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Characteristics and Emissions of Heavy-Duty Vehicles in Tennessee Under the MOBILE6 Model

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Heavy-duty vehicle (HDV) classifications used for modeling emissions in the MOBILE6 model have been expanded from 2 classifications in MOBILE5 to 16 classifications in MOBILE6. The new classifications are based on vehicle weight and fuel used (i.e., gasoline or diesel). The heavier vehicles have higher emissions, so it is important to use correct vehicle weight distributions. Tennessee's HDV registration data show a distribution very similar to the national defaults, but with more vehicles in the heaviest weight category (HDV8B). More than 50% of Tennessee's HDVs fall in the lightest vehicle category (HDV2B). The biggest difference in truck characteristics in Tennessee versus national defaults in MOBILE6 is the higher HDV fraction on Tennessee rural Interstates. Also, the ratio of single-unit trucks to trailer trucks varies considerably by facility type. The emissions of volatile organic compounds and carbon monoxide per mile of travel of gasoline-fueled single-unit trucks can be 2.5 to 5 times higher than those of heavy-duty diesel trailer trucks. The emissions of nitrogen oxides per mile of travel of diesel-fueled tractor–trailer trucks can be five times higher than those of gasoline-fueled single-unit trucks. For these reasons it is important to accurately characterize the HDV fleet. The characteristics of the Tennessee HDV fleet are compared with national defaults used in MOBILE6, and a new scheme for classifying vehicles by road type is presented.

Heavy-duty vehicles (HDVs) contribute a major portion of mobile-source air pollution emissions, especially nitrogen oxides (NO_x). To accurately calculate mobile-source emissions, detailed information is needed concerning the HDV fleet and the vehicle miles traveled (VMT) that are attributable to HDVs. Previous studies have suggested methods to improve transportation data needed for estimating emissions, emphasizing the role of HDVs (*1*). This paper summarizes initial efforts made to characterize the HDV fleet in Tennessee for the purpose of improving a statewide inventory of mobile-source emissions. Mobile-source emissions are calculated using the new MOBILE6 emissions model (*2*), which uses a different and more complicated scheme to predict HDV emissions and requires more input data than the MOBILE5 model.

EMISSIONS AND NEW VEHICLE CLASSIFICATION SCHEME

Under the MOBILE5 emissions model, there were eight vehicle classifications, only two of which were HDVs: heavy-duty gasoline vehicles (HDGVs) and heavy-duty diesel vehicles (HDDVs). With MOBILE6, the U.S. Environmental Protection Agency (EPA) has provided for much more sensitivity in modeling mobile-source emissions by expanding the number of vehicle types to 28—of which 19 are HDV types. The HDVs include eight classes of HDGVs, eight classes of HDDVs, and three classes of buses (gasoline and diesel). Table 1 lists the class designations and definitions.

The bases for distinguishing different vehicles are the body type, fuel used, and the gross vehicle weight rating (GVWR) based on the manufacturer's specifications. GVWR is the maximum recommended loaded-vehicle weight, including passengers and cargo. Emissions generally increase with increasing GVWR-based vehicle weight. This effect is illustrated for NO_x emissions in Figure 1, which shows emissions calculated using MOBILE6 for calendar year 2000 at a speed of 35 mph on arterials. Increasingly heavier gasoline trucks are shown as Classes 6 through 12 and increasingly heavier diesel trucks as Classes 16 through 23. The NO_x emissions of the heaviest diesel truck (Class 23) are five times higher than those of the lightest heavy-duty diesel truck (Class 16). Classes 25 to 27 are gasoline and diesel buses, which also show emissions levels higher than most other vehicles.

Figures 2 and 3 exhibit similar patterns for emissions of carbon monoxide (CO) and volatile organic compounds (VOCs) except that the highest emissions are from gasoline-fueled HDVs. The highest CO and VOC emissions factors are for gasoline-fueled buses (Class 25). Diesel-fueled vehicles consistently have lower emissions factors for CO and VOCs than gasoline-fueled vehicles, even when the heavy diesel-fueled vehicles are compared with light-duty gasoline-fueled vehicles.

HOW SPEED AFFECTS HDV EMISSIONS

HDDVs have a significantly higher emissions factor for NO_x at higher speeds. NO_x emissions factors for fleet-average HDDVs are 60% to 70% higher at 65 mph than at 35 mph, as illustrated in Figure 4. Figure 4 also shows the two speed-adjustment factors used in MOBILE6 for two roadway types. According to MOBILE6, the NO_x emissions of HDDVs are 33% higher when traveling at 35 mph on freeways than when traveling at the same speed on arterials.

Higher emissions factors for HDDVs on Interstates versus arterials are predicted in MOBILE6 to account for the higher NO_x emissions that occur from HDDVs with illegal "defeat devices" used to control engine air-to-fuel ratios. In October 1998, EPA fined seven companies that sold 1.3 million trucks with these devices, which improve fuel economy at high speeds but increase NO_x emissions

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TABLE 1 EPA Vehicle Classifications Used in the MOBILE6 Model

