Development of On-Road Mobile Source Emission Inventories for Rural Counties

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ABSTRACT

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Under the proposed eight-hour National Ambient Air Quality Standards (NAAQS), many additional counties throughout the U.S. will be designated as nonattainment counties. Upon designation, these counties will be subject to most of the same transportation air quality regulations as those counties designated under the one-hour NAAQS. These counties must develop strategies for attaining the NAAQS and incorporate these strategies into State Implementation Plans (SIPs). The counties must demonstrate that the transportation plans and programs proposed for these counties conform to the SIPs before implementing projects and programs. To support this regulator process accurate on-road mobile source emissions inventories are needed.

This paper describes a methodology for estimating base year and projecting future year mobile source emissions inventories for application to any rural county. The methodology is appropriate for rural counties that do not have validated traditional four-step travel demand models available. The methodology uses Highway Performance Monitoring System (HPMS) data, which is available in all states as a part of a Federal Highway Administration (FHWA) directed program and trend line projection techniques. The methodology describes methods for disaggregation of vehicle miles of travel (VMT) by vehicle type, estimation of vehicle speeds by roadway functional classification, and estimation of mobile source emissions using the U.S. Environmental Protection Agency's (EPA) MOBILE model. Emissions estimates prepared using the methodology are compared to emissions estimates for the same geographic area prepared using traditional four-step models.

VMT

The Highway Performance Monitoring System (HPMS) county-level data is the primary data source used for the procedure described in this paper. An example of this data for Travis County, Texas is provided in Table 1. The data consists of roadway centerline miles, roadway lane miles, and VMT, cross-classified by functional classifications and area types. The functional classifications are interstate (urban and rural), urban freeways, principal arterials (urban and rural), minor arterials (urban and rural), rural major collector or urban collector, rural minor collector, and local road or street. The area types are rural (1-4,999), small urban (5,000 - 49,999), urbanized (50,000 - 199,999), and urbanized (200,000 plus). HPMS data is collected by state departments of transportation on a formal and on going basis as part of the larger HPMS data collection program

The VMT data is annual average daily traffic (AADT). AADT is the estimate of typical traffic on a road segment for all days of the week, Sunday through Saturday, over a period of one year.

The HPMS universe consists of all public roads within the state. There is also a stratification dimension based on volume (13 volume groups) which is used in the HPMS sampling procedure as a statistical device to reduce sample size, ensure inclusion of higher volume roadways, and increase the precision of VMT estimates. The EPA requires that the VMT used to develop on-road mobile source emissions estimates be consistent with HPMS VMT estimates. For travel model-based estimates, this requirement is achieved through an adjustment factor. For the method described in this paper no adjustment is required. HPMS VMT estimates are available for all counties. While data collected as part of the HPMS program is the best available, as with any data there are limitations. There are always measurement and sampling errors, even though HPMS methods are designed to minimize these errors.

TABLE 1
Example HPMS Data
Travis County, Texas, 1998

	INTERSTATE	URBAN FRWY	PRIN ART	MIN ART	MAJ COLL	MIN COLL	LOCAL	TOTAL
RURAL MILES (POP 1-4,999)								
CENTERLINE	0.0078	0.000	29.462	48.030	169.085	29.241	1,068.396	1,344.221
VMT	832	0	471,239	604,565	738,759	35,224	293,025	2,143646
LANE MILES	0.042	0.000	85.832	158.212	401.218	59.132	2,136.792	2,841.228
SMALL URBAN MILES (POP 5,000 - 49,999)								
CENTERLINE	0.302	0.000	0.000	0.000	0.618	0.000	0.000	0.920
VMT	35,922	0	0	0	2,570	0	0	38,493
LANE MILES	1.812	0.000	0.000	0.000	1.236	0.000	0.000	3.048
URBANIZED MILES (POP 50,000 0 199,999)								
CENTERLINE	0.000	0.000	0.000	0.000	0.000	0.000	2,085.830	2,085.830
VMT	0	0	0	0	0	0	2,835,132	2,835,132
LANE MILES	0.000	0.000	0.000	0.000	0.000	0.000	4,171.660	4,171.660
URBANIZED MILES (POP 200,000+)								
CENTERLINE	28.074	67.903	168.048	109.095	269.180	0.000	313.398	955.698
VMT	3,577,801	4,291,218	3,935,990	1,127,324	1,460,349	0	117,397	14,510,082
LANE MILES	177.623	343.818	631.286	269.340	587.058	0.000	626.796	2,635.921
TOTAL MILES								
CENTERLINE	28.383	67.903	197.510	157.125	438.883	29.241	3,467.624	4,386.669
VMT	3,614,557	4,291,218	4,407,230	1,731,890	2,201,679	35,224	324,554	19,527,355
LANE MILES	173.477	313.818	717.118	427.552	989.512	59.132	6,935.248	9,651.857

SUMMER WEEKDAY ADJUSTMENT FACTORS

Emissions inventories are typically needed for average summer (June, July, and August) weekdays (Mondays through Fridays). Since the HPMS AADT VMT data are for Monday through Sunday, January through December, a conversion factor is required to convert the AADT to summer weekday VMT.

