Estimation and Effects of Vehicle Mix on On-road Emissions Estimates

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ABSTRACT

Heavy-duty vehicles have been considered a large fraction of emissions from on-road vehicles, but have become of greater interest, as the light-duty emissions have been controlled to a greater extent than heavy-duty vehicles. Because a heavy-duty vehicle can produce 10 to 100 times the emissions (of NOx and PM emissions especially) of a light-duty vehicle, heavy-duty vehicle activity needs to be better understood and characterized. One of the key uncertainties with the use of MOBILE6 includes the fraction of heavy-duty vehicles on all types of roadways at all times of day. This paper describes the analysis of extensive automatic traffic recorder (ATR) data collected by State Departments of Transportation to investigate overall and temporal (hour of day, day of week, and month of year) patterns of vehicle mix by roadway type. A method is described and used to cross-reference the vehicle types identified by ATR data into MOBILE6 vehicle types and used to estimate fleet emissions. Comparisons will be provided that show the differences in the spatial and temporal emissions estimates by roadway type compared with estimates using the national average fleet mix.

INTRODUCTION

Heavy-duty vehicles are a large fraction of emissions from on-road vehicles, but have become of greater interest, as the light-duty emissions have been controlled to a greater extent than heavy-duty vehicles. Because a heavy-duty vehicle can produce 10 to 100 times the NOx and PM emissions of a light-duty vehicle, 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 different times of the day. Based on this work, the type of roadway and time of day affect the spatial and temporal variability in emissions through the relative fraction of different vehicle classes.

The Federal Highway Administration provided the databases analyzed in this project. (FHWA, 2004) These databases include vehicle counts and classifications from the Highway Performance Monitoring System (HPMS) and other special monitors using automated traffic recorders (ATR). These data are used to produce the Travel Volume Trends (TVT) reports. The Vehicle Travel Information System (VTRIS) dataset, also maintained by FHWA, includes HPMS and the results of data collection from weigh in motion (WIM) sensors, and other data sources (visual observation, weigh stations, and other special projects) to provide compiled vehicle counts by type of vehicle. Many of these databases are provided to FHWA from individual state submissions.

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 the estimated average number of axles).

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 mix by the roadway functional class identified in Table 2 though vehicle classification counters are usually sited on busy roadways so many of the road types less traveled do not have data. The vehicle count data consists of loop counter and pneumonic (tube counters). Typically there are approximately 20 to 50 counters per state, primarily for multi-lane interstate and highway links. For each site in all the data, the site characteristics required for the analysis include roadway functional classification, county, number of lanes, and number of lanes measured.

The primary goal of this work was to investigate the temporal effect on emissions from total traffic volume and vehicle mix by time of day and roadway types. Using the TVT and VTRIS data, this work investigated total vehicle volumes and vehicle mix as a national average by 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 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 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 multitrailer vehicles
12	6-axle multitrailer vehicles
13	7+ axle multi-trailer vehicles
14	Unclassified
15	Unclassifiable

The method used in this work for the cross-reference was a joint effort by EPA and FHWA to produce estimates for the EPA Trends report. The EPA method was used for this work because it has been vetted, but other methods exist and have been used for some regions of the country and are referenced below.

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, and these are shown in Table 3. The crosswalks for FHWA vehicle class #2 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 groupings as the summary shown. The reported vehicle class estimates both by FHWA class and uses the EPA crosswalk 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 to be used to apportion the vehicles by fuel type.

Table 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%		0%	0%
6,000 lbs or less LDGT1 & LDGT2	35.4%	98.3% (0.524% Class 2b)	24%	0%
6001 –10,000[2] LDGT3, LDGt4, Class 2b	12.3% (0% 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 in keeping with the latest MOVES2004 (EPA, 2005) documentation indicates that 24% of the Class 2b are diesel.

The definition in Table 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 was used to apportion between LDGT1 and LDGT2 or between LDGT3 and LDGT4. Another problem with the method described in Table 3 is that using the default vehicle mix for FHWA Class 2 with the better defined method for FHWA Class 3 will over allocate the vehicle counts to LDT and under allocate to LDV. To remedy this, the suggestion here is that the 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 3. Therefore the crosswalk for converting FHWA vehicle classes into MOBILE6 vehicle classes is described in Table 4.