Class	Definition
1 LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2 LDGT1	Light-Duty Gasoline Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
3 LDGT2	Light-Duty Gas Trucks 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
4 LDGT3	Light Duty Gas Trucks 3 (6,001-8500 lbs. GVWR, 0-3750 lbs. LVW)
5 LDGT4	Light Duty Gas Trucks 4 (6,001-8500 lbs. GVWR, 3751-5750 lbs. LVW)
6 HDGV2B	Class 2b Heavy Duty Gasoline Vehicles (8501-10,000 lbs. GVWR)
7 HDGV3	Class 3 Heavy Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
8 HDGV4	Class 4 Heavy Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
9 HDGV5	Class 5 Heavy Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
10 HDGV6	Class 6 Heavy Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
11 HDGV7	Class 7 Heavy Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
12 HDGV8A	Class 8a Heavy Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
13 HDGV8B	Class 8b Heavy Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14 LDDV	Light Duty Diesel Vehicles (Passenger Cars)
15 LDDT12	Light Duty Diesel Trucks 1 (0-6,000 lbs. GVWR)
16 HDDV2B	Class 2b Heavy Duty Diesel Vehicles (8501-10,000 lbs. GVWR)
17 HDDV3	Class 3 Heavy Duty Diesel Vehicles (10,001-14,000 lbs. GVWR)
18 HDDV4	Class 4 Heavy Duty Diesel Vehicles (14,001-16,000 lbs. GVWR)
19 HDDV5	Class 5 Heavy Duty Diesel Vehicles (16,001-19,500 lbs. GVWR)
20 HDDV6	Class 6 Heavy Duty Diesel Vehicles (19,501-26,000 lbs. GVWR)
21 HDDV7	Class 7 Heavy Duty Diesel Vehicles (26,001-33,000 lbs. GVWR)
22 HDDV8A	Class 8a Heavy Duty Diesel Vehicles (33,001-60,000 lbs. GVWR)
23 HDDV8B	Class 8b Heavy Duty Diesel Vehicles (>60,000 lbs. GVWR)
24 MC	Motorcycles (Gasoline)
25 HDGB	Gasoline Busses (School, Transit and Urban)
26 HDDBT	Diesel Transit and Urban Busses
27 HDDBS	Diesel School Busses
28 LDDT34	Light Duty Diesel Trucks 1 (6,001-8500 lbs. GVWR)

above allowable levels (*3*). These devices are being phased out, and this difference in NO_x emissions factors for HDDVs on freeways and arterials will fade in future years. In HDGVs, NO_x emissions increase only 23% from a travel speed of 35 mph to 65 mph. Unlike for HDDVs, speed corrections for HDGV emissions factors are the same for arterials and Interstates.

HDV FRACTION OF VMT

Because HDV emissions are a significant portion of total mobile-source emissions—typically more than 50% of the total fleet emissions of NO_x—it is important to characterize the HDV portion of the fleet as accurately as possible. To compare the Tennessee truck fleet with the default values used in MOBILE6, several sources of data were analyzed. First, state vehicle registration data were evaluated and compared with the default data for the national average truck fleet used as the MOBILE6 vehicle type mix. Of course, the actual vehicles on Tennessee roadways also include many vehicles registered out of state and not included in the Tennessee vehicle registration database.

Tennessee vehicle registration records include vehicle body style, ownership type, and gross vehicle weight in 11 weight categories (from 9,000 to 80,000 lb). The 11 state weight categories can be grouped to match fairly closely with the 8 vehicle weight categories used in MOBILE6. A total of 235,000 HDVs were registered in

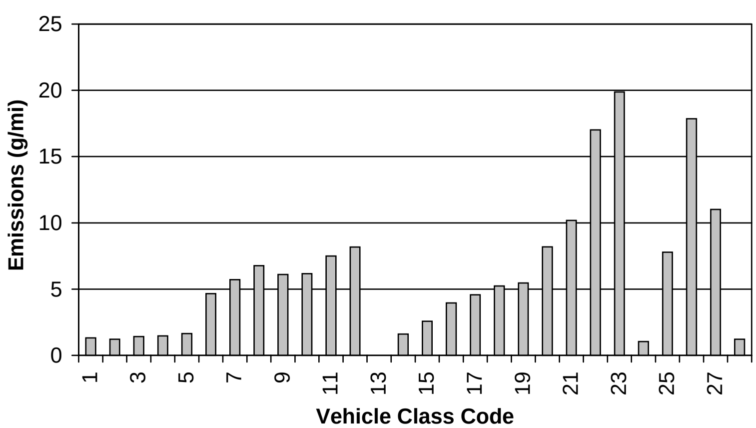

FIGURE 1 MOBILE6 NO_x emissions factors by vehicle type on arterials only, at 35 mph, 2000.

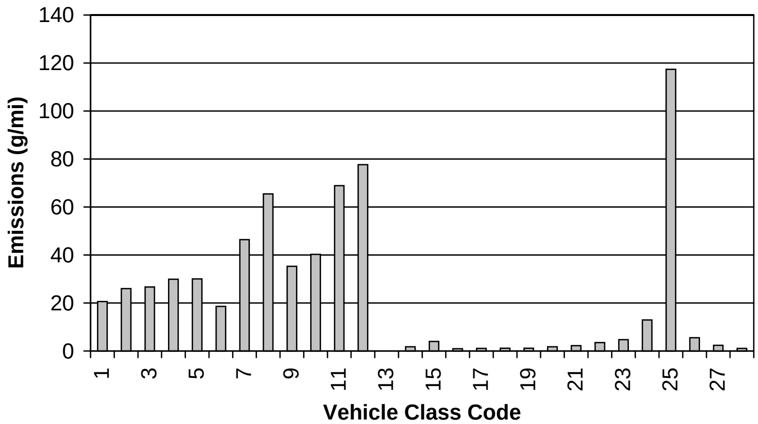

FIGURE 2 MOBILE6 CO emissions factors by vehicle type on arterials only, at 35 mph, 2000.

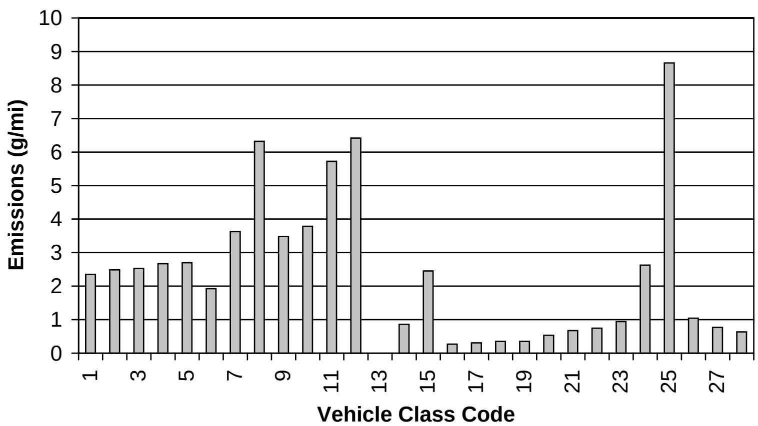

FIGURE 3 MOBILE6 VOC emissions factors by vehicle type on arterials only, at 35 mph, 2000.