State departments of transportation collect vehicle counts using automatic traffic recorders (ATRs) on a continuous basis. These ATR counts are available by season, month, and weekday, as well as AADT.

ATR counts are used to develop seasonal weekday adjustment factors. These factors are the ratio of summer weekday volumes (Monday through Friday, June, July, and August) to total volume (AADT, 365 days, Monday through Sunday, January through December traffic). These factors, when applied to average annual daily VMT produce average summer weekday VMT.

ATR data is not available for all rural counties. In practice, professional judgment is used to group rural counties that have similar traffic characteristics. A single adjustment factor is applied to all the counties in the group.

Table 2 provides an example of the ATR adjustment factors applied to county AADT VMT.

TABLE 2
Example 1999 Summer Weekday VMT Control Total Calculation

County	AADT VMT	ATR Adjustment Factor	Summer Weekday VMT
Bastrop	1,396,844	1.03472	1,445,342
Caldwell	739,979	1.07689	796,876
Comal	2,390,241	1.07843	2,577,708
Ellis	3,550,288	1.08826	3,863,636
Guadalupe	2,358,496	1.02179	2,409,888
Harrison	2,366,915	1.02179	2,418,490

VMT FORECASTS

The procedure described in this paper can be used with HPMS data to estimate base year emissions, for example, 1999 emissions. For conformity analyses and for attainment strategy analyses, estimates of forecast emissions are required. To develop VMT forecasts for rural counties, county HPMS VMT data for 1980 through 1999, in combination with official (i.e., U.S. Census and State Data Center) county population statistics and projections, were used. Most states have an agency that provides “official” county population forecasts.

There are conceptually two types of VMT, local and through. Local VMT is generated by the residents of the county. Through VMT is generated by vehicles passing through the county.

Theoretically, local VMT is more closely related to resident population, while through VMT is more closely related to inter-county travel. Though these distinctions are not absolute (i.e., local VMT is not independent of inter-county travel and through VMT is not independent of county population), they imply very different strategies for forecasting. Local VMT growth is more likely to be a function of county population growth, while through VMT is more likely to be a function of historical trends in inter-county travel. If used alone, however, each tends to err in a different direction. Population-based forecasts (i.e., VMT per capita) tend to under estimate future VMT, especially in small counties adjacent to large urban areas. Conversely, historical-based (i.e., growth trend) forecasts tend to over estimate future VMT, especially in areas where there has been recent atypical rapid growth.

Viewed differently, however, these two forecast strategies can be seen as defining the boundaries of the forecast, that is, defining a range within which one can be relatively confident of the result. Consequently, the strategy adopted is to use the midpoint of the two forecasts. In other words, both methods are used.

First, a forecast is developed for each county based on the per capita-based method, using a VMT-to-population ratio (based on 1980, 1990 and 1995 population and VMT) applied to future official State Data Center population projections. Next, a regression analysis is performed on the county-historic HPMS VMT data from 1980 to 1999 to develop the coefficients, which are then used to forecast future county VMT. Then, the two forecasts are combined and the midpoint calculated. The midpoint of the two methods is used as the forecast VMT for each county for each forecast year. Table 3 is an example of the 2007 VMT forecast for six rural counties and the estimation of the midpoint. Finally, seasonal adjustments are applied to the VMT forecasts to produce summer weekday VMT.

TABLE 3
Example 2007 VMT Forecast Calculation

County	Method		
	Regression	Ratio	Midpoint
Bastrop	1,776,848	1,665,616	1,721,232
Caldwell	883,871	778,101	830,986
Comal	3,302,365	2,503,522	2,902,944
Ellis	4,580,593	3,993,027	4,286,810
Guadalupe	3,015,548	2,533,373	2,774,461
Harrison	2,972,193	2,289,379	2,630,786

VMT MIX

VMT mix was estimated using weekday vehicle classification data. State departments of transportation collect vehicle classification data. Professional judgment is used to select the classification count data to be applied to each county or group of counties.

