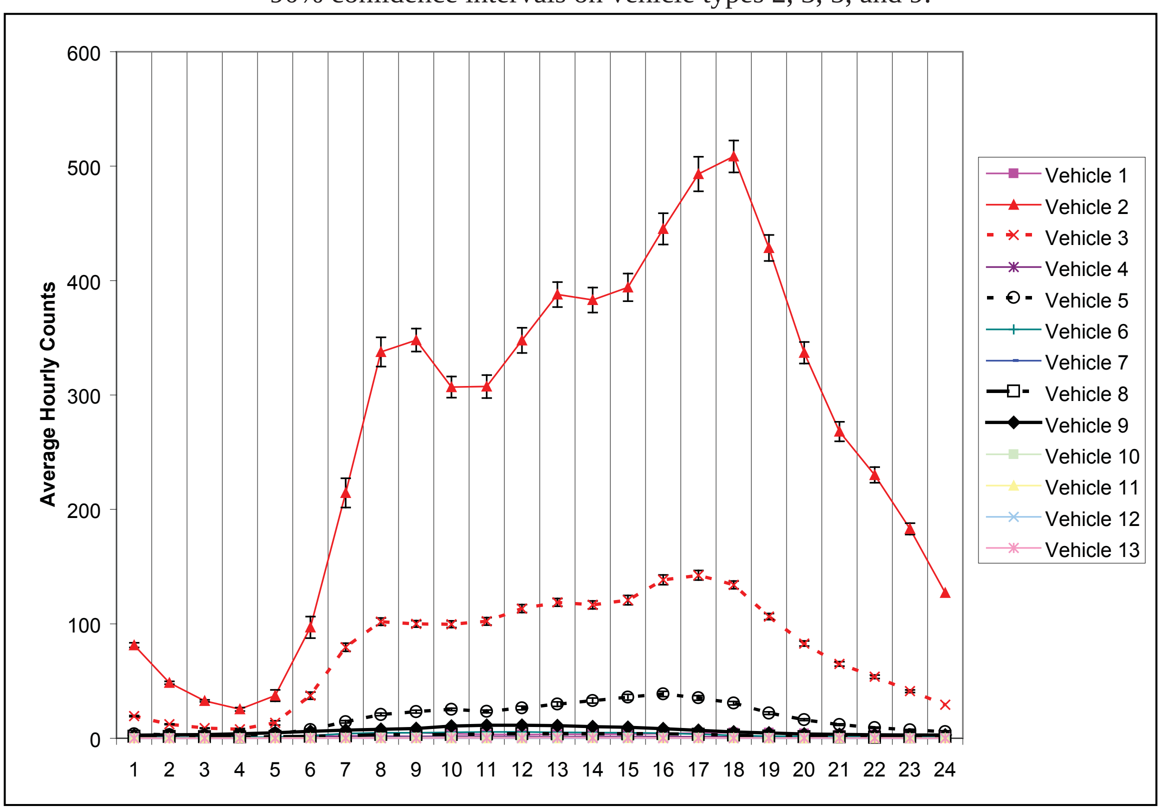

Figure C-16. National average time of day vehicle counts per site for urban other roads with 90% confidence intervals on vehicle types 2, 3, 5, and 9.

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APPENDIX D - ANALYSIS OF 2000 TRAVEL VOLUME TRENDS (TVT) DATA AND

2000 VEHICLE TRAVEL INFORMATION SYSTEM (VTRIS) DATA

D-1. INTRODUCTION

The goal of the analysis in this Appendix is two-fold: (1) the first goal is to examine the state-to-state variability in the TVT temporal profiles, and (2) to compare the temporal patterns of the TVT data with those of the VTRIS data. The first is to determine if regions should consider using a specific profile for that region. The second goal is to determine if the temporal variation of the VTRIS data is sufficiently compatible to those of the TVT data to use TVT for total traffic volume and VTRIS for vehicle mix fractions by roadway. The TVT is a more robust source of total traffic volume, and so has historically been considered the best source for those estimates.

For this analysis, only the TVT and VTRIS data sets collected in the year 2000 were used because only the 2000 TVT data was available to us in a database format. Note that the number of states for which there were VTRIS data is substantially smaller than for the TVT data. To illustrate, Table D-1 below displays the number of states by facility class that were used in the calculation of the monthly profiles (after dropping states for which there were fewer than twelve months of data). One should also bear in mind that data submittal to VTRIS is voluntary on the part of the states. Thus, the VTRIS data for a given state may only be a subset of vehicle classification data that is truly available for that state. However, for the purpose of this analysis, it is worthwhile to see if the national average profiles of each dataset have a semblance to one another.

Table D-1. Number of States used in the calculation of the monthly temporal profiles.

Facility Class	Number of TVT States	Number of VTRIS States
Rural		
01 – Principal Arterial - Interstate	32	3
02 – Principal Arterial – Other	33	5
06 – Minor Arterial	30	2
07 – Major Collector	28	1
08 – Minor Collector	10	0
09 – Local System	8	0
Urban		
11 – Principal Arterial – Interstate	32	2
12 – Principal Arterial – Other Freeways or Expressways	22	3
14 – Principal Arterial – Other	29	1
16 – Minor Arterial	24	1
17 – Collector	15	0
19 – Local System	7	0

The vehicle classification data in the VTRIS data measures the hourly volumes of vehicles on various roadway types by vehicle class. The vehicle class volumes for the VTRIS data were summed together to make a total hourly volume that would be comparable to the hourly volumes in the TVT data.

D-2. DATA HANDLING PROCEDURES

For the two datasets to be compared, it was necessary to use the same data formatting and aggregation routines. The more important quality assurance routines are described along with an illustrative example of the reason for that routine.

In general, the hourly profiles were calculated by first dropping a day's worth of observations at a site where there were more than eight hours of zero volumes. This quality assurance step is similar to one employed by the Department of Transportation to eliminate records with more than seven consecutive hours with zero volumes in order to drop records where equipment failure was likely. The next quality assurance step was to drop any site data in a given month for which there were not all seven days of the week represented for that month. This step was to eliminate any bias in the hourly profiles due to day of week variability.

Figure D-1 below illustrates the day of week variability in the hourly data for Urban Interstates (Class 11). Figure D-1 shows typical morning and evening peak periods on Monday through Friday, but only single peak periods on Sunday and Saturday.

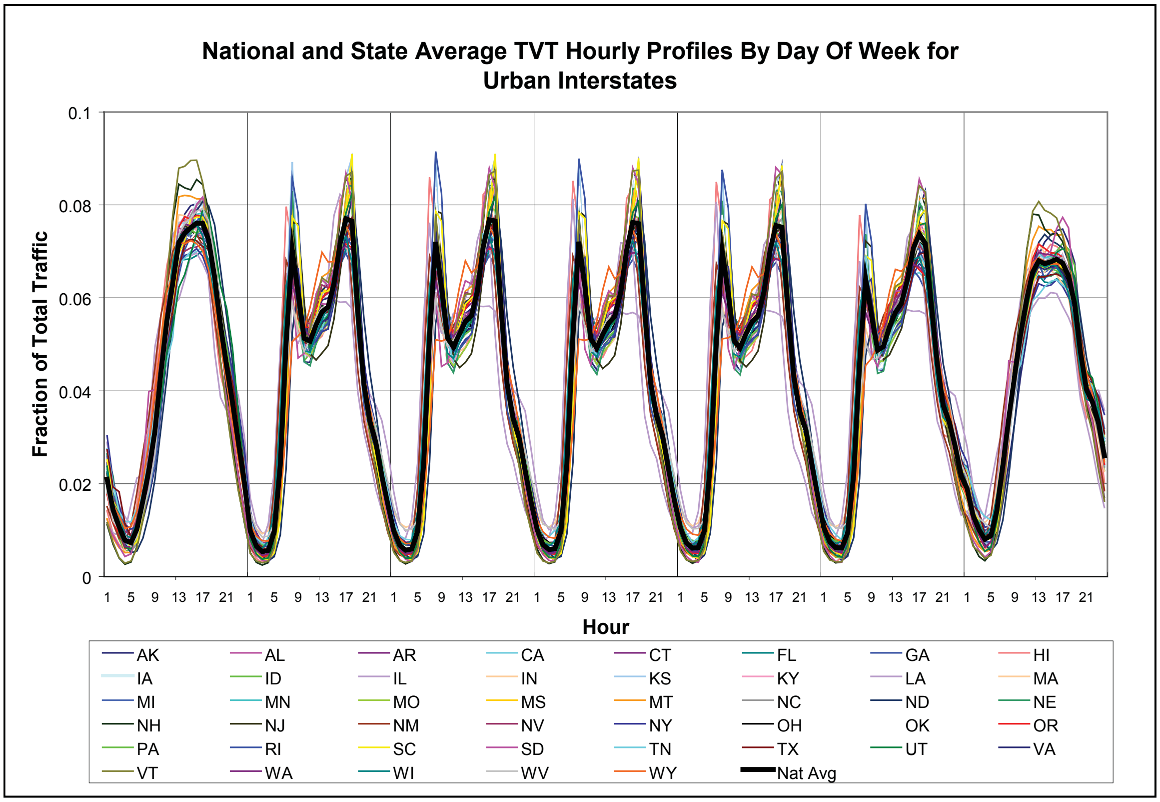

Figure D-1. Day of week variability in hourly volumes from Sunday to Saturday.