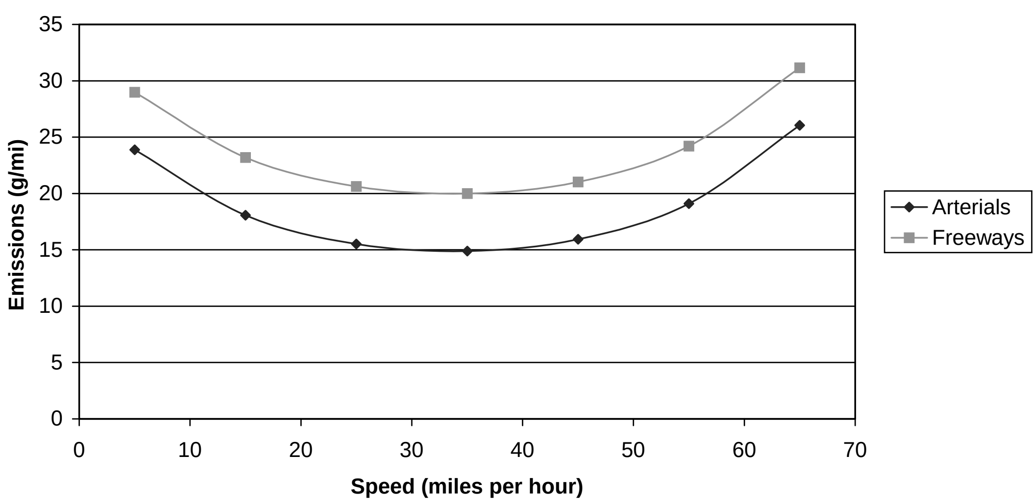

FIGURE 4 NO_x emissions factors for HDDVs versus speed: MOBILE6 2000 defaults.

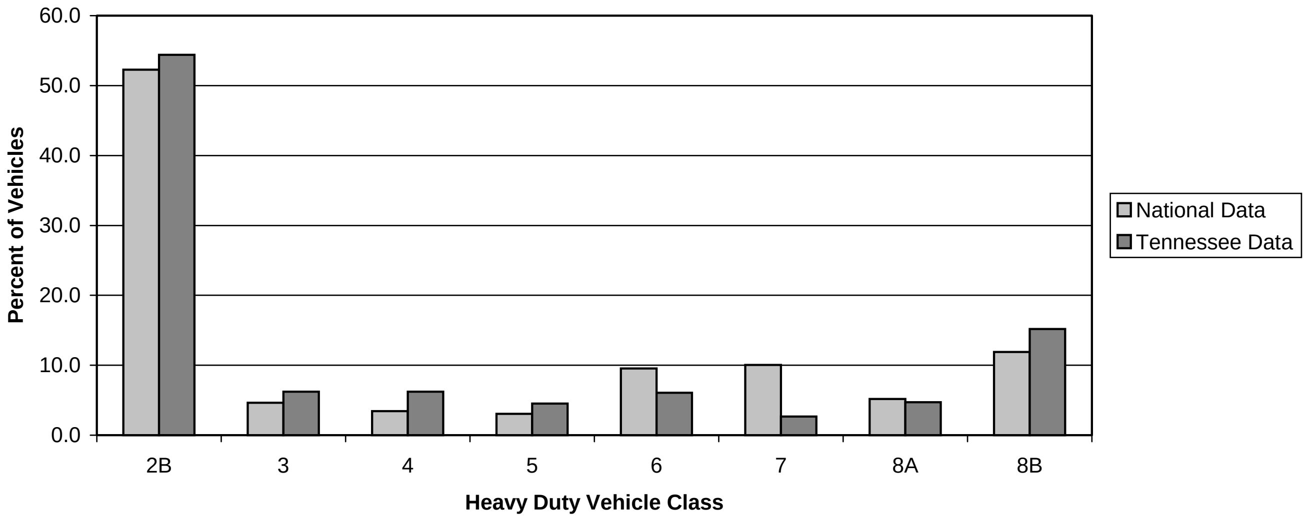

FIGURE 5 HDV mix by vehicle count: percent by class.

Tennessee in 2000, equal to 1.7% of the national HDV fleet of 13.6 million vehicles. Figure 5 illustrates the proportion of vehicles in each weight category registered in Tennessee. The proportion of each vehicle type based on the national inventory used to develop the MOBILE6 default VMT mix is also shown (*4*).

As illustrated in Figure 5, most HDVs fall in the two extreme weight ranges: 54% of HDVs in Tennessee and 52% nationally are in the lowest heavy-duty weight category, HDV2B (8,501 to 10,000 lb). Only 15% of HDVs in Tennessee and 12% nationally are in the highest heavy-duty weight category, HDV8B (<60,000 lb). The remaining 30% of HDVs in Tennessee are spread over the other six weight categories, with 3% to 6% in each. A similar pattern exists for the national HDV fleet.

Although the largest percentage of HDVs in Tennessee are in the lightest weight category and have the lowest emissions, the significance of these vehicles changes when one considers the annual mileage accumulation rates (AMARs) for each vehicle type. Table 2 lists age-weighted annual mileage and the first-year mileage used in MOBILE6 for each vehicle type. While gas-fueled HDV2Bs are driven an average of 13,000 mi per year, diesel-fueled HDV8Bs are driven an average of 58,000 mi per year. One-year-old diesel HDV8Bs (such as tractor–trailer combinations) are typically driven 125,000 mi per year or more, and tractor–trailers with two drivers available at all times may be driven 250,000 mi per year. The average of 58,000 mi per year includes all trucks, many of which are old and are driven less than new vehicles.