A brief description of the allocation and conversion procedure follows. Classification counts classify vehicles into the standard FHWA vehicle classifications shown in Table 4 and Figure 1. Motorcycles are not counted separately and are included as a default (subtracted from LDGV). Unclassified vehicles are counted as a separate category. These are included in the largest classification category, which is comprised of LDGV and LDDV. The eight EPA vehicle classes are defined as follows:

LDGV light-duty gasoline vehicles
LDGT1 light-duty gasoline trucks up to 6,000 pounds (GVWR)
LDGT2 light-duty gasoline trucks from 6,001 to 8,500 pounds (GVWR)
HDGV heavy-duty gasoline vehicles over 8,500 pounds (GVWR)
LDDT light-duty diesel trucks
LDDV light-duty diesel vehicles

HDDV heavy-duty diesel vehicles over 8,500 pounds (GVWR)
MC motorcycles

TABLE 4
FHWA Vehicle Types

Vehicle Type Description	DOT Class	FHWA Class
Motorcycles and passenger vehicles	C	None
Two axle four tire single unit trucks	P	None
Buses	B	None
Six tire single unit vehicles	SU2	None
Three axle single unit vehicles	SU3	None
Four or more axle single unit vehicles	SU4	None
Three axle single trailer	SE3	2S1
Four axle single trailer	SE4	2S2, 3S1
Five axle single trailer	SE5	3S2, 2S3
Six or more axle single trailer	SE6	3S3, 3S4
Five or less axle multi trailer	SD5	2S1-2
Six axle multi trailer	SD6	2S2-2, 3S1-2
Seven or more axle multi trailer	SD7	3S2-2
Unclassified	None	Varies

Vehicle classification counts are first aggregated into three intermediate vehicle groups as follows, see Table 5:

LDT 0.80 * P
LDGT2 (0.20 * P) + (0.20 * B) + (0.20 * SU2)
HDV (0.80 * B) + (0.80 * SU2) + (SU3+SU4+SE3+SE4+SE5+SE6+SD5+SD6+SD7)