Table 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 x FHWA Vehicle Class 3
LDT1	0.0007	0.072	0.082 x FHWA Vehicle Class 2 + 0.983 x 0.082 x FHWA Vehicle Class 3
LDT2	0.0007	0.238	0.272 x FHWA Vehicle Class 2 + 0.983 x 0.272 x FHWA Vehicle Class 3
LDT3	0.0138	0.074	0.084 x FHWA Vehicle Class 2 + 0.983 x 0.084 x FHWA Vehicle Class 3
LDT4	0.0138	0.034	0.039 x FHWA Vehicle Class 2 + 0.983 x 0.039 x FHWA Vehicle Class 3
HDV2B	0.2414	0.038	8% of 6.6% of FHWA Class 3 + See Table 3 for other FHWA Classes
HDV3	0.7264	0.004	See Table 3
HDV4	0.8307	0.003	See Table 3
HDV5	0.4906	0.002	See Table 3
HDV6	0.7075	0.008	See Table 3
HDV7	0.8882	0.010	See Table 3
HDV8A	0.9996	0.011	See Table 3
HDV8B	1.0000	0.038	See Table 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.

The diesel fraction was 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 5. The diesel fractions were derived from EPA default information provided by EPA (2004).

Table 5. Converting MOBILE6 vehicle types to MOBILE5 vehicle types.

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

Applying this method for the 2002 in-use resulted in the cross reference between FHWA and MOBILE6 and MOBILE5 vehicle types. This cross-reference was used to convert FHWA vehicle class counts into MOBILE vehicle types. EPA estimates of diesel fraction and default vehicle mix change from one in-use year to the next, so this cross-reference is only valid for 2002 estimates. The result of the cross-reference method was then produced for 2002 for MOBILE6 and MOBILE5 vehicle type descriptions as shown in Tables 6 and 7.

Table 6. MOBILE6 vehicle type cross-reference estimate for 2002.

Veh Type	Diesel Fraction	Default Mix	FHWA Vehicle Type												
			1	2	3	4	5	6	7	8	9	10	11	12	13
LDV	0.002	0.459	0.000	0.523	0.514	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LDT1	0.001	0.072	0.000	0.082	0.080	0.000	0.056	0.056	0.056	0.000	0.000	0.000	0.000	0.000	0.000
LDT2	0.001	0.238	0.000	0.272	0.267	0.000	0.185	0.185	0.185	0.000	0.000	0.000	0.000	0.000	0.000
LDT3	0.014	0.074	0.000	0.078	0.083	0.000	0.135	0.135	0.135	0.005	0.005	0.005	0.005	0.005	0.005
LDT4	0.014	0.034	0.000	0.036	0.038	0.000	0.062	0.062	0.062	0.002	0.002	0.002	0.002	0.002	0.002
HDV2B	0.241	0.038	0.000	0.010	0.005	0.000	0.017	0.017	0.017	0.001	0.001	0.001	0.001	0.001	0.001
HDV3	0.726	0.004	0.000	0.000	0.004	0.000	0.121	0.121	0.121	0.006	0.006	0.006	0.006	0.006	0.006
HDV4	0.831	0.003	0.000	0.000	0.001	0.000	0.050	0.050	0.050	0.007	0.007	0.007	0.007	0.007	0.007
HDV5	0.491	0.002	0.000	0.000	0.001	0.000	0.048	0.048	0.048	0.006	0.006	0.006	0.006	0.006	0.006
HDV6	0.707	0.008	0.000	0.000	0.002	0.000	0.122	0.122	0.122	0.033	0.033	0.033	0.033	0.033	0.033
HDV7	0.888	0.010	0.000	0.000	0.001	0.000	0.068	0.068	0.068	0.037	0.037	0.037	0.037	0.037	0.037
HDV8A	1.000	0.011	0.000	0.000	0.001	0.000	0.111	0.111	0.111	0.282	0.282	0.282	0.282	0.282	0.282
HDV8B	1.000	0.038	0.000	0.000	0.000	0.000	0.025	0.025	0.025	0.621	0.621	0.621	0.621	0.621	0.621
HDBS	0.750	0.002	0.000	0.000	0.000	0.677	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HDBT	1.000	0.001	0.000	0.000	0.000	0.323	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MC	0.000	0.006	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
All		1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 7. MOBILE5 vehicle type cross-reference estimate for 2002.

Veh Type	Default Mix	FHWA Vehicle Type												
		1	2	3	4	5	6	7	8	9	10	11	12	13
LDGV	0.458	0.000	0.522	0.514	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LDGT1	0.310	0.000	0.353	0.348	0.000	0.241	0.241	0.241	0.000	0.000	0.000	0.000	0.000	0.000
LDGT2	0.107	0.000	0.112	0.120	0.000	0.194	0.194	0.194	0.007	0.007	0.007	0.007	0.007	0.007
HDGV	0.036	0.000	0.007	0.007	0.169	0.123	0.123	0.123	0.020	0.020	0.020	0.020	0.020	0.020
LDDV	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LDDT	0.002	0.000	0.002	0.002	0.000	0.003	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000
HDDV	0.082	0.000	0.002	0.010	0.831	0.440	0.440	0.440	0.972	0.972	0.972	0.972	0.972	0.972
MC	0.006	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
All	1	1	1	1	1	1	1	1	1	1	1	1	1	1

At least two alternative methods have been suggested to cross reference FHWA categories with MOBILE classes of vehicle types. Georgia Tech Institute (Yoon, et al., 2004) and Texas Transportation Institute (TCEQ, 2004) have each proposed a method to cross reference vehicle count information from automatic traffic recorder data to MOBILE vehicle classifications. These methods either used data that is generally not available, or require local information (registrations primarily) for specific regions.