The higher mileage driven by HDV8Bs means that their contribution to the HDV emissions inventory is greater than that of HDV2Bs. In fact, HDV8Bs contribute the largest annual fraction of VMT of all vehicle types. Figure 6 illustrates the VMT-weighted HDV mix for Tennessee. The heaviest trucks, HDV8Bs, account for 41% of heavy-duty VMT and the lighter HDV2Bs for 32% of heavy-duty VMT. Categories HDV3, HDV4, HDV5, HDV6, HDV7, and HDV8A together make up the remaining 27% of VMT.

TABLE 2 Summary of HDV Fleet Characteristics

EPA Vehicle Class	Weight Range (1000's lbs)	National Vehicle Counts for 2001*	Age Weighted Annual Mileage for HDGVs (miles/yr)	Age Weighted Annual Mileage for HDDVs (miles/yr)	Age Weighted Diesel Fraction	First Year Mileage for HDGVs (miles/yr)	First Year Mileage for HDDVs (miles/yr)	Typical Speed (mph)	Utilization Hours/Day 250 Days/Yr	MOBILE6 Default VMT Fraction (%)	Approx. Class Distribution Profile** (% VMT)
HDV2B	**8.5 - 10**	7,103,086	12,787	14,900	0.205	19,977	27,137	25	4.3	4.0	60% of SUT
HDV3	**10 - 14**	628,635	12,787	15,263	0.594	19,977	32,751	25	5.2	0.4	6% of SUT
HDV4	**14 - 16**	465,538	11,015	17,646	0.430	21,394	30,563	25	4.9	0.3	4% of SUT
HDV5	**16 - 19.5**	414,563	11,015	17,646	0.178	21,394	30,563	25	4.9	0.2	3% of SUT
HDV6	**19.5 - 26**	1,295,221	11,015	19,076	0.403	21,394	40,681	25	6.5	0.8	12% of SUT
HDV7	**26 - 33**	1,364,961	11,015	19,076	0.640	21,394	40,681	25	6.5	1.0	15% of SUT
HDV8A	**33 - 60**	701,520	11,015	37,450	0.995	21,394	87,821	25	14.1	1.2	23% of TT
HDV8B	**>60**	1,617,840	11,015	58,278	1.000	21,394	124,208	55	9.0	4.0	77% of TT
Total		13,591,364							Total	11.9	

*Taken from the complete table of vehicle counts in *Fleet Characterization Data for MOBILE6* (*4*, p. 29)
**Assuming HDV8A and HDV8B are Trailer-Trucks (TT) and all others are Single Unit Trucks (SUT)

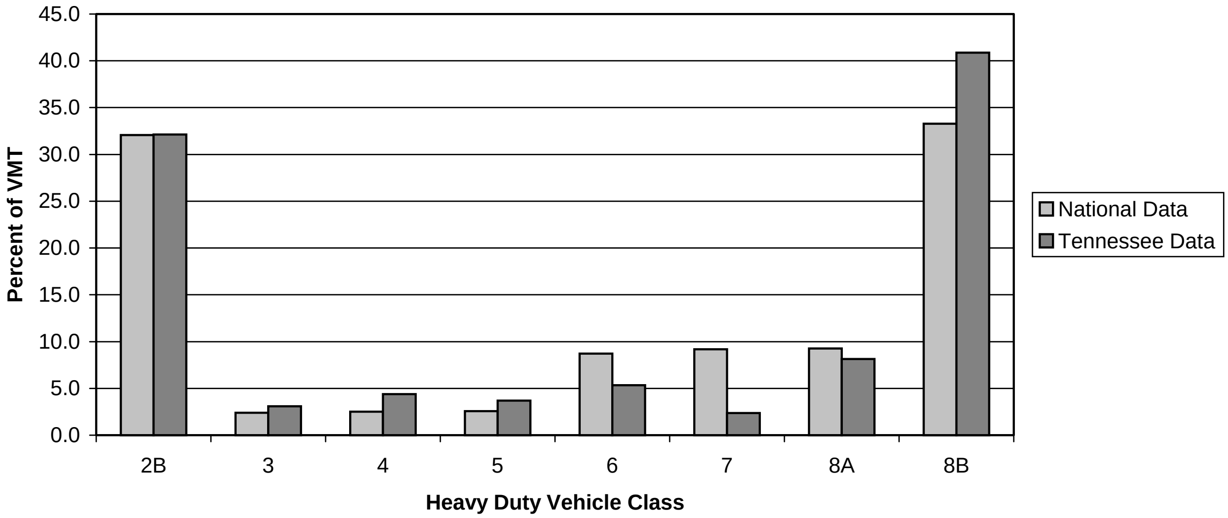

FIGURE 6 HDV mix by VMT: percent by class.

DIESEL VEHICLE SALES FRACTION

In the EPA scheme of vehicle classification, vehicles are first categorized on the basis of vehicle weight, then diesel vehicle fractions are used to separate the gasoline-fueled vehicles from the diesel-fueled vehicles. Table 2 lists the age-weighted diesel vehicle fractions used in MOBILE6 for the 2000 fleet. Only 20% of the relatively lightweight HDV2B vehicles sold are diesel fueled, and 80% are gasoline fueled. The two heaviest vehicle categories, HDV8A and HDV8B, are 100% diesel. The vehicles in the remaining five categories range from 18% to 64% diesel fueled.

HDV CLASSIFICATIONS BY ROAD TYPE

EPA's vehicle classification scheme used in the MOBILE6 model uses vehicle registration data, vehicle sales data, and average AMARs to define the nation's HDV fleet in terms of the relative miles traveled by vehicles in each weight category. Table 2 shows the MOBILE6 default percentage of VMT traveled by each HDV type. Nationwide, HDVs account for 11.9% of VMT. This estimate is probably good on a nationwide basis, but HDVs tend to use some road types more than others. For example, the heaviest vehicles (HDV8Bs) consist largely of tractor–trailers with gross vehicle weights approaching 80,000 lb (the load limit for five-axle trucks in most states), which travel mostly on Interstates and very little on minor arterials and local streets. The lightest trucks (HDV2Bs) consist largely of single-unit trucks (i.e., no trailer) such as delivery vans and utility trucks that frequently travel arterial and local streets. To accurately estimate emissions on individual roadways, more data are needed concerning the mix of HDVs by road type.