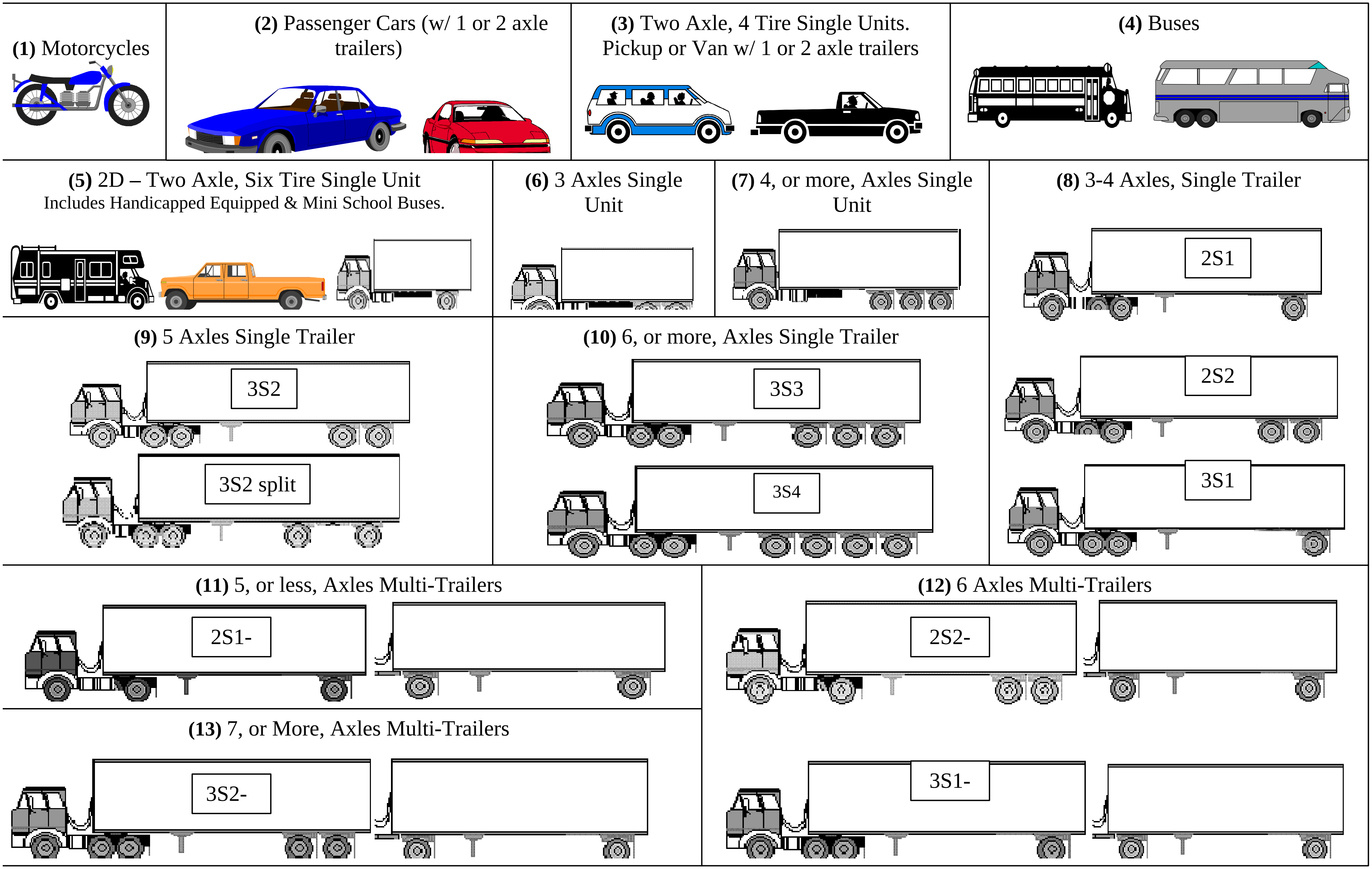

FIGURE 1. FHWA Vehicle Classifications

TABLE 5
FHWA Vehicle Types Grouping

FHWA Vehicle Types	EPA Vehicle Types		
	LDT	**LDGT2**	**HDV**
Passenger cars (C)	NA	NA	NA
2-axle, 4-tire single unit (P)	0.80	0.20	
Buses (B)		0.20	0.80
2-Axle, 6-tire, single unit (SU2)		0.20	0.80
3-Axle single unit (SU3)			1.00
4-Axle or more single unit (SU4)			1.00
3-Axle single trailer (SE3)			1.00
4-Axle single trailer (SE4)			1.00
5-Axle single trailer (SE5)			1.00
6-Axle or more single trailer (SE6)			1.00
5-Axle or less multi-trailer (SD5)			1.00
6-Axle multi-trailer (SD6)			1.00
7-Axle or more multi-trailer(SD7)			1.00

Next, the remaining FHWA categories and these three intermediate groups were disaggregated into the eight EPA vehicle groups as shown below and in Table 6. Note that vehicle classification count procedures do not distinguish between gasoline and diesel light-duty trucks consequently MOBILE5 defaults are used to separate light-duty vehicles into gasoline and diesel fractions. County vehicle registration data are used to separate gasoline from diesel heavy-duty trucks. Motorcycles are not counted directly and are included as a default, subtracted from LDGV.

LDGV 0.987 * C + unclassified vehicles (MOBILE5 default, 1990 shown)
LDDV 0.012 * C + unclassified vehicles (MOBILE5 default, 1990 shown)
LDGT1 0.986 * LDT (MOBILE5 default, 1990 shown)
LDDT 0.014 * LDT (MOBILE5 default, 1990 shown)
LDGT2 (0.20 * P) + (0.20 * B) + (0.20 * SU2)
HDGV 0.358 * HDV (County registration data, 1990 state aggregate shown)
HDDV 0.642 * HDV (County registration data, 1990 state aggregate shown)
MC 0.001 of total (subtracted from LDGV)

TABLE 6
MOBILE5 Vehicle Types

FHWA Vehicle Types	MOBILE5 Vehicle Types							
	LDGV	LDGT-1	LDGT-2	HDGV	LDDV	LDDT	HDDV	MC
Passenger cars (C)	0.987				0.012			0.001
2-axle, 4-tire single unit (P)		0.80	0.20					
Buses (B)			0.20	0.286			0.514	
2-Axle, 6-tire, single unit (SU2)			0.20	0.286			0.514	
LDT		0.986				0.014		
HDV				0.358			0.642	

This procedure is applied using county-specific vehicle classification data. Finally, Table 7 shows the aggregation of the roadway functional categories used for the three nominal functional classifications (freeway, arterial, and collector). The ability to estimate VMT mix by functional classification group depends on the classification county data available. For some states, the data may only permit the application of a single VMT mix to all roadway functional classifications.

The results of this procedure are illustrated in Tables 8, 9, and 10.

TABLE 7
Vehicle Classification Distribution Aggregated Functional Classifications

Aggregated Functional Classifications	HPMS Functional Classifications
Freeways	Urban Interstate Freeway Urban Other Freeway Rural Interstate Freeway
Arterials	Urban Principal Arterial Urban Minor Arterial Rural Principal Arterial Rural Minor Arterial
Collectors	Urban Major Collector Urban Minor Collector Urban Collector Rural Collector

TABLE 8
1999 County Weekday Freeway Vehicle Classification Distribution

County	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Bastrop	0.718	0.125	0.039	0.039	0.002	0.001	0.075	0.001
Caldwell	0.718	0.125	0.039	0.039	0.002	0.001	0.075	0.001
Comal	0.604	0.143	0.045	0.055	0.002	0.001	0.149	0.001
Ellis	0.724	0.127	0.038	0.039	0.002	0.001	0.069	0.001
Guadalupe	0.613	0.150	0.046	0.091	0.002	0.001	0.097	0.001
Harrison	0.511	0.126	0.040	0.153	0.001	0.001	0.167	0.001

TABLE 9
1999 County Weekday Arterial Vehicle Classification Distribution

County	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Bastrop	0.597	0.215	0.066	0.041	0.002	0.001	0.077	0.001
Caldwell	0.705	0.163	0.050	0.028	0.002	0.001	0.051	0.001
Comal	0.762	0.145	0.042	0.024	0.002	0.001	0.023	0.001
Ellis	0.663	0.157	0.050	0.055	0.002	0.001	0.072	0.001
Guadalupe	0.762	0.145	0.042	0.024	0.002	0.001	0.023	0.001
Harrison	0.597	0.190	0.054	0.075	0.002	0.001	0.082	0.001