Total Traffic Volume

To understand how the vehicle mix estimates can affect emissions estimates on a temporal and spatial basis, one must first understand traffic volume trends. The Traffic Volume Trends (TVT) data can be used to understand typical trends in activity by roadway type. In this work the 2000 TVT data were averaged as hourly traffic volume counts. A sample of the 2000 results for rural and urban road types is shown in Figures 1 and 2. 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. Overall weekday and weekend day temporal profiles remain constant amongst themselves with less variability day to day.

Figure 1. National average weekly total traffic volume for rural roads.

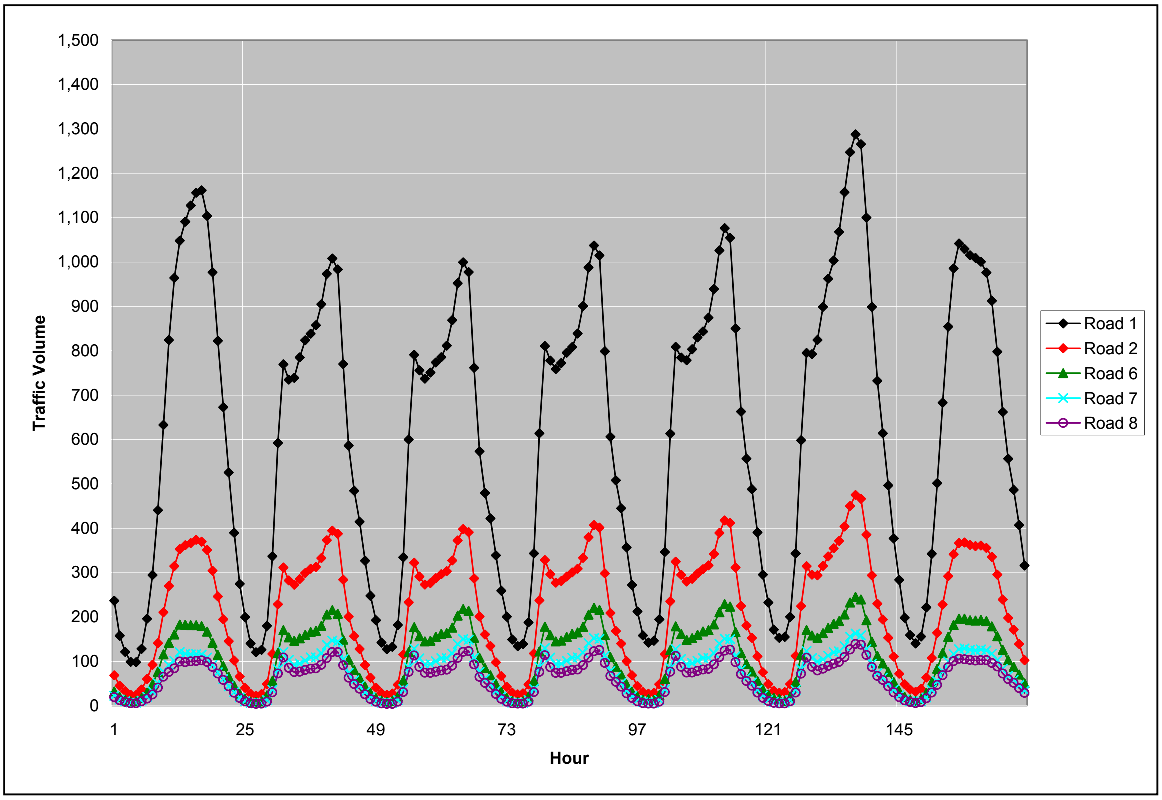
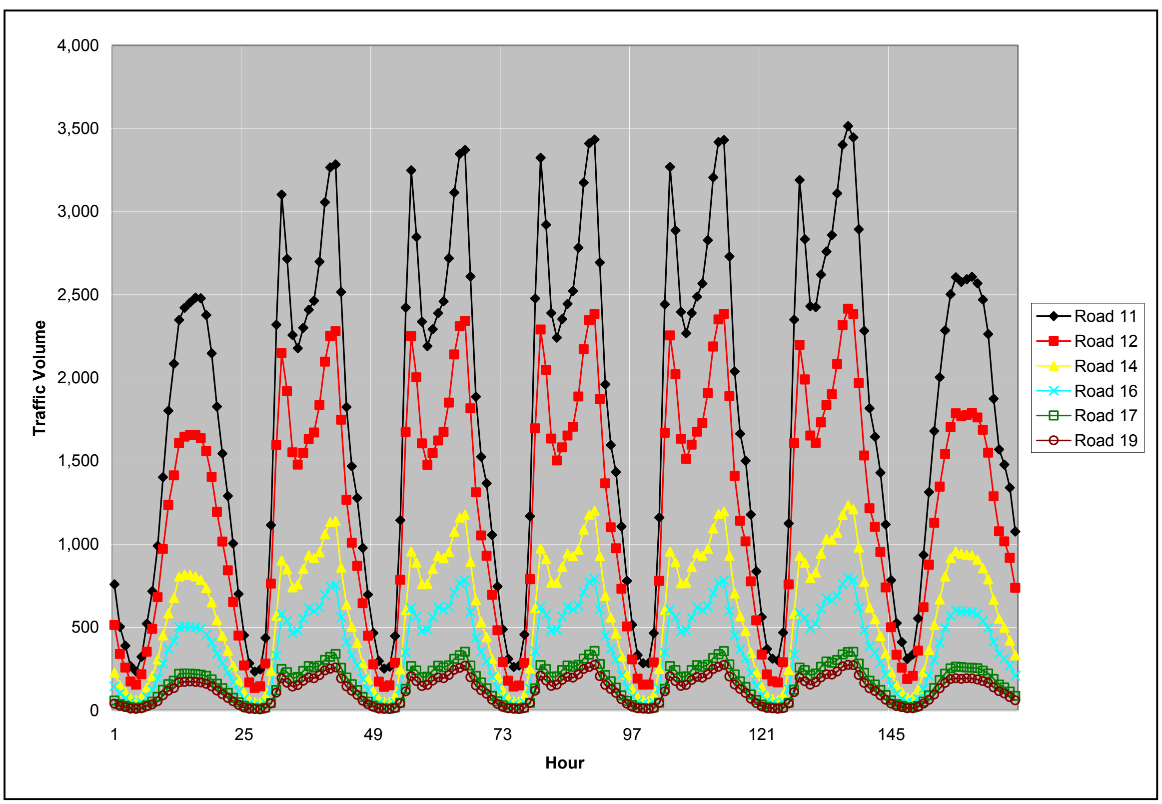