Figure D-2 below displays the average daily total volumes at two VTRIS Washington sites for urban interstates where the average daily volume at site P3N was an order of magnitude greater than that at site 111. Averaging together the Monday hourly P3N volume with the other days of the week at site 111 resulted in an hourly temporal profile with an unusually large peak on Monday . To remove this potential source of bias, site-months were required to have observations for all seven days of the week.

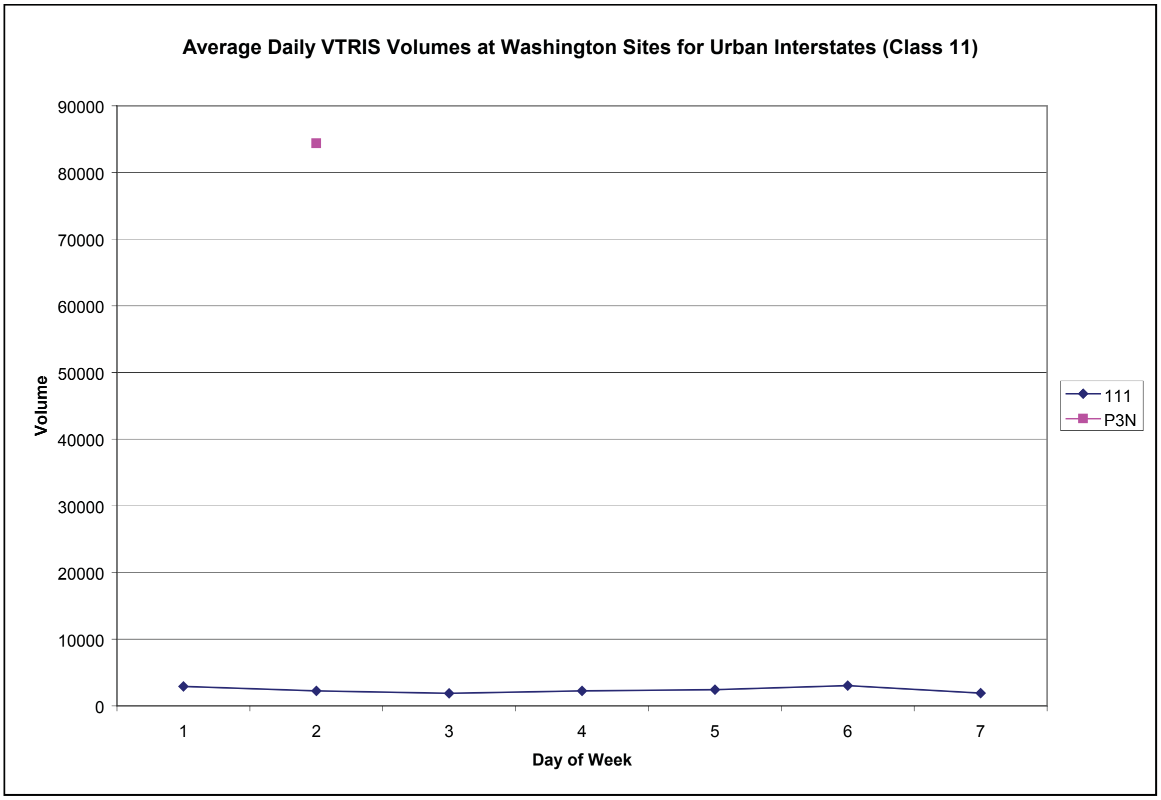

Figure D-2. Average daily volumes at two VTRIS Washington State urban interstate sites.

Finally, the November TVT volumes for the state of Alaska appeared to be shifted by one column. Every hourly volume ended in the digit zero, and they were typically ten times greater in magnitude than the other months. Figure D-3 displays the monthly temporal profile with the month of November included in the Washington profile on rural interstates. November for Alaska was dropped in the analysis.

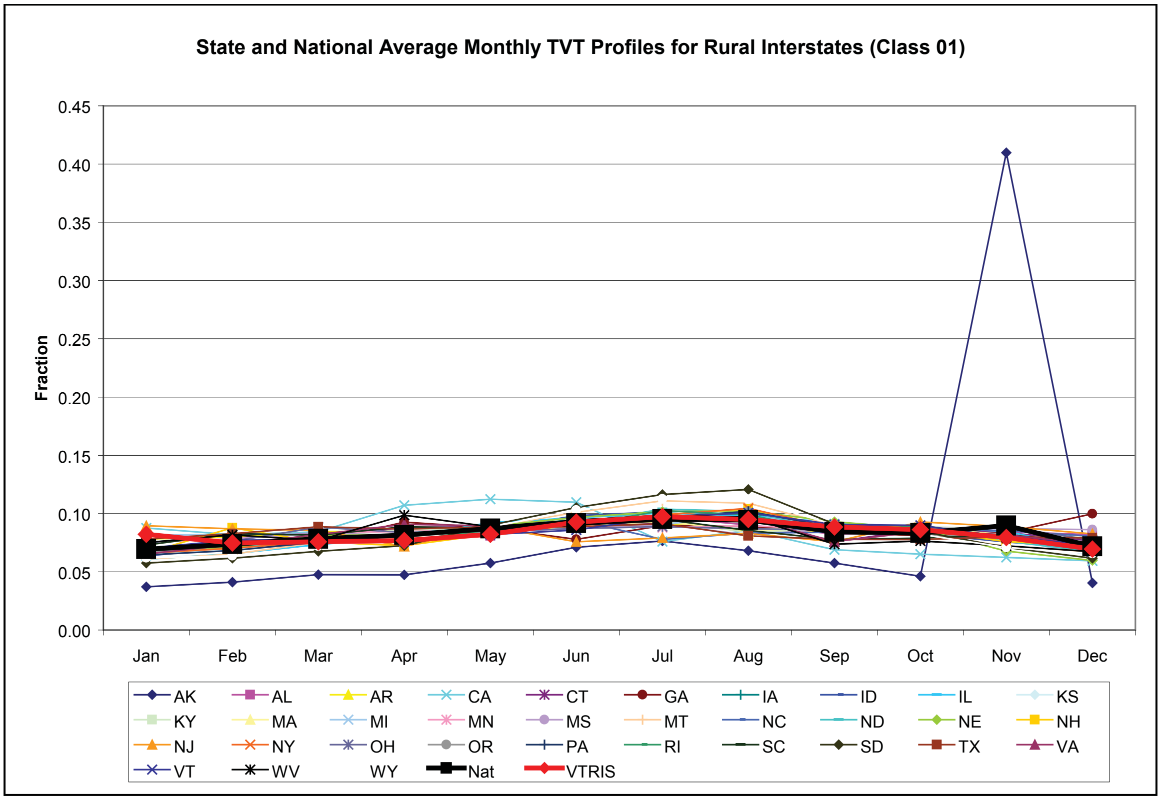

Figure D-3. Monthly temporal profile including the month of November for Alaska.

Calculation of Temporal Profiles

The total volume counts were averaged at individual sites before being averaged across sites (VTRIS hourly total volume counts were calculated as the sum of the hourly class counts). The reason for doing this was to ensure that sites with longer periods of observation were not more heavily weighted than others, but rather sites with heavier traffic volumes would be more influential in averages across sites. The site averages were calculated by first totaling the counts across lanes in the same roadway direction. Different directions at a site were treated separately. Then the counts were averaged for each site-direction pair by hour, day of week (i.e., Sunday through Saturday), and month. This means that at most five values (because there are fewer than 5 weeks in any month) were averaged together, corresponding to the total number of days of a week during one month. For example, all Monday counts during January for hour 10 were averaged together at each site-direction pair. The site averages were used as the starting point for all further analyses.