TABLE 10
1999 County Weekday Collector Vehicle Classification Distribution

County	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Bastrop	0.488	0.310	0.090	0.037	0.001	0.002	0.070	0.001
Caldwell	0.505	0.277	0.082	0.055	0.001	0.002	0.076	0.001
Comal	0.528	0.251	0.077	0.086	0.001	0.002	0.053	0.001
Ellis	0.678	0.183	0.060	0.031	0.002	0.001	0.044	0.001
Guadalupe	0.528	0.251	0.077	0.086	0.001	0.002	0.053	0.001
Harrison	0.624	0.227	0.071	0.039	0.002	0.001	0.036	0.001

SPEED MODEL OVERVIEW
Emissions are a function of vehicle type, VMT, and speed. Speed itself is a function of roadway classification (capacity) and congestion (volume). Speed estimates are developed using the hourly volumes and capacities by roadway functional classification, along with freeflow speeds derived from the Highway Capacity Manual (HCM). Volume/delay relationships are based on the speed model originally developed by the North Central Texas Council of Governments (NCTCOG) for the Dallas/Fort Worth area. Speed estimates are developed using total VMT separated into peak and off-peak travel. Speeds and capacities fit the combined area types and roadway functional classifications of HPMS.

HPMS data is separated into four area types and seven roadway functional classifications. Area type is defined by population. Areas with a population of 4,999 or less are defined as rural. Areas with a population between 5,000 and 49,999 are designated small urban. Areas with a population of 50,000 or more are defined as urban. (The HPMS area types of urban and large urban are grouped.) HPMS area type and roadway functional classifications are summarized in Table 11.

TABLE 11
HPMS Area Types and Roadway Functional Classifications

Area Type	**Roadway Functional Classification**						
Rural Small Urban Urban	Interstate	Freeway	Other Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local

Total HPMS VMT is allocated into four time periods (1 hour, 8.5 hours, 1 hour, and 13.5 hours) using time-of-day factors developed from urban travel surveys. (0.1069, 0.5033, 0.1018, and 0.2880). The four time periods correspond to the AM peak (7:15 a.m. - 8:15 a.m.), mid-day (8:15 a.m. - 4:45 p.m.), the PM peak (4:45 p.m. - 5:45 p.m.), and overnight (5:45 p.m. - 7:15 a.m.). Volumes are further disaggregated by directional split. A directional split (60/40) is based on aggregate observed values for areas for which data are available. The directional delay due to congestion (in minutes per mile) is computed using the speed model.

The speed model uses the following volume/delay equation:

$$Delay = Min\left[A\,e^{B(\frac{V}{C})}\,, M \right]$$

Where:

Delay	=	congestion delay (in minutes/mile);
A & B	=	volume/delay equation coefficients;
M	=	maximum minutes of delay per mile; and
V/C	=	time-of-day directional V/C ratio.

The delay model parameters (A, B, and M) are shown in Table 12.

TABLE 12
Volume/Delay Equation Parameters

Facility Category	A	B	M
High Capacity Facilities (> 3,400 vehicles per hour [VPH], e.g., Interstates and Freeways)	0.015	3.5	5.0
Low Capacity Facilities ($\leq$ 3,400 VPH, e.g., Arterials, Collectors and Locals)	0.050	3.0	10.0

Given the estimated directional delay (in minutes/mile) and the estimated freeflow speed, the directional congested speed is computed as follows:

$$Congested\ speed = \frac{60}{\dfrac{60}{Freeflow\ speed} + Delay}$$

This speed model is applied to each cell of the area type/functional classification matrix for each time period by direction. This results in the calculation of 224 separate speed estimates (28 cells, 2 directions, 4 time-of-day periods). Figure 2 shows the relationship between the volume-to-capacity ratio, the freeflow speed, and the congested speed.