Figure 2. National average weekly total traffic volume for urban roads.



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 averaging across sites. The steps followed in processing the class count 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. Average roadway counts were calculated for each roadway function class, month, day of week, and hour of the day.

Vehicle Type Fractions (Mix)

For this work, ENVIRON used the VTRIS database which provides vehicle classification from automatic traffic recorder (ATR) in FHWA vehicle classes from data submitted by several states across the U.S. Because the FHWA classes do not necessarily match the MOBILE vehicle classes, ENVIRON adapted an EPA and FHWA method described in the Introduction to cross-reference the FHWA vehicle class into MOBILE vehicle types. 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 were shortened to the eight MOBILE5 vehicle types for clarity, but the method could be used with 28 MOBILE6 vehicle types for emission estimation.

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 averaging 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.

In developing national vehicle counts/VMT/vehicle mix fraction estimates, it was understood that any regional differences in the data would be explicitly included in the average. However given the potential for regional differences, as demonstrated in Table 8, higher fractions of heavy-duty vehicles were found on rural (FHWA road types 01, 02, and 06) and urban (FHWA road types 11, 14,and 17) road types. Also, higher fractions of heavy-duty vehicles are found on higher volume (FHWA road types 01 or 11) compared to lower volume roads within rural and urban types. Only 6 road types were presented here to demonstrate the effect for simplicity and clarity and to combine with national average vehicle travel as presented in the TVT data. Table 8 also shows sample emission rates by vehicle type for rural interstates (other facility types differ from these mainly by only the average speed adjustment in MOBILE6) demonstrating that HDDV is the primary vehicle type affect estimates of NOx and PM emissions overall.

Table 8. Average vehicle mix and example 2002 rural interstate emissions rates by road type.