The hourly profiles were calculated as follows:

1. The hourly volumes for each site-direction were averaged together by day of week for each state.

2. The state fractional profiles for each day of the week were calculated as the hourly fraction of the daily total volume for each day of the week at each site.
3. The national average hourly profile by day of week was calculated as the average of the state fractional averages. As discussed below, the national fractional profiles were calculated as the average of the state fractional profiles.
4. The overall hourly state volumes by day of week were averaged across the days of the week to create a single hourly profile for each state.
5. The overall hourly state fractional profiles were calculated as the average hourly volume over the average daily volume for each state.
6. Finally, the national average hourly profile was calculated as the average of the state fractional profiles[1,2].

In generating the day of week profiles, we started from the hourly data that was already checked for completeness at each site for each day of the week by month.

1. The average hourly volumes by day of week and state were totaled to generate an average day of week volume by state.
2. The state fractional day of week profiles were calculated as the fraction of the daily volume to the weekly total volume.
3. The national average day of week fractional profile was calculated as the average of the state day of week profiles.

The monthly profiles were generated as follows:

1. The monthly daily total volume averages by state was calculated from the day-of-week complete dataset generated above.
2. All states without twelve months of daily averages were dropped.
3. The state fractional profiles were calculated as the fraction of the average daily volume to the sum of the average daily volumes over all twelve months.
4. The national fractional profile was calculated as the average over the state fractional profiles.

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[1]It would be possible at this point to generate a weighted average national profile where different weighting factors could be assigned by state. For example, it would be possible to generate a population-weighted or VMT-weighted national profile instead of weighting each state equally.

[2]The national fractional profiles were calculated from national average volumes initially, but upon finding that, in the VTRIS data, the state of New Jersey had volumes that were typically ten times higher than the other states. This forced the national VTRIS profile to be overly influenced by the trends in the New Jersey data. By averaging the state fractional profiles, the national profile is more influenced by the trends in the state-level data, rather than the magnitude of the volumes from one state to another. In order to be consistent in the analysis of both the VTRIS and TVT data, the TVT national profiles were recalculated from the averages of the state fractional profiles. A more detailed discussion is provided under the “Calculation of National Average Profiles” section.

Calculation of National Average Profiles

The national temporal profiles were initially calculated from the average of the state volumes. However, the VTRIS volumes from the state of New Jersey were substantially greater in magnitude than the other states, so the national profile that was generated was almost exactly that for the state of New Jersey. Figure D-4 below is an example the over-influence of the large volumes on the national profile. In particular, the point for July shows a spike in the national profile that is representative of only the state of New Jersey. The other two states, Arizona and Iowa, do not show the same July spike.

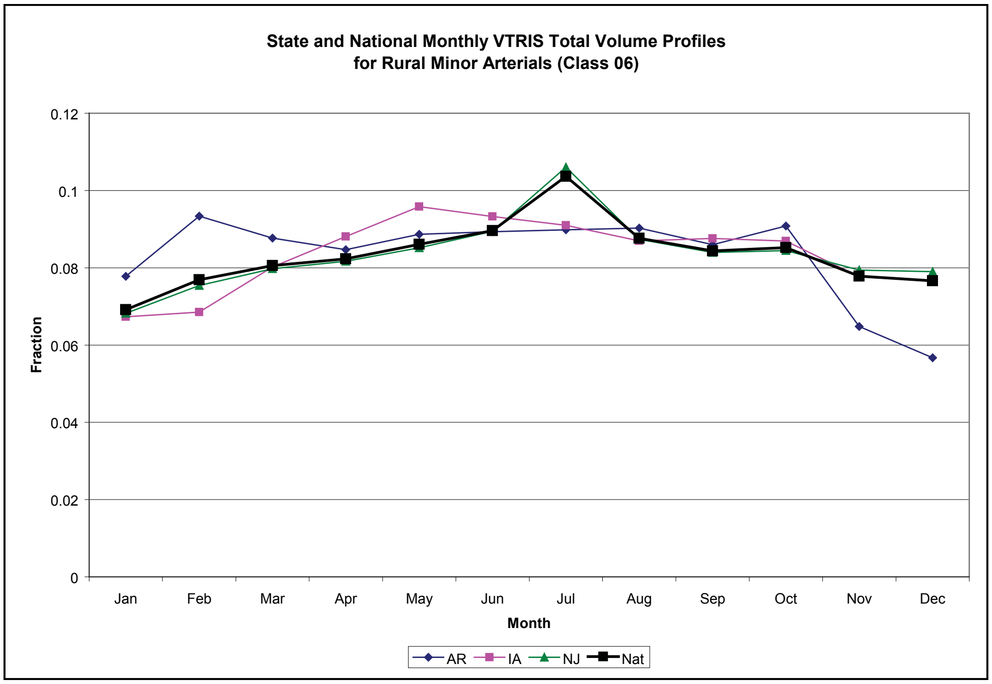

Figure D-4. National VTRIS monthly profile calculated from averages of state volumes.

To capture the temporal changes from hour to hour, from one day in the week to the next, or from one month to the next, the national temporal profiles presented below were calculated as averages of the normalized state temporal profiles. This procedure was performed to eliminate the influence of single states, such as that of New Jersey in Figure D-4. Figure 5 illustrates the revised national average VTRIS monthly profile calculated as the average of the state profiles to compare with Figure 4. In this figure, the July spike in the national average profile was diminished, and so considered more representative of the larger sample average.

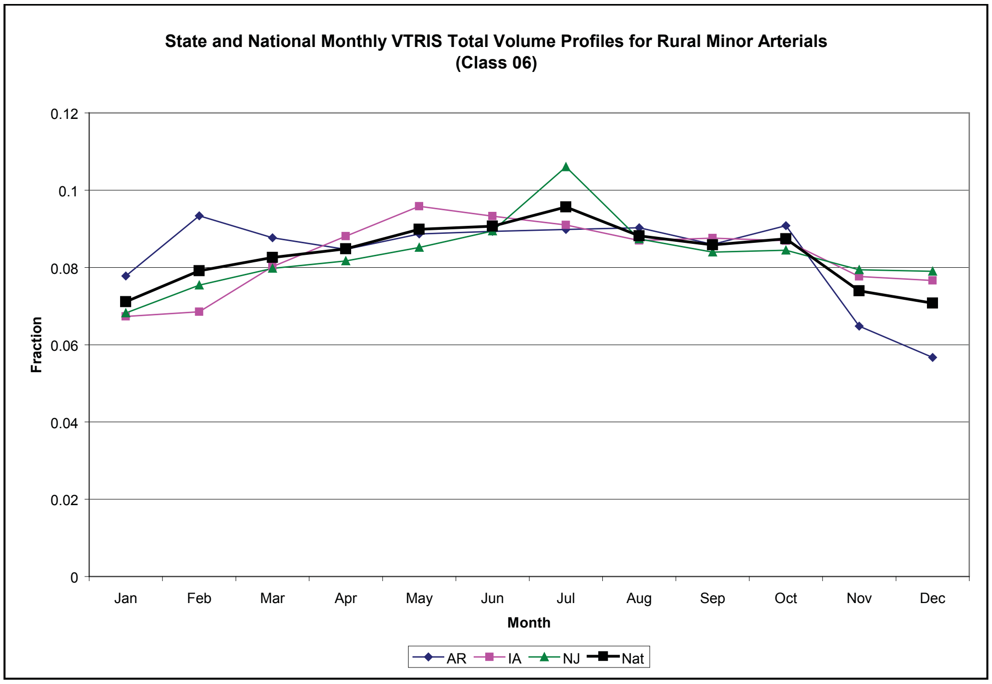

Figure D-5. National VTRIS monthly profile calculated from averages of state profiles.

D-3. RESULTS OF REGIONAL VARIABILITY AND TVT/VTRIS NATIONAL AVERAGE COMPARISONS

While it can be demonstrated that some states were statistically significantly different from the national average by road type and for some hourly, day of week, and monthly profiles, no consistent regional grouping could be identified to define regional profiles.

The state-to-state variability was examined by conducting a chi-square goodness-of-fit test, and we also determined if a state's volumes were often more than one standard deviation away from the national average. Both methods reveal that there are typically a number of states that would be considered to be significantly different than the national average.