Very little data are available nationally concerning the distribution of vehicle weights on different roadways. However, many states and local agencies routinely perform vehicle classification counts on various types of roadways. These classification counts are usually performed as part of FHWA's highway performance monitoring system using manual methods or road tubes (*5,* Chapter 3). The FHWA vehicle classification method uses body type, number of axles, number of trailers, and axle spacing to classify vehicles, both automobiles and trucks. Table 3 shows the definitions of the 13 standard classifications prescribed by FHWA.

Manual classifications are based on the number of axles and trailers, while axle count and axle spacing are used to classify vehicles when using road tubes. Single-unit trucks are classified as Class 5, 6, or 7 depending on whether they have two, three, or four axles, respectively. Trailer trucks are classified as Class 8 to 13 depending on the number of axles and number of trailers. Tractor–trailer articulation can also be used to classify trucks. For example, a 3S-1-2 is a multiple-trailer truck (Class 12) with a tractor with two axles, followed by a trailer with one axle, and another trailer with two axles.

Unfortunately, the FHWA vehicle classification scheme does not indicate the actual weight or GVWR of the vehicle. In fact, vehicles in each category can have a wide range of actual weights. FHWA reported actual vehicle weight distributions in the 1999 *Truck Characteristics Analysis* (*6; 7,* Chapter 3). This report indicated that single-unit step vans, utility trucks, and platform trucks typically weighed less than 14,000 lb, but many trucks were heavier—especially beverage trucks, most of which weigh 20,000 to 40,000 lb. The gross vehicle weights of cement trucks and dump trucks may exceed 60,000 lb. Most five-axle tractor–trailers (e.g., enclosed vans, refrigerated vans, liquid or gas tankers, and automobile transporters) weigh 60,000 to 80,000 lb, but numerous trucks were in the 19,500 to 33,000 lb range, typical of tractors without trailers or with empty trailers.

Axle count data can be used as an approximate measure of maximum gross vehicle weight. Federal standards limit vehicle weights to 20,000 lb per axle. Most vehicles are designed to have less weight per axle than this maximum, especially on the front steering axle. A typical 18-wheel tractor–trailer with five axles is generally limited to a gross vehicle weight of 80,000 lb, equivalent to 16,000 lb per axle.

Using 16,000 lb per axle as a typical upper limit, a two-axle vehicle would be expected to have a maximum gross vehicle weight of 32,000 lb, limiting the EPA classifications to those between HDV2B and HDV7. A three-axle vehicle could have a gross vehicle weight of up to 48,000 lb, falling in the EPA classification HDV8A. Vehicles with four or more axles can have gross vehicle weights of more than 60,000 lb, placing them in EPA class HDV8B; most trailer trucks have five axles and normally fall in this class. Some trailer trucks may

TABLE 3 FHWA Vehicle Classification Scheme F

Class Number	Description	Class Code	Axles	Tires	Tractor-Trailer Articulation	Wheel Base Rules: Spacing Btw Axles Min. (inches)	Max. (inches)
1	Motorcycles	Bike	2	2		12	72
2	Cars	Car	2	4		72	118
3	Pick-up, Panel, Van	2A-L	2	4		118	146
4	Buses	Bus	2			234	480
5	Single Unit Trucks	2A-S	2	6		146	234
6	Single Unit Trucks	3A-S	3			12	480
7	Single Unit Trucks	4A-S	4			12	480
8	Single Trailer Trucks	<5-D	3 or 4		2S-1,3S-1,2S-2	12	480
9	Single Trailer Trucks	5A-D	5		3S-2,2S-3	12	480
10	Single Trailer Trucks	>6-D	6 or 7		3S-3,3S-4	12	480
11	Multi-trailer Trucks	<6-M	5		2S-1-2	12	480
12	Multi-trailer Trucks	6A-M	6		2S-2-2,3S-1-2	12	480
13	Multi-trailer Trucks	>6-M	7		Any 7 axle	12	480

A = Axle
S = Single (Single vehicle, no trailer)
Btw = between
D = Double (Tractor with trailer)
M = Multiple (Tractor with 2 trailers)

have as few as three axles and have a gross vehicle weight of less than 48,000 lb, putting them in EPA class HDV8A. Multiple-trailer trucks with four to seven axles normally fall in EPA class HDV8B. Single-unit trucks usually have two or three axles. The heaviest single-unit trucks have additional lift axles that are used when the vehicle is fully loaded. Heavy single-unit dump trucks, garbage trucks, and cement trucks may have one or two lift axles plus three standard axles to allow for heavy loads without exceeded highway weight limit standards (i.e., 80,000 lb).

Although vehicle classification data using the FHWA classes are available in many areas for many roadways, it is not easy to convert the FHWA classifications to the EPA classifications for use in emissions modeling. A 1997 NCHRP report (*1*) published a cross-reference table designed to convert FHWA classifications to the eight vehicle classes used in the old MOBILE5 model (Table 4). Unfortunately, the table cannot be used to convert FHWA classifications to the new 16 vehicle categories used in MOBILE6. Research is needed to develop a cross-reference table of vehicle classifications (or multiple tables for different road types) for use with the new model. EPA technical guidance on the use of MOBILE6 (*8*) states that vehicle classification counts can be used to determine the total HDV fraction of VMT (i.e., from all HDVs combined). The total HDV fraction should then be allocated to each of the eight EPA classes (HDV2B, HDV3, HDV4, HDV5, HDV6, HDV7, HDV8A, and HDV8B) by using the same relative proportions of each vehicle type as in the national default mix (Figure 6). This means that the same relative proportions of light trucks and heavy trucks will be used for all road types.