Road	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
01	0.410	0.288	0.099	0.015	0.001	0.002	0.178	0.008
02	0.447	0.315	0.109	0.014	0.001	0.002	0.110	0.002
06	0.466	0.330	0.114	0.015	0.001	0.002	0.066	0.008
11	0.462	0.323	0.110	0.013	0.001	0.002	0.084	0.005
14	0.476	0.333	0.113	0.013	0.001	0.002	0.048	0.014
17	0.509	0.347	0.111	0.009	0.001	0.002	0.021	0.000
Average	0.467	0.326	0.110	0.013	0.001	0.002	0.073	0.008
VOC (g/mi.)	1.243	1.45	2.295	1.488	0.578	0.774	0.449	1.84
NOx (g/mi.)	1.203	1.424	1.775	5.789	1.926	1.989	17.498	1.44
PM (g/mi.)	0.0074	0.0099	0.0165	0.083	0.2352	0.1967	0.4181	0.0213

The rural and urban vehicle mixes affect the spatial resolution of emissions when compared to one regional average mix for all roadways. To demonstrate this effect, national emissions were determined using the fraction of traffic and vehicle speed along each road type the following typical estimates shown in Table 9 derived from TVT data.

Table 9. VMT by road type (TVT, November 2004).

FHWA Road	Road Type	VMT Fraction	MOBILE Road	Speed
1	Rural Interstate	0.093	Freeway	60
2	Rural Other Arterial	0.144	Arterial	45
6	Other Rural	0.138	Arterial	30
11	Urban Interstate	0.150	Freeway	45
14	Urban Other Arterial	0.337	Arterial	20
17	Other Urban	0.138	Arterial	20

Applying emissions by vehicle type for 2002 (from runs of MOBILE6 using default input files), the vehicle mix from Table 8, and VMT fraction found in Table 9 to each road type, the emissions were calculated and normalized region-wide in Table 10. It is clear from Table 10 that higher NOx and PM emissions would be found in rural areas (road types 01, 02, and 06) and higher volume road types within rural and urban road groupings. VOC emissions do not show much dislocation due to vehicle mix trends. The relative fraction of NOx and PM emissions on rural freeways for instance would practically double when using the appropriate vehicle mix for that roadway, while urban surface streets show much lower NOx and PM emissions with the appropriate vehicle mix. This analysis implicitly does not change the overall VMT or overall emissions national, just the roadway type apportionment.

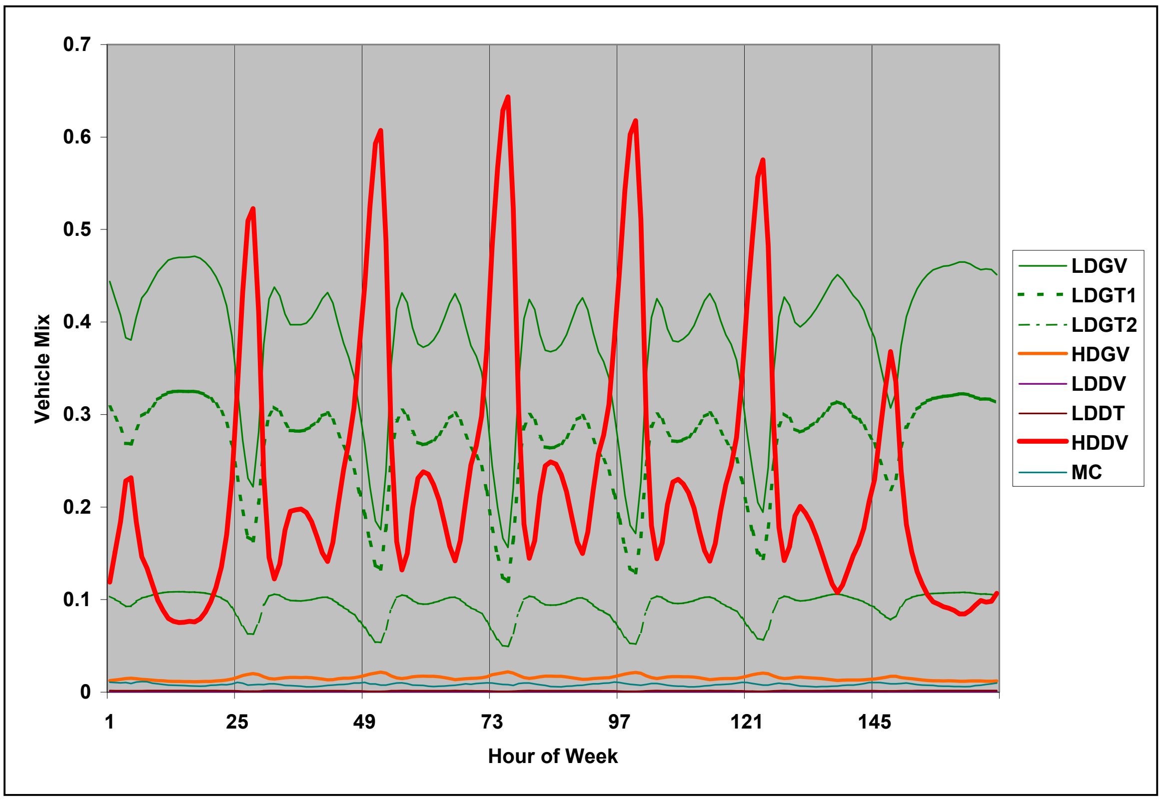
Table 10. Fraction of 2002 emissions by road type.