Hourly Profiles

Following is a plot of the TVT hourly state profiles for rural interstates along with the TVT national average in bold black and the VTRIS average in bold red. This demonstrates that while many states demonstrate apparent differences from the national average, these differences are not large.

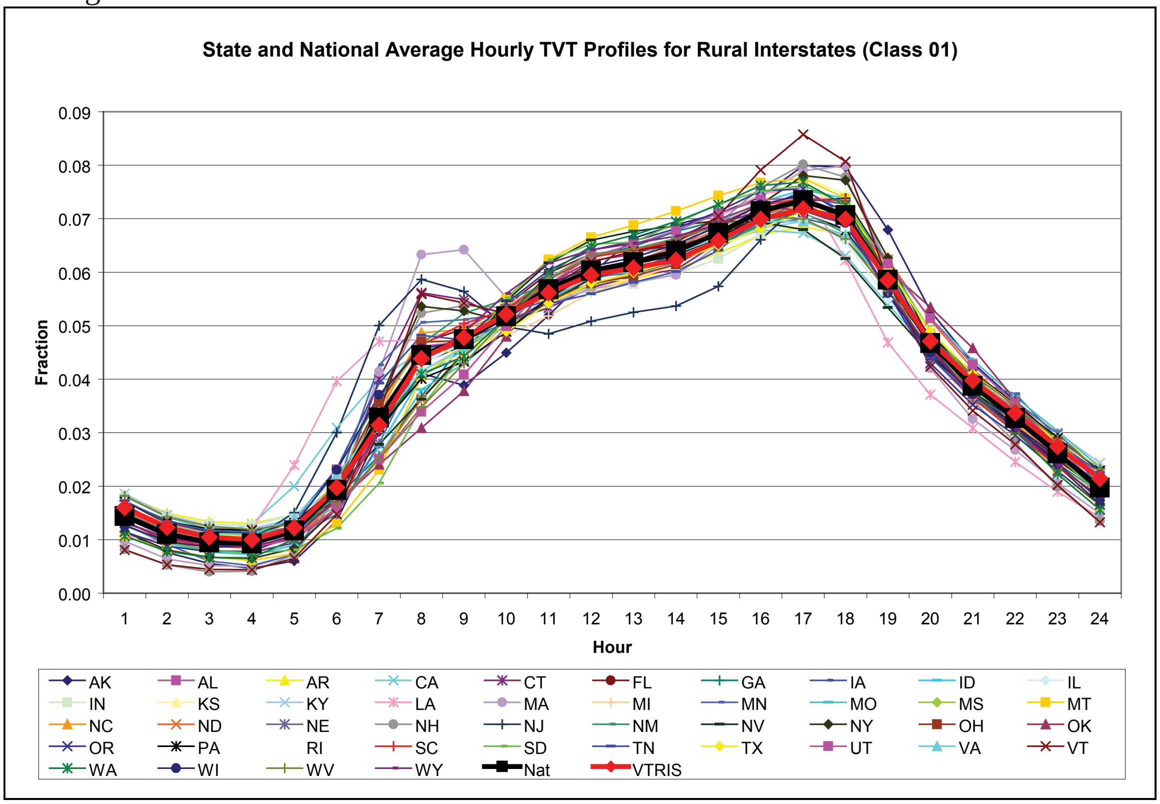

Figure D-6. State and national average TVT hourly profiles for rural interstates.

In Figure D-6, there is a clear diurnal pattern that all the states follow, with the greatest variance in the early morning commute hours between 6 a.m. and 10 a.m. With the exception of

New Jersey, the state profiles follow the national profile rather closely during the mid-day hours, followed by a slightly greater variance around the evening commute hours between 5 p.m. and 6 p.m. Figure 7 below is a plot of the national profile with one-standard deviation error bars, and Figure 8 shows the national profile generated from the TVT data along with the VTRIS national average, both with 90% confidence intervals. The 90% confidence intervals on the TVT national average are quite small, given that the national profile is calculated as the average of the state profiles, which is not a substantially large sample size. The confidence intervals around the VTRIS data are larger, reflecting primarily the smaller sample of states used in the average.

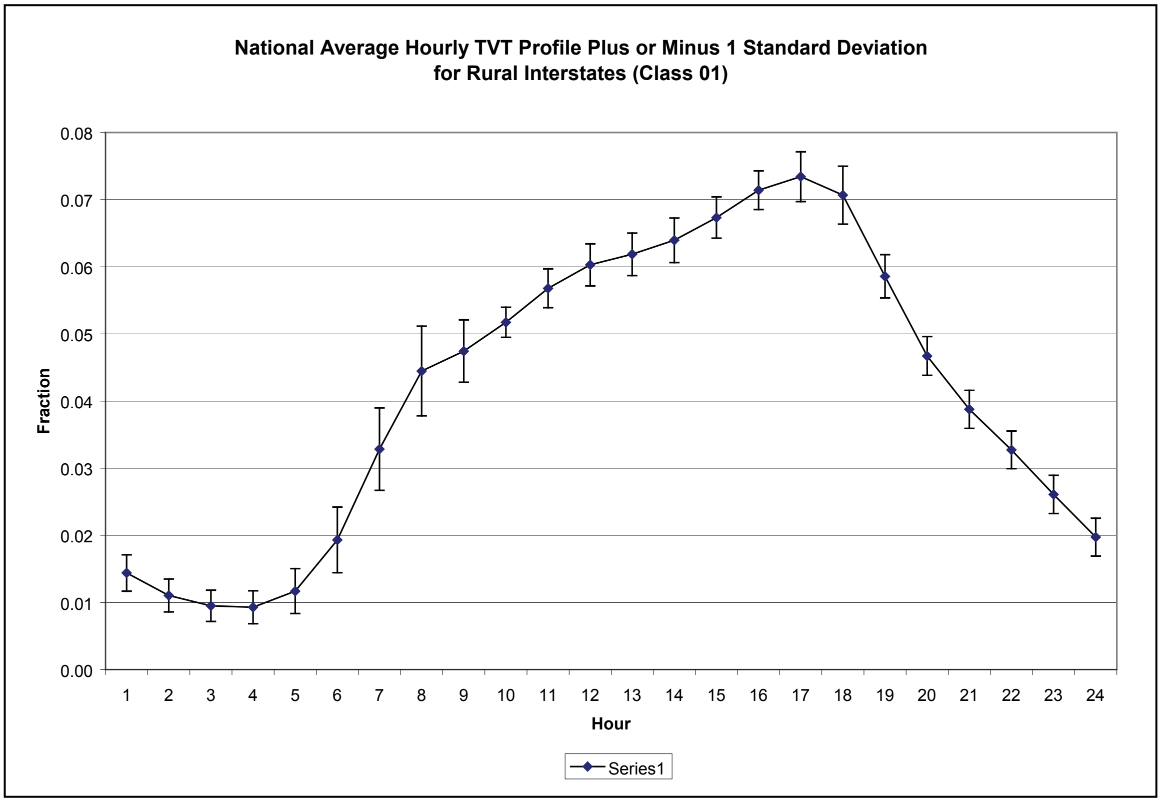

Figure D-7. National average TVT hourly profile plus or minus 1 standard deviation.

