APPENDIX F

Baltimore Area MOBILE Source Emissions Technical Support Document

An Explanation of Methodology

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INTRODUCTION

The purpose of this technical document is to explain how Maryland estimates emissions from highway vehicles for inclusion in its emission inventories and State Implementation Plans (SIP).

Highway Vehicle Emissions Inventory

The operation of highway vehicles has proven to be a significant contributor to air pollution, particularly to ground-level ozone, as they emit both VOCs and NOx during operation. Ground-level ozone is not created directly rather, it is formed through a chemical reaction between VOCs and NOx in the presence of sunlight. Given that both VOCs and NOx are emitted from the operation of highway vehicles, Maryland's ozone-related emission inventory efforts have been focused on these pollutants.

Estimating the emission rate and activity levels of all vehicles on the road during a typical summer day is a complicated endeavor. If every vehicle emitted the same amount of pollution all the time, one could simply multiply those emission standards (emission rate in grams of pollution per mile) times the number of miles driven (activity level) to estimate total emissions. But, the fact is that emission rates from all vehicles vary over the entire range of conditions under which they operate. These variables include air temperature, speed, traffic conditions, operating mode (started cold? started warm?) and fuel. The inventory must also account for non-exhaust or evaporative emissions. In addition, the fleet is composed of several generations, types of vehicles and their emission control technologies, each of which performs differently. This requires that the composition of the fleet (vehicle ages and types) must also be included in the estimation algorithm.

In order to estimate both the rate at which emissions are being generated and to calculate vehicle miles traveled (activity level), Maryland examines its road network and fleet to estimate vehicle activity. For ozone-related inventories, this is done for a typical summer weekday. For CO and PM emission inventories, this may be done for a typical winter weekday or annual conditions. Not only must this be done for a baseline year, but it must also be projected into the future. This process involves a large quantity of data and is extremely complex.

Computer models have been developed to perform these calculations by simulating the travel of vehicles on the State's roadway system. These models then generate emission rates (or emission factors) for different vehicle types for area-specific conditions and then combine them in summary form. The "area-specific conditions" include vehicle and highway data, plus control measure characteristics and future year projections of all variables.

Overview of Methodology

EPA guidance documents were used to develop the base and future year emissions inventories for the Baltimore Nonattainment Area. They include:

- Policy *Guidance on the Use of MOBILE6 for SIP Development ad Transportation Conformity*, US EPA Office of Air and Radiation, dated January 18, 2002.
- *Technical Guidance on the Use of MOBILE6 for Emission Inventory Preparation*, US EPA Office of Air and Radiation, and Office of Transportation and Air Quality, dated January 2002.

- *User's Guide to MOBILE 6.1 and MOBILE6.2, Mobile Source Emission Factor Model*, EPA420-R-02-028, dated October 2002.

Mobile source emission factors were calculated using EPA's MOBILE6.2 emission model. The methodologies used to produce the emission results conform to the recommendations provided in EPA's Technical Guidance. Local data has been used for the primary data items that have a significant impact on emissions. For this submission, local data inputs to the analysis process reflect the latest planning assumptions based on 2005 data. These include:

- VMT and speeds
- Vehicle type mixes
- Vehicle age distributions/diesel sales fractions
- Seasonal adjustments
- Hourly distributions
- Temperatures/humidity/barometric pressure
- Inspection/Maintenance parameters
- Fuel program characteristics.

The analysis methodology is consistent with past statewide inventory efforts including the 2002 National Emissions Inventory (NEI) submission. A detailed methodology that addresses the key input data sources and analysis tools used for the Baltimore Area inventory is provided in below.

To complement this document, attachments have been provided with additional detail regarding the analysis methodology and the MOBILE6.2 input parameters. These include:

Table 1 Summary of Attachments

Title	Description
MOBILE6.2 Input Parameter Summary	Provides summary of input parameters related to traffic data sources, fuel, weather, I/M, and other MOBILE6.2 related parameters.
MOBILE6.2 Sample Input File	Provides examples of the MOBILE6.2 input files.

ANALYSIS PROCESS AND TOOLS

The Baltimore Area inventory analysis utilizes several key software/programs for producing the county emissions totals. These tools are outlined in Table 2.

Table 2 Summary of Inventory Analysis Tools

Tool	Purpose
MOBILE6.2	Produces emission factors for each pollutant in Grams/Mile for VOC and NOx
PPSUITE	Processes the highway data, Calculates hourly congested speeds for each state roadway segment, Prepares MOBILE6.2 input files, Processes MOBILE6.2 output files

MOBILE6.2

The heart of the highway vehicle emission calculation procedure is EPA's highway vehicle emission factor model, MOBILE. This is a FORTRAN program that calculates **average** in-use fleet emission factors for ozone precursors for each of twenty-eight categories of vehicles under various conditions affecting in-use emission levels (e.g., ambient temperatures, average traffic speeds, gasoline volatility) as specified by the model user. MOBILE produces the "emission rates" referred to in the previous section.