FHWA Road	One Average Regional Mix			Road Specific Mix		
	VOC	NOx	PM	VOC	NOx	PM
01	8%	10%	9%	7%	16%	19%
02	13%	15%	14%	12%	18%	20%
06	13%	13%	14%	14%	13%	13%
11	13%	14%	15%	13%	15%	17%
14	37%	34%	34%	38%	29%	25%
17	15%	14%	14%	15%	9%	7%
Rural	34%	38%	37%	33%	47%	51%
Urban	66%	62%	63%	67%	53%	49%

The vehicle mix was also found to depend upon a number of temporal factors including day of week and hour of day. Temporal variability of emissions has been an issue for several areas modeling air quality primarily for ozone formation, but it may also be a concern for particulate and carbon monoxide for some areas. Some areas include VMT variability but keep the vehicle mix constant throughout the day or by day of week. The finding of this work was that the temporal variability in vehicle mix is significant and would affect emission estimates by hour of day as well as by day of the week. Our estimates indicated very little variability in month-to-month vehicle mix, however some states have shown seasonal variability in vehicle mix (MTC 2004).

The vehicle class mix showed clear differences by hour of day and day of week, especially distinguishing between weekdays and weekend days. Figure 3 shows the hourly change in the vehicle mix throughout the average weekly activity for rural interstates. In this figure, it can be seen that Sunday (first day of week), Saturday, and weekdays are clearly different from one another. 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 midday peak in the mix of heavy-duty vehicles.

Figure 3. Vehicle mix on rural interstates (road type 01).



The biggest effect on emissions, especially NOx and PM, is the fraction of heavy-duty vehicles. In Figure 4, the HDDV mix is shown for each road type and shows that the weekly trend is mirrored in each road type averages. The overnight peak in HDDV means that the NOx and PM emissions will be higher overnight than most areas currently model. This is demonstrated in Figure 5, which shows the traffic volume for HDDV, VOC, NOx, and PM emissions on rural interstates (road type 01). The NOx and PM emissions clearly follow the HDDV traffic volume even though all vehicles were modeled for emissions. Figure 6 shows the alternative road type to rural freeways, lower volume urban surface streets, road type 17. The temporal trend is less clear for less traveled urban streets than for rural interstates, though the heavy-duty traffic is overall lower than the regional average.

Figure 4. HDDV mix for each road type.