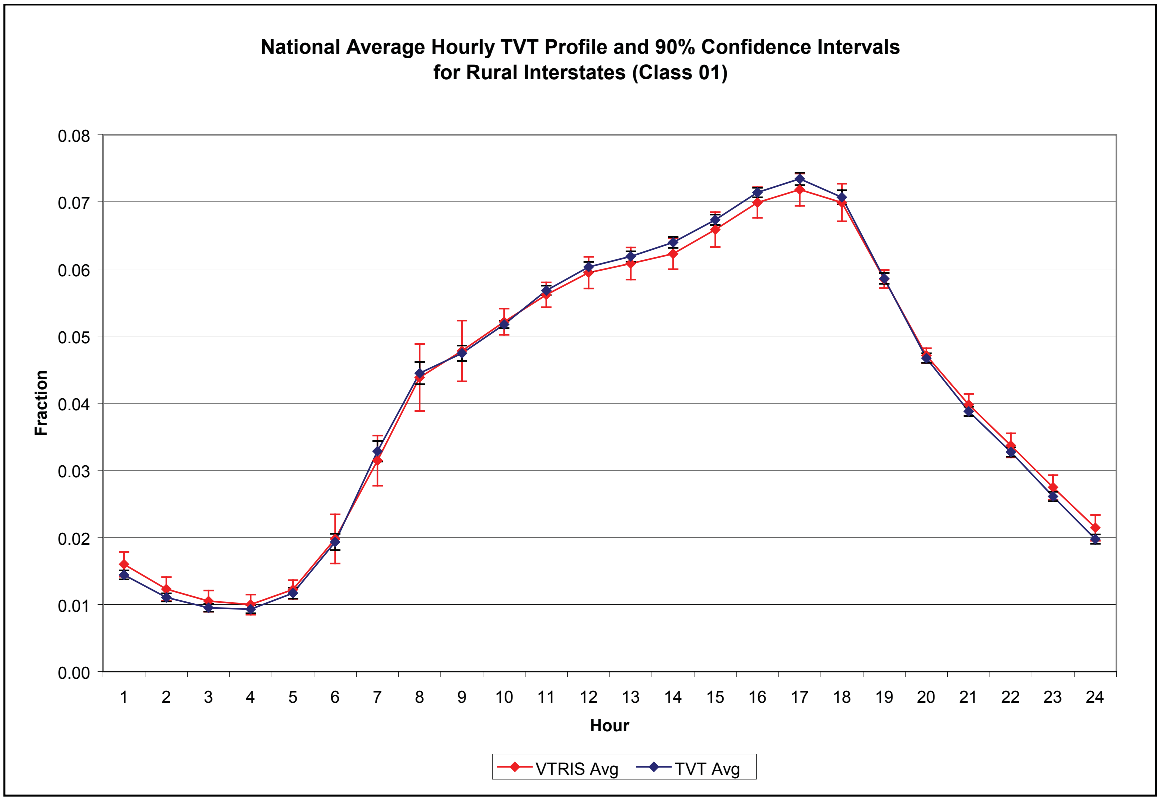

Figure D-8. National average TVT and VTRIS hourly temporal profile with uncertainty.

Despite the seemingly close agreement between the state hourly profiles and that of the national average, there were only 10 out of 44 states that were not statistically significantly different from the national average. This is primarily because the categorical chi square tests for even small differences in profiles, so only a few hours need to be different to see a statistical difference. Following in Table D-2 are the significance levels as well as the number of hours a state value was more than 1 standard deviation away from the national average for rural interstates.

Table D-2. Chi Square statistical tests for difference from national average for rural interstates (Low p-values and large number of hours different than the mean are statistical indicators of difference).

State	p-value	Number of Hours Greater than 1 Standard Deviation Away from the National Mean	State	p-value	Number of Hours Greater than 1 Standard Deviation Away from the National Mean
AK	0.028	18	NE	0.002	3
AL	0.044	0	NH	0.000	14
AR	0.000	10	NJ	0.000	11
CA	0.000	8	NM	0.171	2
CT	0.000	6	NV	0.000	10
FL	0.171	2	NY	0.000	10
GA	0.000	4	OH	0.073	0
IA	0.992	0	OK	0.000	7
ID	0.191	1	OR	0.000	13
IL	0.000	5	PA	0.000	5

State	p-value	Number of Hours Greater than 1 Standard Deviation Away from the National Mean	State	p-value	Number of Hours Greater than 1 Standard Deviation Away from the National Mean
IN	0.000	11	RI	0.041	0
KS	0.916	2	SC	0.000	0
KY	0.000	8	SD	0.000	11
LA	0.000	13	TN	0.000	7
MA	0.000	19	TX	0.043	2
MI	0.001	4	UT	0.001	8
MN	0.000	6	VA	0.000	1
MO	0.000	10	VT	0.000	16
MS	0.620	0	WA	0.000	12
MT	0.000	17	WI	0.002	0
NC	0.522	0	WV	0.000	8
ND	0.819	5	WY	0.469	4

Day of Week Profiles

The day of week profiles show a similar pattern in that individual States may differ from the national average for a day of the week, but overall one cannot discern a clear regional pattern from the data. Figure D-9 shows a comparison of the TVT national and individual state profiles by the day of week on rural interstates. Figure 10 shows the national average TVT day of week profile along with the VTRIS average profile, both with 90% confidence intervals.

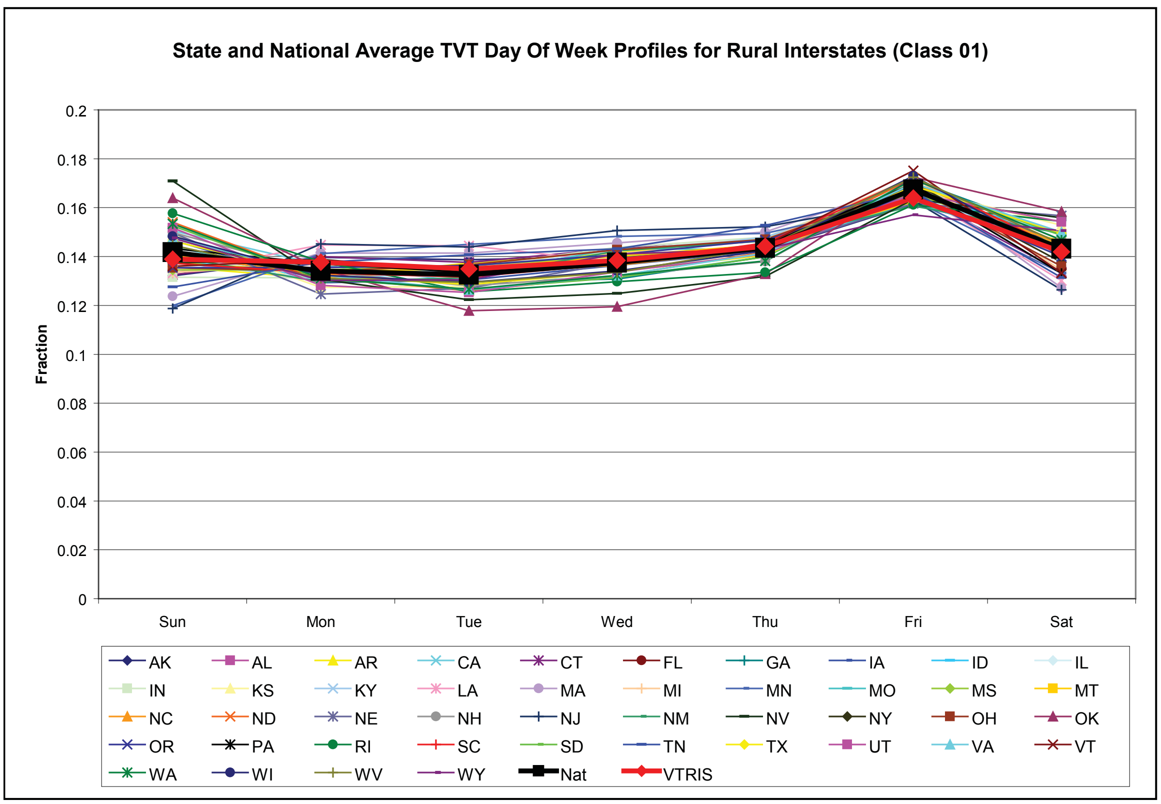

Figure D-9. State and national average TVT day of week profiles for rural interstates.