The FHWA vehicle classification scheme readily separates single-unit trucks from trailer trucks. Furthermore, VMT for single-unit trucks and trailer trucks are routinely measured and summarized by state and by road type in FHWA's annual *Highway Statistics*

TABLE 4 Cross-Reference Table: FHWA Vehicle Classes Converted to EPA's Old (MOBILE5) Vehicle Classes (*1*)

EPA Vehicle Classes	FHWA Classes: 1 Bike	2 Car	3 2A-L	4 Bus	5 2A-S	6 3A-S	7 4A-S	8 <5-D	9 5A-D	10 >6-D	11 <6-M	12 6A-M	13 >6-M
1 LDGV		98.8											
2 LDGT1			90.6		10.7	0.7	0.1	0.1					
3 LDGT2			4.0	20.0	9.9	0.0	0.5	0.0					
4 LDDV		1.2											
5 LDDT			3.0	80.0	1.9		0.4						
6 HDGV			1.7		50.4	14.4	4.6	5.1	1.0	1.0			
7 HDDV			0.7		27.1	84.9	94.6	94.8	99.0	99.0	100.0	100.0	100.0
8 MC	100.0												
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.0	100.0	100.0	100.0

NOTE: Values in the table are percentages.

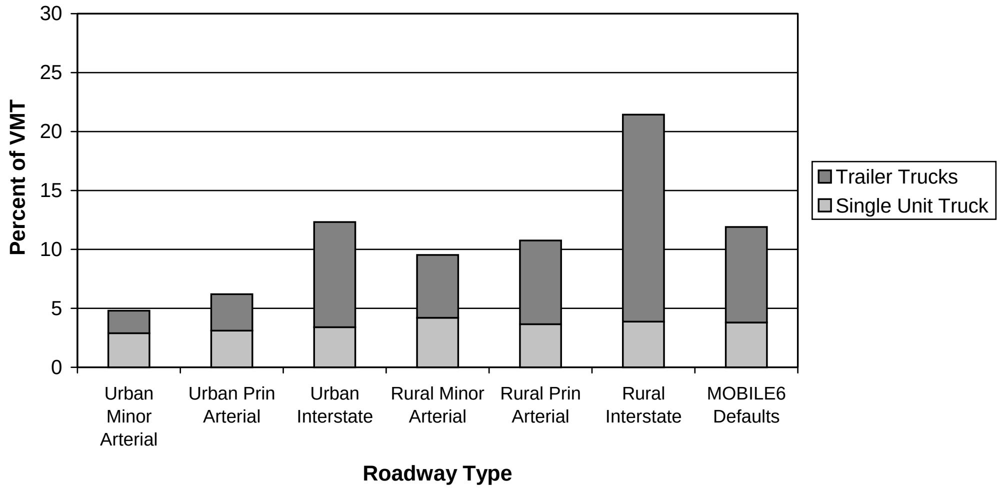

FIGURE 7 Percentage of single-unit trucks versus trailer trucks for six roadway types: 50 state averages from FHWA's 1999 highway statistics (Prin = principal).

(*9,* Tables VM-1 and VM-2). Figure 7 illustrates the 50-state average truck VMT fraction by roadway type. Notice that the percentage of VMT attributed to heavy-duty single-unit and trailer trucks is much higher on rural Interstates (22%) than on any other road type. Rural roads consistently have more heavy-duty VMT than urban roads, and Interstates consistently have more heavy-duty VMT than arterials.

The lowest heavy-duty truck VMT are for urban minor arterials, with only 5% total VMT due to heavy-duty trucks. Note also that most of the truck VMT on urban minor arterials are from single-unit trucks, while truck VMT on rural and urban Interstates are predominantly by trailer trucks. The MOBILE6 default truck mix (assuming HDV2Bs are single-unit trucks) closely matches the 50-state average for urban Interstates. Rural Interstates tend to have higher truck VMT than the MOBILE6 defaults; urban arterials tend to have fewer truck VMT than the MOBILE6 defaults. These differences in truck mixes can significantly affect air pollution emissions, especially the spatial allocation of emissions.

Similar heavy-duty truck mix data for Tennessee are illustrated in Figure 8. These data are based on truck classification counts performed by the Tennessee Department of Transportation (Tennessee DOT) on representative roads in the eight ozone-nonattainment counties in Tennessee. These data were used by the metropolitan planning organizations in Nashville, Knoxville, and Memphis, Tennessee, to calculate mobile-source emissions for conformity analyses. Average VMT due to heavy-duty trucks were 27% on rural Interstates, 18% on urban Interstates, and less than 5% on urban arterials and local streets.

Although EPA's current guidance calls for totaling all HDV VMT and allocation based on the national average VMT mix in MOBILE6,