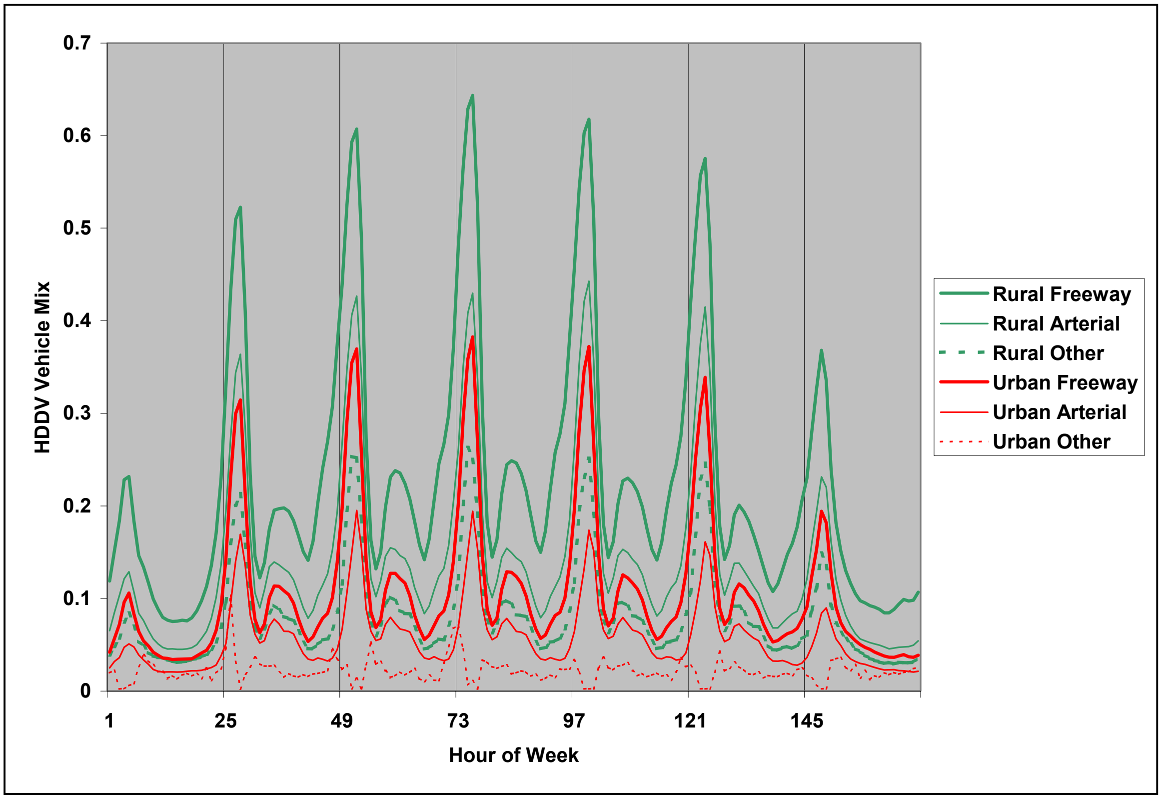


Figure 5. Hour of week change in (clockwise) HDDV traffic volume, VOC, PM, and NOx 2002 emissions for road 01, rural freeways.

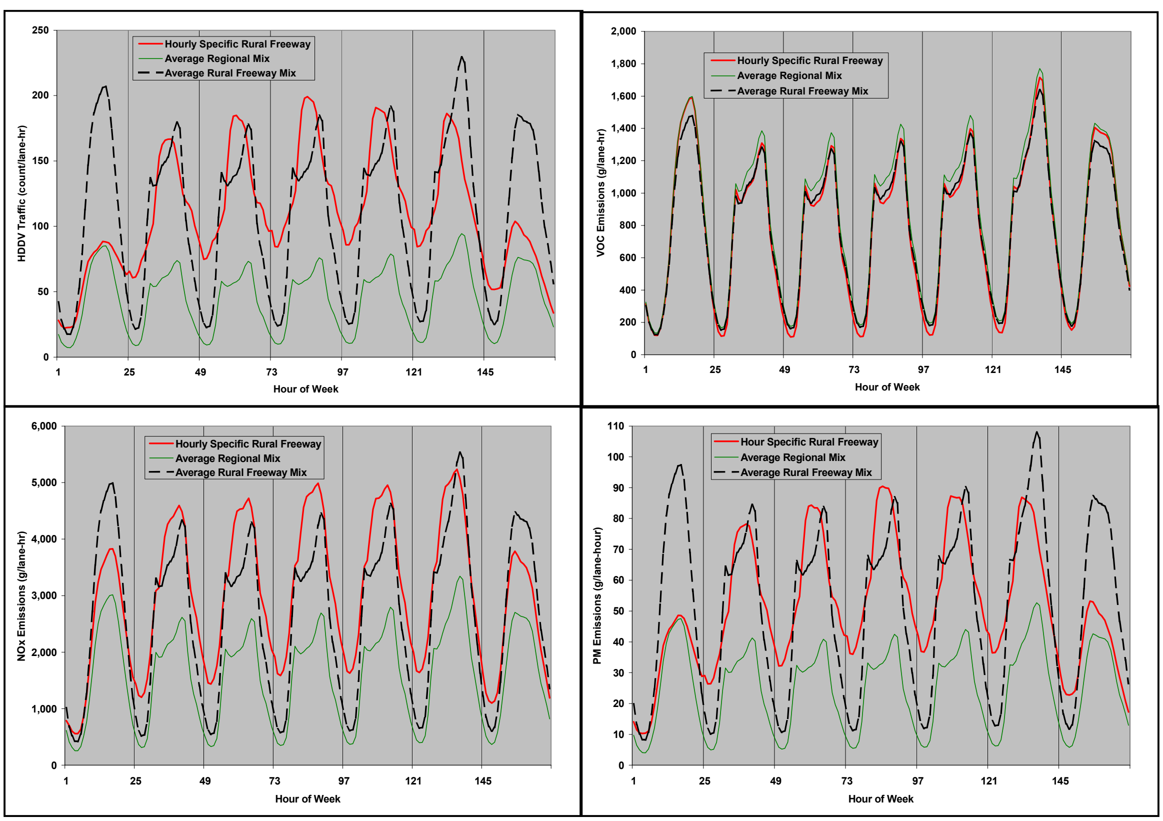
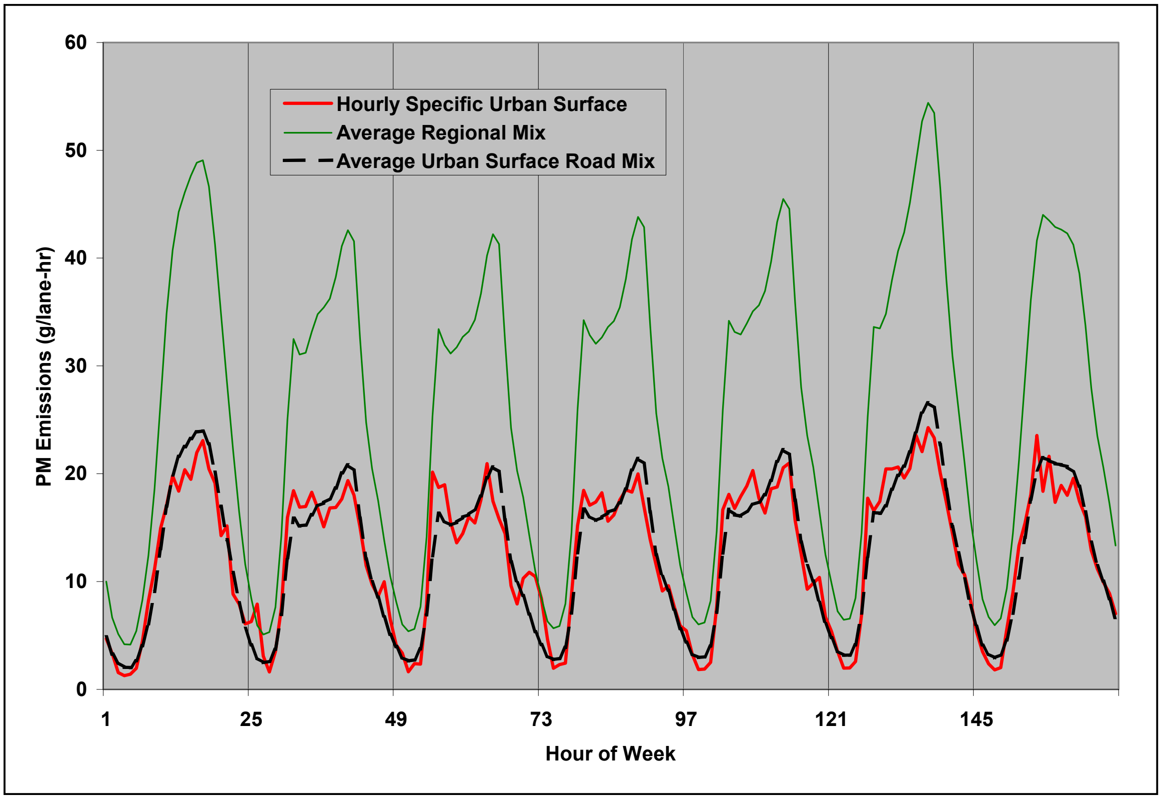