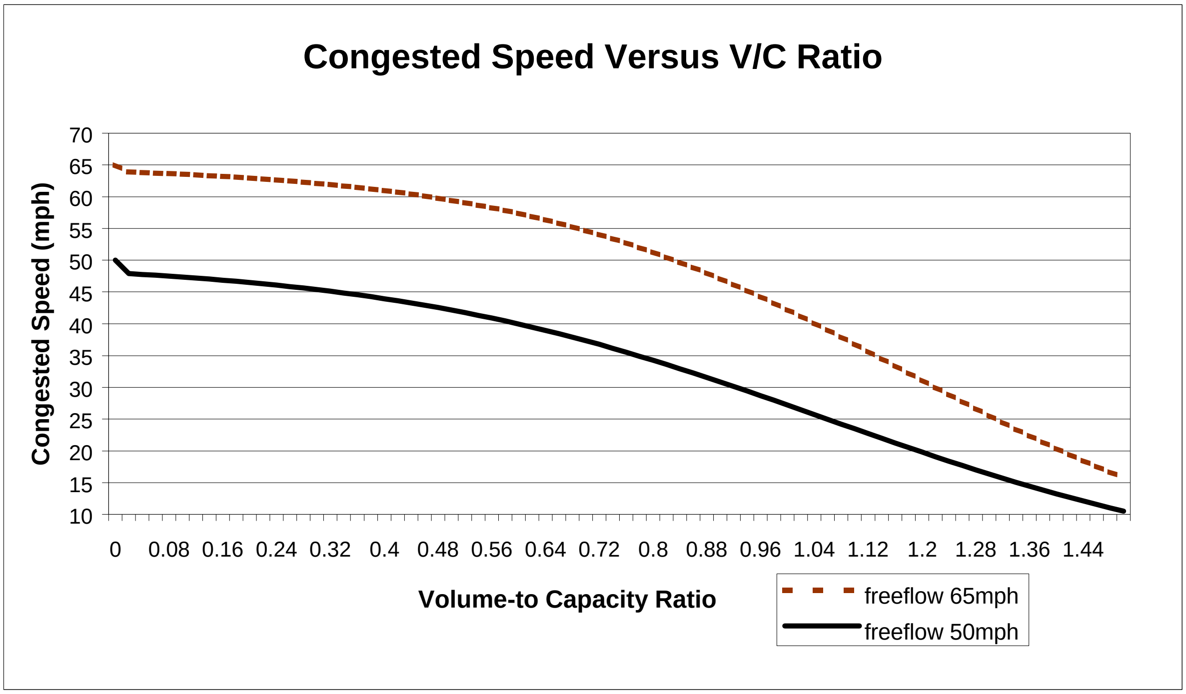

FIGURE 2. Congested Speed Versus Volume-to-Capacity Ratio

Capacity and Freeflow Speed

Capacity and freeflow speed are critical parameters for the speed model. Capacity is the maximum flow past a given point on a roadway. It varies by the type of roadway (i.e., by functional classification). Freeflow speed is the maximum speed at which traffic will move along a given roadway if there are no impediments (e.g., congestion, bad weather, etc.). The capacities and freeflow speeds used for this analysis are taken from the HCM. For HPMS functional classifications 1 and 2 (interstate and freeway), both capacities and freeflow speeds are taken directly from the HCM (Figure 3-3). The capacity (2,200 passenger cars per hour per lane [pcphpl]) and freeflow speed (70 mph) for four-lane freeways was used for all interstates, regardless of area type. Similarly, a freeflow speed of 65 mph and capacity of 2,100 pcphpl was used for all freeways (HCM Figure 3-2a).

HPMS functional classifications 3, 4, 5, 6, and 7 (principal arterial, minor arterial, major collector, minor collector, and local) have traffic control devices (i.e., signals or stop signs), which determine their capacities. The capacities of these signalized roadways were calculated based on signalized intersection capacity defined as shown (HCM 1994: 9-5, equation 9-3):

$$Ci = Si * (gi/C)$$

Where:

- Ci = capacity of lane group i, VPH;
- Si = saturation flow rate of lane group i, vehicles per hour of effective green time (VPHG); and
- gi/c = effective green ratio for lane group i.

The saturation flow rate (Si) is the flow in VPH that could be accommodated by the lane group assuming that the green phase was always available to the lane group (i.e., green ratio = 1.0). Computation of the adjusted saturation flow rate begins with the ideal saturation flow rate of 1,900, which is adjusted to reflect variance from ideal conditions. The saturation flow rate was adjusted for area type using the following assumptions (HCM 1994: 9-14, equation 9-12):

$$S = N*fw*fhv*fg*fp*fbb*fa*frt*flt$$

Where:

- S = saturation flow rate adjustment factor (rounded to 2 decimal places);
- N = number of lanes in the lane group;
- fw = lane width adjustment factor (12-foot lane for all area types assumed);
- fhv = heavy vehicle adjustment factor (5% heavy vehicles for all area types to adjust for passenger vehicle equivalents, not to be confused with VMT mix);
- fg = approach grade factor (level terrain assumed for all area types);
- fp = parking lane adjustment (none for rural areas, 1 maneuver per hour for urban areas);
- fbb = bus blocking factor (none for rural areas, 10 per hour for urban areas, mid-point for small urban areas);
- fa = area type adjustment (0.9 for urban area, 1.0 for all other areas);
- frt = right turn adjustment factor (shared lane for right turns for all area types, high

pedestrians crossing for urban areas, moderate for small urban areas, and low for rural); and

flt = left turn adjustment factor (exclusive left turn lanes and protected phasing for rural areas, shared left turn lanes and protected plus permitted phasing for urban areas, mid-point for small urban areas).

The saturation flow rate adjustment factors used for the three different area types are shown in Table 13.