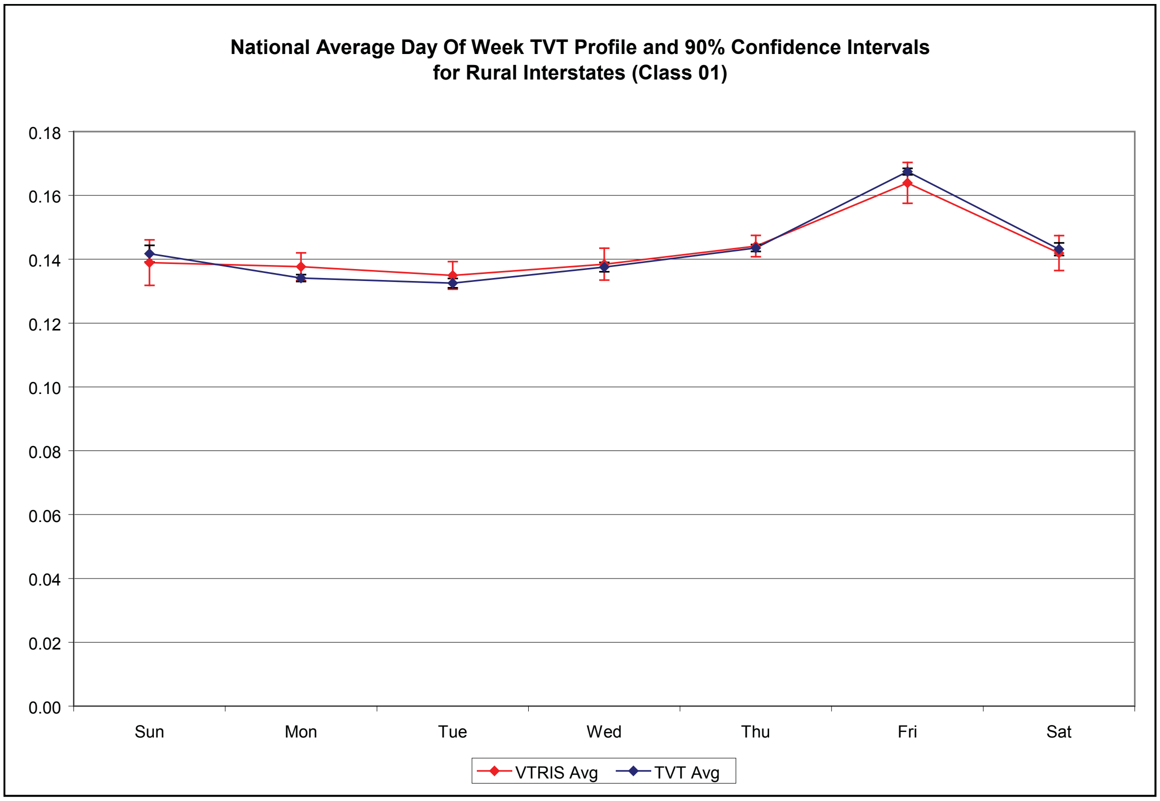

Figure D-10. National average TVT and VTRIS day of week temporal profile and uncertainty on rural interstates.

In general, the day of week temporal profiles are fairly consistent from state to state. Figure 11 displays the day of week temporal profiles for urban interstates by state with the national average in bold black and the VTRIS average in bold red. Again there is quite close agreement, both from state to state and with the VTRIS average.

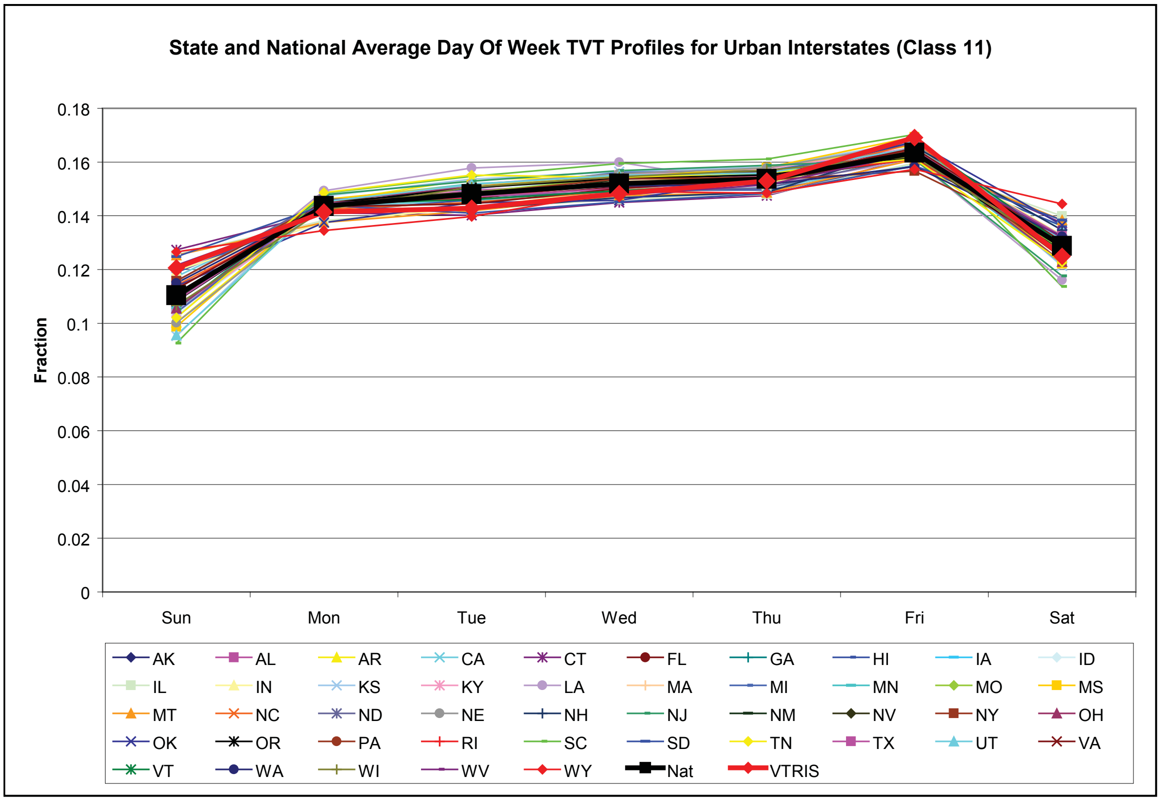

Figure D-11. National average and state temporal profiles by day of week.

There were two instances when the data from the state of Oklahoma was substantially different from all others in the daily profiles, presented in Figures D-12 and D-13 below.

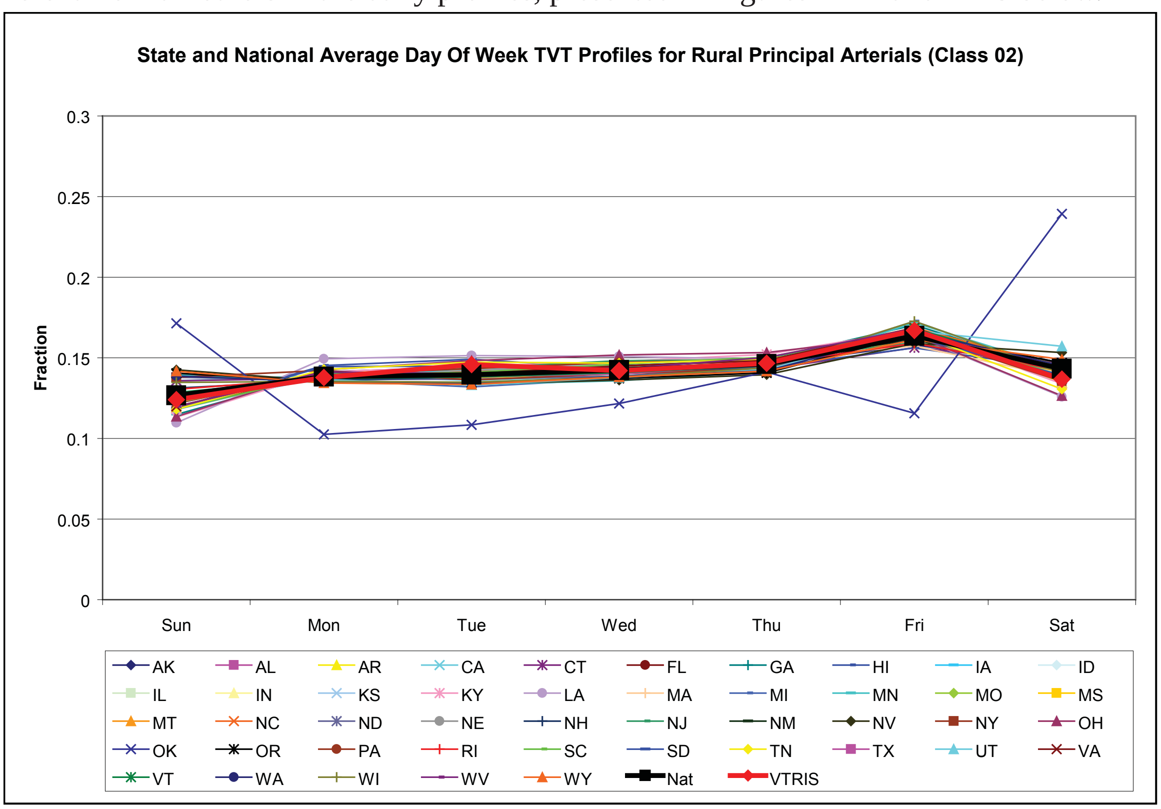

Figure D-12. Illustration of a different day of week temporal profile for Oklahoma on rural principal arterials.