Figure 6. PM 2002 emissions for road type 17, urban surface roads.



CONCLUSIONS

The vehicle mix is a significant source of uncertainty for spatial and temporal distribution of on-road of NOx and PM emissions. At least for the immediate future, HDDV NOx and PM emissions rates will be in excess to other vehicle types, and so the vehicle mix of heavy and light-duty vehicles will affect the NOx and PM emission estimates.

Future work should include more investigation into the cross reference of FHWA vehicle classification to MOBILE6 vehicle types. Heavier vehicles (FHWA 5 – 13) might be better distinguished using vehicle weight data such as from weight-in-motion data combined with vehicle classification data. However, the actual vehicle weight does not necessarily group into the gross vehicle weigh ratings that EPA uses to distinguish vehicle types.

The site characteristics of the data disserve additional analysis to investigate any site selection bias. The choice of site will undoubtedly have an effect on the vehicle mix, such as whether the site is located primarily in a residential or industrial neighborhood. Some sites could be intentionally biased because the transportation agency was interested in the impact of specific facilities such as a port, rail intermodal, truck terminal, or other facilities with high levels of truck traffic.

REFERENCES

Brzezinski, D. 2004. Modeling tool to estimate national average VMT mix by in-use month and year. Environmental Protection Agency, September, *personal communication*.

Beardsley, M. 2003. Environmental Protection Agency, September, *personal communication*.

EPA (2005), "MOVES2004 Highway Vehicle Population and Activity Data," EPA420-P-04-020 December 2004.

FHWA 2004. Traffic Volume Trends (TVT), Vehicle Travel Information System (VTRIS), http://www.fhwa.dot.gov/policy/ohpi/travel/index.htm.

MTC 2004. "Evaluation of Different Methods to Calculate Heavy-Truck VMT." Performed by the Midwest Transportation Consortium for U.S Department of Transportation, December.

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.

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 conference.

KEY WORDS

On-road, Heavy-duty, Emissions, Vehicle Mix, and Vehicle Classification.

ACKNOWLEDGEMENTS

ENVIRON acknowledges EPA funding, and help from EPA staff, Sue Kimbrough and Dave Brzezinski, in producing this work.