TABLE 13
Saturation Flow Rate Adjustment Factors by Area Type

Area Type	fw	fhv	fg	fp	fbb	fa	frt	flt
Rural	1	0.95	1	1	1	1	0.98	0.95
Small Urban	1	0.95	1	0.98	0.98	1	0.94	0.90
Urban	1	0.95	1	0.95	0.96	0.90	0.90	0.85

The effective green ratios used for different roadway functional classifications are shown in Table 14. The same ratios were used for all area types. (Interstates and freeways are unsignalized and do not require green ratios.)

TABLE 14
Effective Green Ratios (gi/C) by HPMS Roadway Functional Classification

Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local
0.60	0.55	0.50	0.40	0.30

The adjusted saturation flow rate (expressed in pcphpl) for all signalized streets (i.e., not interstate or freeway) for the three area types is shown in Table 15.

TABLE 15
Adjusted Saturation Flow Rate (pcphpl) by Area Type

HPMS Area Type	Ideal Flow	Adjustment Factor	Adjusted Saturation Flow
Rural	1,900	0.88	1,672
Small Urban		0.77	1,463
Urban		0.59	1,121

The freeflow speed for rural and urban arterials (HPMS functional classifications 3 and 4) were taken directly from HCM (HMC 1994: 7-10 and 11-6 respectively). The freeflow speed for other roadway functional classifications decreases from arterial freeflow speed by 5 mph increments. No freeflow speed is below 30 mph. The hourly lane capacities for all functional classifications and area types are shown in Table 16.

TABLE 16
Hourly Lane Capacities (vehicles per hour per lane [vphpl])

HPMS Area Type	HPMS Roadway Functional Classification						
	Interstate	**Freeway**	**Other Principal Arterial**	**Minor Arterial**	**Major Collector**	**Minor Collector**	**Local**
Rural	2,200	2,100	1,003	920	836	669	502
Small Urban	2,200	2,100	878	805	732	585	439
Urban	2,200	2,100	673	617	561	448	336

Similarly, freeflow speeds are provided for each of the four area types and seven roadway functional classifications (the 28-cell matrix representing the HPMS typology). Freeflow speeds do not vary by direction or time of day. These are shown in Table 17.

TABLE 17
Freeflow Speeds (mph)

HPMS Area Type	HPMS Roadway Functional Classification						
	Interstate	**Freeway**	**Other Principal Arterial**	**Minor Arterial**	**Major Collector**	**Minor Collector**	**Local**
Rural	70	65	55	50	40	35	30
Small Urban	70	65	45	40	35	30	30
Urban	70	65	40	35	30	30	30

Volume-to-capacity ratios are generated for each combination of time period, roadway functional classification, area type, and direction using the following capacities and VMT:

- Volume: VMT is multiplied by each of the four the time period factors yielding VMT for each time period. VMT per time period is divided by centerline miles, yielding volume for each time period. This procedure is performed for each combination of time period, roadway functional classification, area type, and direction.

- Capacity: Lane miles are divided by centerline miles to produce lanes. Lanes are multiplied by the lane capacities (i.e., adjusted saturation flows) generated by the process described above, producing hourly lane capacities. Hourly lane capacities are multiplied by the number of hours in the time period to produce time period capacities. This procedure is performed for each combination of time period, roadway functional classification, and area type. (Capacity is the same for each direction and time period.)

- V/C ratios: The speed model is applied to the resulting volumes and capacities for each functional classification and area type combination. This yields volumes adjusted for the impact of congestion-related delay for each combination of time period, functional classification, area type, and direction.

FUTURE YEAR ROADWAY IMPROVEMENTS

Proposed improvements are taken from the respective State Transportation Improvement Programs (STIPs) for each county and any long-range transportation plans that are available for the county. Specifically, improvements are defined as changes to centerline miles and lane miles. Improvements that have no impact on either centerline or lane miles are not captured by this process. The projected improvements (increases) in centerline miles and lane miles of the highway network are added to the most recent HPMS data to reflect future year improvements.

For Texas, and probably for most states, 20-year transportation plans for rural counties are not prepared hence obtaining reasonable estimates of 20-year capacity improvements is probably not possible. Capacity improvement plans for 5 to 10 years are possible.

ESTIMATION OF EMISSIONS

EPA's MOBILE5 program is used to compute the mobile source emissions factors for the rural counties. MOBILE5 was used directly to compute 24-hour diurnal emissions rates. MOBILE5 is applied using a Texas Transportation Institute (TTI) program (POLFAC5) to estimate the emissions factors by speed for each of four time periods (the AM peak [7:15 a.m. - 8:15 a.m.], mid-day [8:15 a.m. - 4:45 p.m.], the PM peak [4:45 p.m. - 5:45 p.m.], and overnight [5:45 p.m. - 7:15 a.m.]).