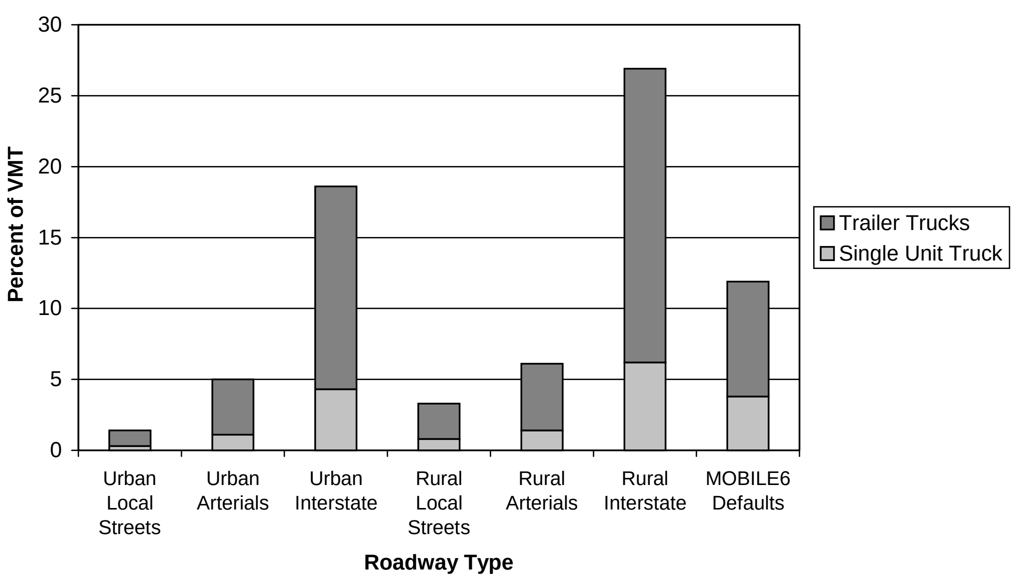

FIGURE 8 Percentage of single-unit trucks versus trailer trucks for six Tennessee roadway types (data from Tennessee DOT and metropolitan planning organizations).

a more accurate approach might be to develop typical HDV class-distribution profiles for single-unit trucks and trailer trucks separately. Different roadway types in different areas have distinctly different fractions of single-unit versus trailer trucks. This difference is illustrated in Figure 9 based on manual classification counts collected for this paper in East Tennessee. Rural Interstates have much higher fractions of trailer trucks (24%) than single-unit trucks (3%), while local streets, urban collectors, and urban minor arterials have higher fractions of single-unit trucks (5% to 7%) than trailer trucks (0% to 2%). Most tractor–trailer trucks fall in Class HDDV8B, while most single-unit trucks fall in Class HDGV2B. On the basis of the emissions factors shown in Figures 1 to 3, NO_x emissions from HDDV8Bs are 3.7 times higher than those from HDGV2Bs, while VOC and CO emissions from HDGV2Bs are 2.5 and 5.3 times higher, respectively, than from HDDV8Bs. Separate HDV class-distribution profiles for single-unit trucks versus trailer trucks could be used in combination with classification counts of single-unit trucks versus trailer trucks to improve the accuracy of mobile-source emissions inventories. This would not be inconsistent with EPA's current guidance that allows the use of "local-based vehicle aggregation schemes" in MOBILE6.

One advantage of having classification profiles for single-unit trucks versus trailer trucks is that all state DOTs routinely measure and report to FHWA single-unit truck and trailer truck classifications as part of the FHWA's highway performance monitoring system. EPA's vehicle classification scheme cannot be measured on highways because it is based on vehicle weights. Highly detailed vehicle classification schemes cannot be performed with current technology for vehicle counting and classification. Road tube counters, induction loops, and manual methods all can be used to determine the numbers of single-unit and trailer trucks with reasonable accuracy. Some states have even proposed that future vehicle classifications be based on only three categories of vehicles:

- Light passenger automobiles, sport utility vehicles (SUVs), vans, and pickup trucks;
- Heavy-duty single-unit trucks; and
- Heavy-duty trailer trucks.

Truck weigh-scale and weigh-in-motion sensors might be useful for measuring HDV weight distributions, but the MOBILE6 vehicle classes are based on GVWR, not actual weight. Furthermore, weigh-in-motion sensors are often used only to screen axle weights for potential violators. When the weigh-in-motion sensor shows a high value, the truck is diverted to a conventional truck scale for weighing. Overweight vehicle weights are recorded (and the owner or driver fined), but routine vehicle weights are not.

A first approximation of two separate class-distribution profiles can be approximated from an analysis of the data used in MOBILE6. MOBILE6 uses national vehicle registration data and survey data that provide a count of vehicles in each class as well as the annual mileage driven by vehicles in each class (Table 2). The highest annual mileage accumulation for all classes is for the first year of use (i.e., for a new truck). The first-year mileage ranges from 20,000 mi to 41,000 mi for truck classes HDV2B though HDV7. This mileage can easily be accumulated by a truck driven 4 to 6 h/day at 25 mph for 250 days a year, such as might be typical of a single-unit truck used for local or regional deliveries and service. Most delivery and service trucks are single-unit trucks. First-year mileages for truck classes HDDV8A and HDDV8B, are 88,000 and 124,000 mi, respectively. For HDDV8Bs, accumulating this much mileage would require driving 9 h/day at 55 mph for 250 days a year and would indicate a truck in long-haul service. Most long-haul service trucks are trailer trucks. Class HDDV8A would appear to be a combination of single-unit and trailer trucks based on the first-year mileage. If, for simplicity, all trucks in Classes HDV2B through HDV7 are assumed to be single-unit trucks, then two profiles can be calculated. Trailer trucks would be allocated 77% to HDV8B and 23% to HDV8A. Single-unit trucks would be allocated 60% to HDV2B, 6% to HDV3, 4% to HDV4, 3% to HDV5, 12% to HDV6, and 15% to HDV7. Using this allocation scheme and the national average default MOBILE6 VMT mix would indicate that 44% of HDV VMT are by trailer trucks and 56% are by single-unit trucks. This estimation seems too high for single-unit trucks. One reason might be that trailer trucks are undercounted. Many states register tractor–trailers on the basis of gross vehicle weight of the power unit alone, which is often less than 33,000 pounds and would fall in EPA Class HDV5, HDV6, or HDV7.