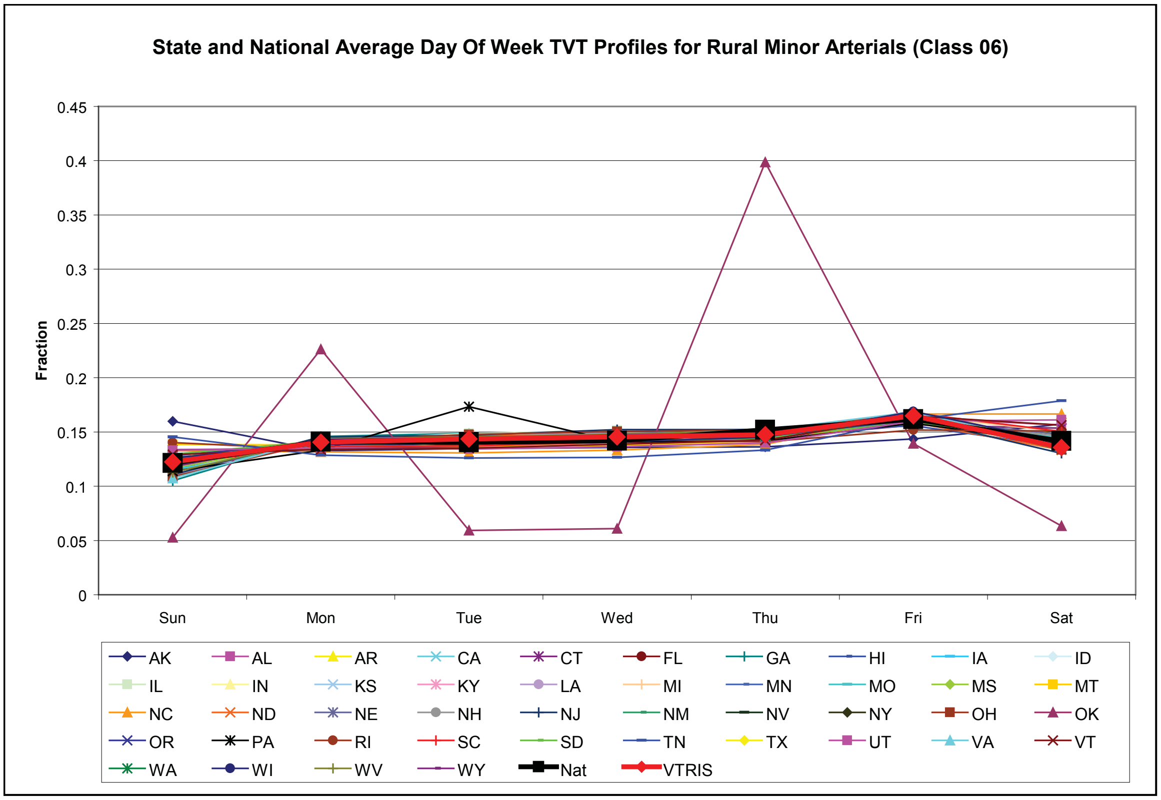

Figure D-13. Illustration of a different day of week temporal profile for Oklahoma for rural minor arterials.

Upon further investigation, we found that there were two sites, one at facility class 02 (urban principal arterials) and one at facility class 06 (rural minor arterials) that were both substantially different than the other sites. These sites also had substantially greater volumes than at the other sites. Figures D-14 and D-15 below illustrate the average daily volumes by site for these roadway types for Oklahoma. Note that these sites fulfilled the completeness criterion that there be a complete set of seven daily averages, but they do not exhibit typical weekly patterns. The greater volumes at these sites overly influence the state average profile. A further investigation into these two sites may reveal special circumstances that may justify removing them from the analysis.

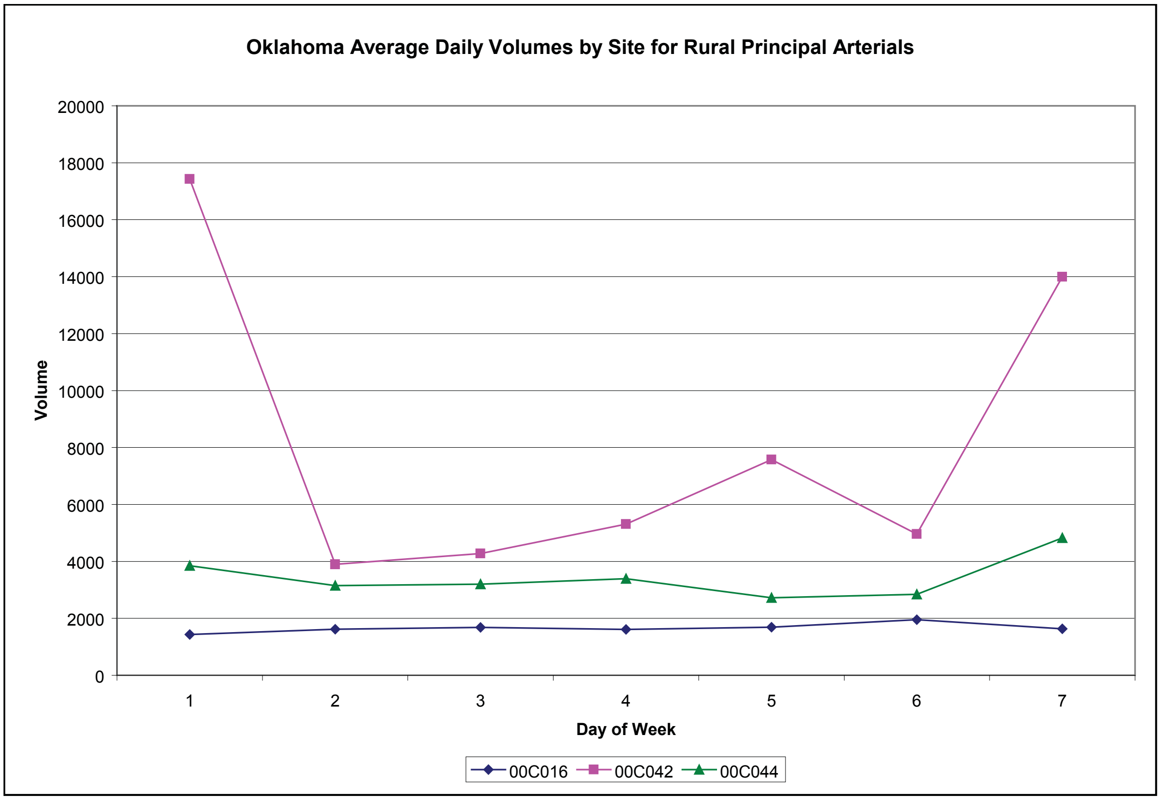

Figure D-14. Daily average volumes by site for Oklahoma, roadway class 02.