POLFAC5 is one of a series of programs developed by TTI to facilitate the estimation of mobile source emissions. It is used to in conjunction with MOBILE5 to obtain emissions rates for three pollutants (volatile organic compounds [VOC], carbon monoxide [CO], and nitrogen oxide [NOx]) for a range of speeds (i.e., 3 mph through 65 mph) for each of eight vehicle types.

Estimation of Temperatures by Time-of-Day

Temperatures for 24-hour periods and Reid Vapor Pressure (RVP) data are provided by the Texas Natural Resource Conservation Commission (TNRCC) for the three summer months (June, July, and August). The average of the minimum and maximum temperature of the 24-hour temperatures for these three months is used as low and high temperature of the season. The temperature for the four time-of-day periods is calculated by averaging the temperatures in the same time period. The low, high, and ambient temperatures for the 24-hour period and the four time-of-day time period temperatures for each Metropolitan Statistical Area (MSA) are shown in Tables 18 and 19.

TABLE 18
MSA Temperature Ranges

MSA	Low	High	Ambient	Future RVP
Austin	74.6	93.6	87.3	7.8
Dallas	74.0	92.3	86.2	7.8
Fort Worth	74.0	92.3	86.2	7.8
Longview	73.0	91.6	85.4	7.8
San Antonio	75.9	93.2	87.5	7.8

TABLE 19
MSA Temperatures by Time Period

MSA	Time Period			
	AM Peak	Mid-Day	PM Peak	Overnight
Austin	77.9	88.0	91.3	80.2
Dallas	78.1	88.5	91.2	79.9
Fort Worth	78.1	88.5	91.2	79.9
Longview	78.2	88.1	88.9	77.5
San Antonio	78.0	88.5	92.3	81.1

MOBILE5 Setups
Emissions rates for each of the eight EPA vehicle types for a range of speeds are prepared using MOBILE5 24-hour diurnal and four time-of-day time period setups for each rural county. The only difference between the 24-hour diurnal setups and the four time periods for each analysis year is the temperature. The best available vehicle age distribution data is used. No inspection and maintenance (I/M) or anti-tampering program (ATP) credits are assumed. For forecast years, the national low emitting vehicle standard emissions rates (NLEV) are applied to LDGV, and the 2004 nationwide diesel standard is assumed. Tier 2 adjustments are applied to the resulting emissions estimates.

Emissions Estimates
For each county and analysis year, the mobile source emissions for each of the four time periods are computed and combined, along with diurnal emissions estimates, into a 24-hour emissions estimate. MOBILE5 emissions factors are applied to HPMS and speed model data. HPMS data includes centerline miles, lane miles, and VMT for each county. VMT, speed, and distance (lane miles) are combined with average V/C ratio for each HPMS area type, functional classification,

and direction, for each time period. In this way, area type, functional classification, and direction constitute virtual links with distinct speeds, capacities, V/C ratios, and VMT. VMT mix varies by roadway functional classification group.

Tier 2 adjustments are applied separately using EPA guidance (MOBILE5 Information Sheet #8, EPA420-F-00-001, April 2000).

VALIDATION

The Beaumont-Port Arthur area link-based emissions estimates for three pollutants (VOC, CO, and NOx) used to validate this procedure are summarized in Table 20. Comparisons for Longview are presented in Table 21, and comparisons for Austin are presented in Table 22.

TABLE 20
Comparison of Link- versus HPMS-Based Emissions Estimate for the Beaumont-Port Arthur Three-County Area 1990 (Emissions in Tons Per Day)

Category	VMT	Link-Based Average Speed	Link-Based	HPMS-Based Average Speed	HPMS-Based	% Difference
VOC	10,099,149	36.0	29.35	39.6	30.33	3.34%
NOx			42.33		44.54	5.22%

TABLE 21
Comparison of Link- versus HPMS-Based Emissions Estimate for the Longview Area 1990 (Emissions in Tons Per Day)

Category	VMT	Link-Based Average Speed	Link-Based	HPMS-Based Average Speed	HPMS-Based	% Difference
VOC	3,582,793	34.1	10.99	36.2	11.08	0.82%
NOx			13.78		15.00	8.85%

TABLE 22
Comparison of Link- versus HPMS-Based Emissions Estimate for the Austin Area 1990
(Emissions in Tons Per Day)

Category	VMT	Link-Based Average Speed	Link-Based	HPMS-Based Average Speed	HPMS-Based	% Difference
VOC	30,083,310	36.4	89.68	40.4	95.55	6.55%
NOx			101.64		109.78	8.01%

The Beaumont-Port Arthur area counties are ideal for this comparison because they include rural and low-density urban counties. Most rural counties do not have a link-based travel model available, so such comparisons are not possible. From this comparison, it is clear that the HPMS-based emissions estimation method captures the combined link-based emissions in the aggregate relatively well.

At the time this work was done MOBILE6 was not available consequently no evaluation of the procedure using MOBILE6 has been performed. An evaluation of the procedure using MOBILE6 will be performed in the summer of 2001 by TTI. Please contact the authors for these results.