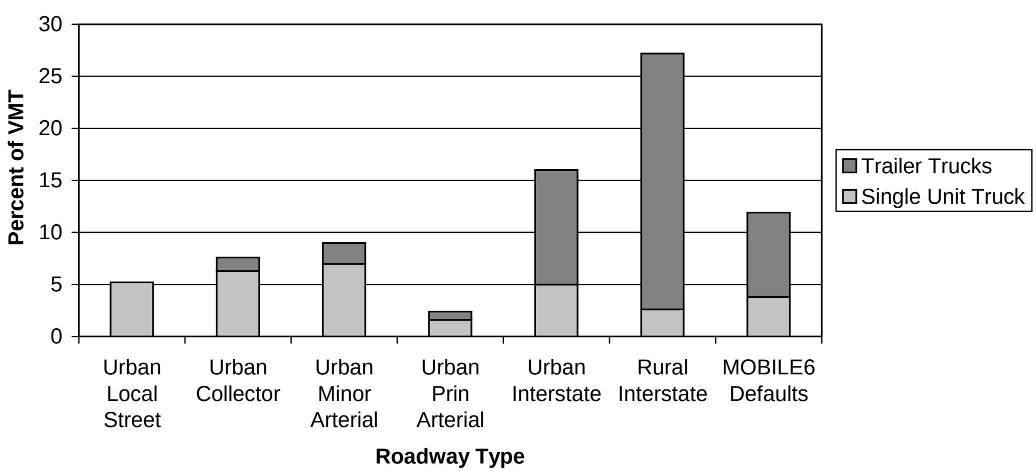

FIGURE 9 Percentage of single-unit trucks versus trailer trucks for six roadway types in east Tennessee in 2002.

More research is needed to better characterize the classification distribution of single-unit trucks versus trailer trucks.

The same single-unit truck class allocations can be used to develop a crude cross-reference table for equating the 13 FHWA vehicle classes to the 16 MOBILE6 vehicle classes, as shown in Table 5. Two-axle, single-unit trucks typically have GVWRs of 9,000 to 32,000 lb depending on whether they have small or large wheels and whether they have dual rear wheels. They correspond to FHWA Class 5 (2A-S) and MOBILE6 Classes HDV2B, HDV3, HDV4, HDV5, HDV6, and HDV7. All vehicles in FHWA Class 5 could be allocated to these six MOBILE6 classes using the same percentages described above and shown in Tables 2 and 5. Three-axle, single-unit trucks fall in FHWA Class 6 (3A-S), with GVWRs between 33,000 and 60,000 lb. These vehicles fall in MOBILE6 class HDV8A. Only the heaviest single-unit trucks have more than three axles, and they are usually lift axles on cement trucks, garbage trucks, and dump trucks. These trucks all fall in FHWA Class 7 (4A-S) and should be in MOBILE6 class HDV8B. FHWA Classes 9 through 13 are all for tractor–trailers with five or more axles. All these vehicles are likely to have GVWRs greater than 60,000 lb, which places them in MOBILE6 Class HDV8B. FHWA Class 8 is for tractor–trailers with three or four axles. A three-axle tractor–trailer would have a GVWR of less than 60,000 lb, which places it in MOBILE6 Class HDV8A. FHWA Class 4 (buses) should be allocated to the equivalent MOBILE6 classes HDBS (school buses) and HDBT (transit buses).

Automobiles and light trucks (vans, SUVs, and pickups) fall into FHWA Classes 2 and 3. Vehicles with wheelbase lengths less than 118 in. are classified as automobiles, and vehicles with wheelbase lengths greater than 118 in. are classified as light trucks. Because many minivans, small SUVs, and small pickup trucks have wheelbase lengths less than 118 in. and many large sedans and station wagons have wheelbase lengths greater than 118 in., these two classes should be combined and the MOBILE6 default vehicle type mix be used to approximate the distribution of vehicles within the two classes. The values shown in Table 5 are the default percentages of these classes in MOBILE6 for 2003. As shown in the table, 52% of light-duty vehicles are expected to be automobiles, and 48% are expected to be one of the four light-duty truck classes that include vans, SUVs, and pickups. The proposed scheme for mapping FHWA vehicle classes to MOBILE6 vehicle classes is summarized in Table 5.

CONCLUSIONS

This paper presents a summary of factors important for estimating the mobile-source emissions of air pollution from the HDV portion of the vehicle fleet. Factors considered include HDV distribution by weight class, vehicle speed, and fraction of total VMT attributable to HDVs and how this value varies by road type. All these factors can significantly influence emissions, especially of NO_x. When the MOBILE6 model is run using all default settings for 2000, the proportion of NO_x emissions attributable to HDVs is 58%. The default HDV mix in MOBILE6 is 11.9%; if the HDV mix is increased to 27%, typical of rural Interstates in Tennessee, the proportion of NO_x attributable to HDVs increases to 80%. Although rural Interstates carry high percentages of tractor–trailer trucks with diesel engines, many urban arterials, collectors, and local streets carry mostly single-unit trucks with gasoline engines and higher VOC and CO emissions.

Because heavy-duty trucks contribute such a large proportion of the total mobile-source emissions, especially NO_x, it is important to characterize the HDV fleet and the VMT by HDVs accurately. A crude cross-reference table for mapping FHWA vehicle classes to MOBILE6 vehicle classes is presented herein. Additional research is

TABLE 5 Cross-Reference Table: FHWA Vehicle Classes Converted to EPA's New (MOBILE6) Vehicle Classes

EPA Vehicle Classes	FHWA Classes 1 Bike	2 Car	3 2A-L	4 Bus	5 2A-S	6 3A-S	7 4A-S	8 <5-D	9 5A-D	10 >6-D	11 <6-M	12 6A-M	13 >6-M
LDGV		52	52										
LDGT1		8	8										
LDGT2		28	28										
LDGT3		8	8										
LDGT4		4	4										
HDV2B					60								
HDV3					6								
HDV4					4								
HDV5					3								
HDV6					12								
HDV7					15								
HDV8A						100		100					
HDV8B							100		100	100	100	100	100
HDBS				50									
HDBT				50									
MC	100												
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

NOTE: Values in the table are percentages. Values shown are suggested by the authors.

needed to compare vehicle type mixes developed using the FHWA vehicle classifications (Scheme F) and this cross-reference table or some improved version of the table. Research is needed on ways to better define the makeup of the single-unit and tractor–trailer portions of the HDV fleet. Additional work is also needed to better define single-unit and tractor–trailer HDV activity on different road types to improve emissions inventories.

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