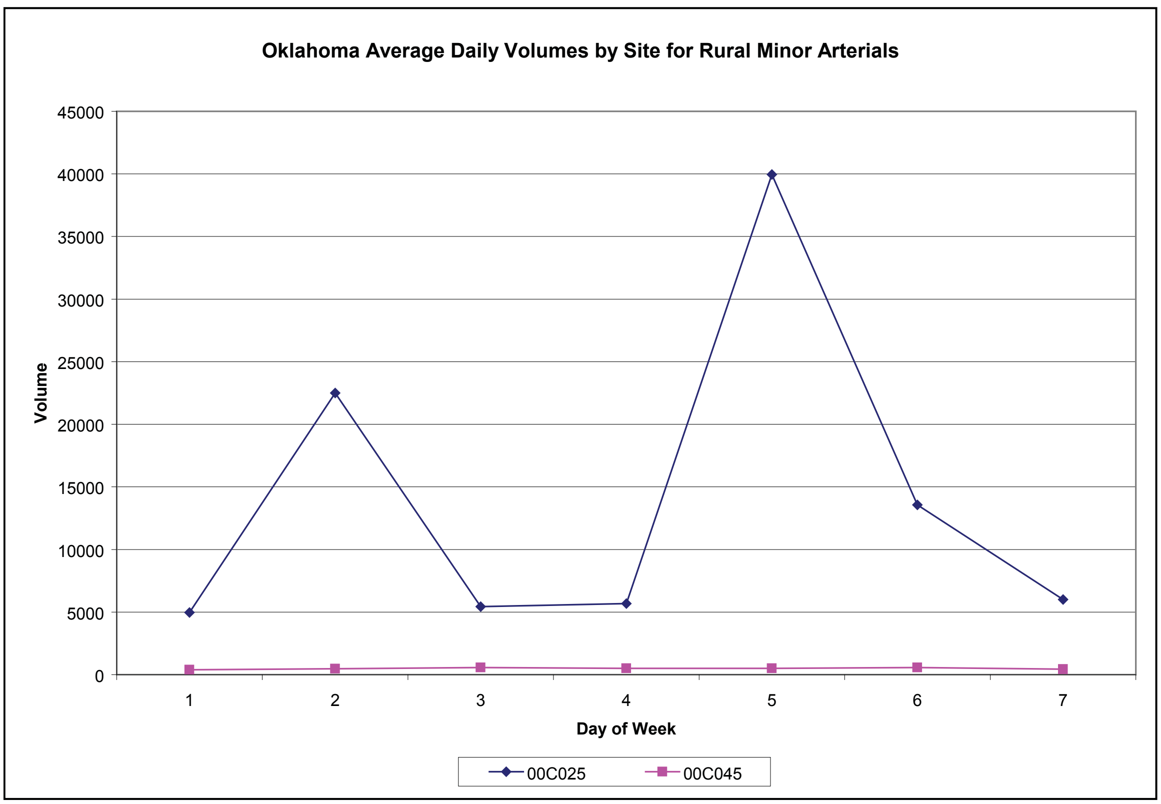

Figure D-15. Daily average volumes by site for Oklahoma, roadway class 06.

Monthly Profiles

The monthly temporal profiles also show the same general trend among the states with a slightly higher volume during summer months. Figure D-16 below illustrates the monthly profiles for rural interstates.

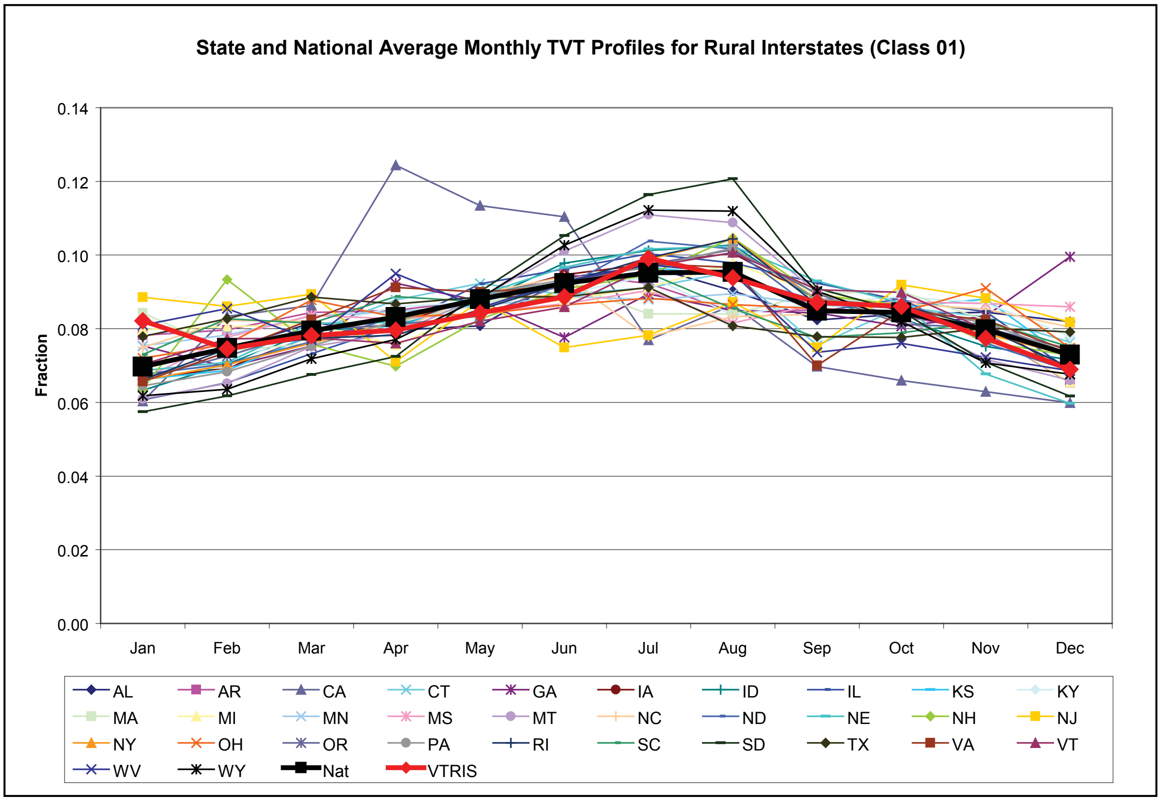

Figure D-16. State and national average TVT monthly profiles for rural interstates.

The comparison between the VTRIS and TVT summary profiles indicates small differences in the overall profile for this road type. The uncertainty ranges in Figure D-17 were calculated based on the state-to-state variability, and so may not include all of the uncertainty in the data ranging from site selection bias and other site-to-site variability.

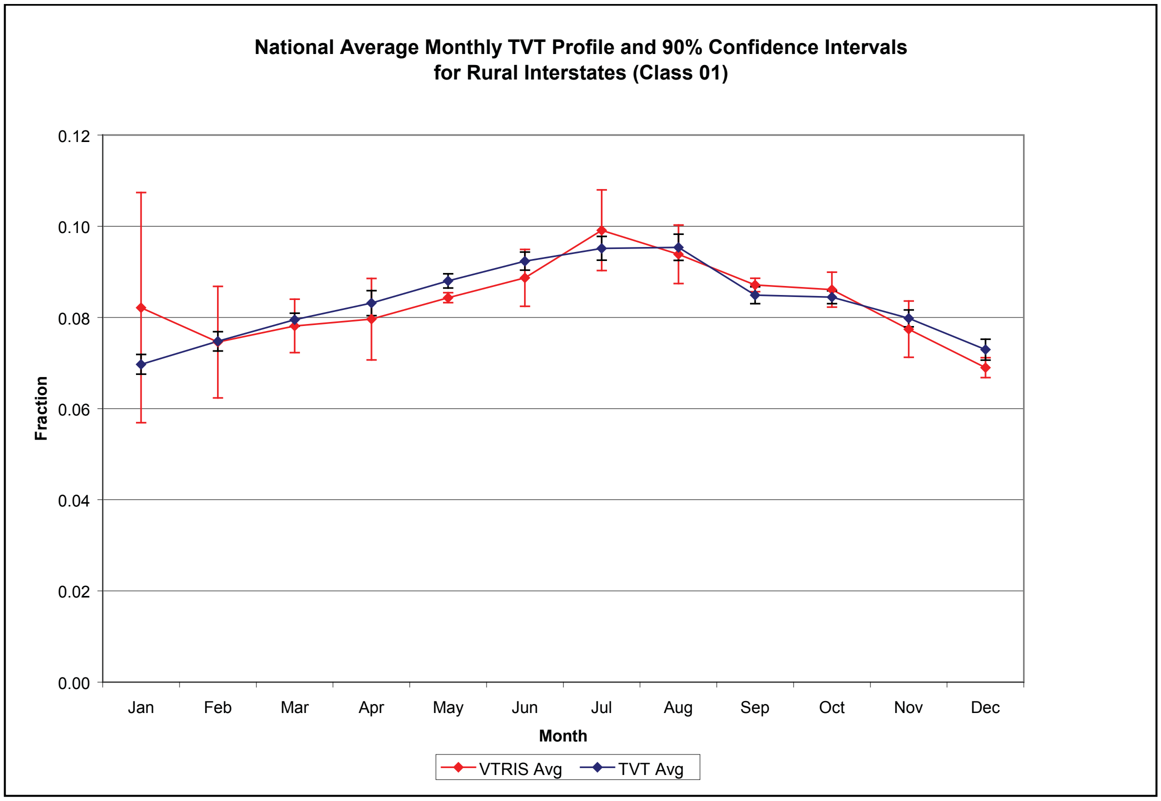

Figure D-17. National average TVT and VTRIS monthly temporal profile and uncertainty.

Summary results for other road types demonstrate that similar conclusions could be made for all road types. Smaller road types have fewer states providing data and therefore higher uncertainty levels. State-to-state variability in the TVT temporal profiles exists, but no consistent regional pattern could be discerned in the temporal profiles. Likewise, the VTRIS total volume temporal profiles were very similar to the TVT profiles for all road types indicating that VTRIS could be used for the vehicle mix fractions applied to the TVT total volume trends.