The Baltimore Area inventory reflects the highway mobile source emission estimations using EPA's MOBILE6.2 emission model. The latest version of MOBILE6.2 is a major revision based on new test data and accounts for changes in vehicle technology and regulations. In addition, the model includes an improved understanding of in-use emission levels and the factors that influence them resulting in significantly more detailed input data. As compared to previous MOBILE versions, MOBILE6.2 has a significant impact on the emission factors, benefits of available control strategies, effects of new regulations, and corrections to basic emission rates.

PPSUITE

The Baltimore region also uses a post processor named PPSUITE (formerly named PPAQ - Post Processor for Air Quality), which consists of a set of programs that perform the following functions:

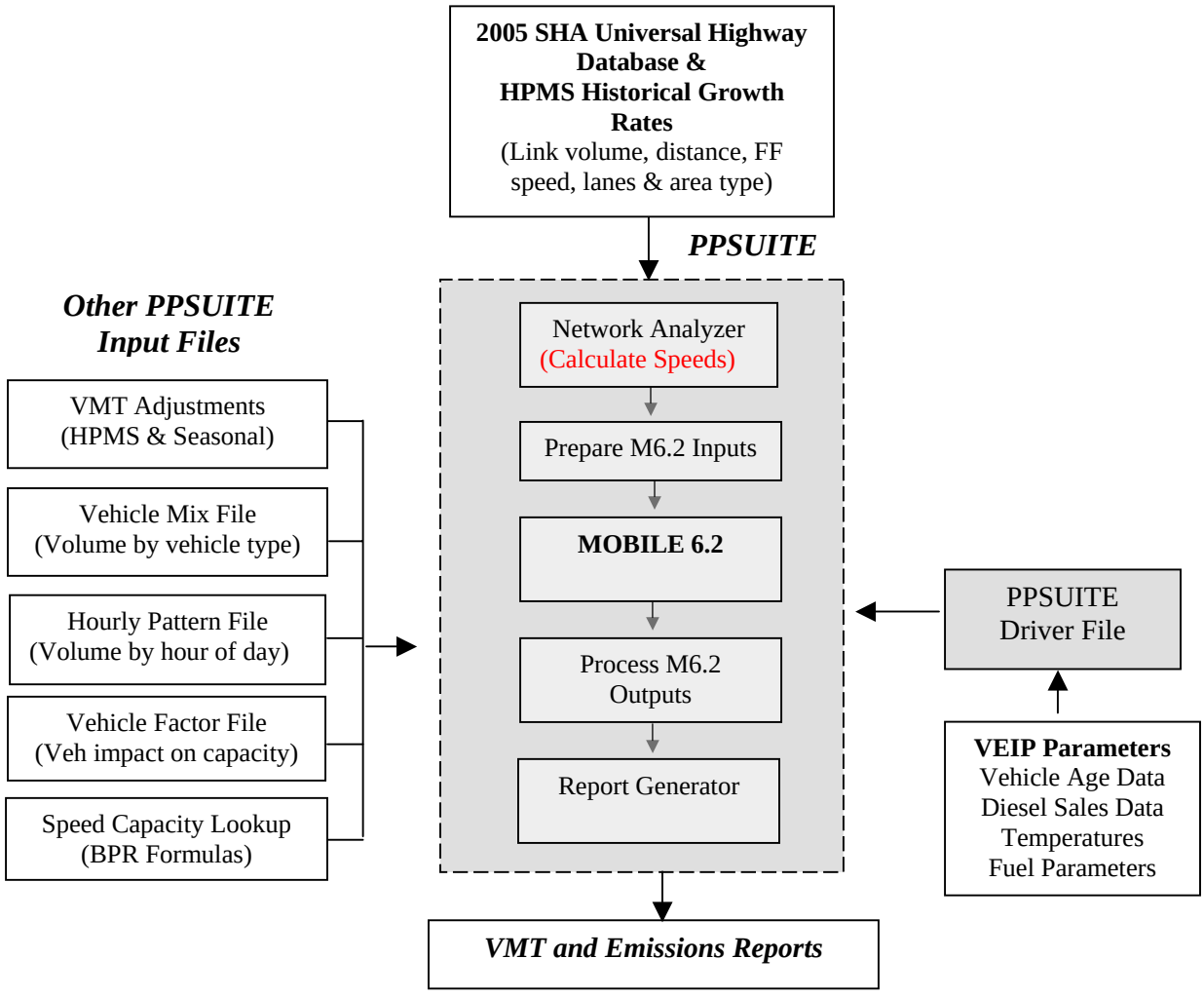
1. Analyzes highway operating conditions
2. Calculates highway speeds
3. Compiles vehicle miles of travel (VMT) and vehicle type mix data
4. Prepares MOBILE6.2 runs
5. Calculates emission quantities from output MOBILE6.2 emission rates and accumulated highway VMT.

PPSUITE has become a widely used and accepted tool for estimating speeds and processing MOBILE emission rates. It is currently being used in other states including Maryland, Pennsylvania, New York City, New Jersey, Louisiana, Virginia, and Indiana. The software is based upon accepted transportation engineering methodologies. For example, PPSUITE utilizes speed and delay estimation procedures based on planning methods provided in the 2000 Highway Capacity Manual, a report prepared by the Transportation Research Board (TRB) summarizing current knowledge and analysis techniques for capacity and level-of-service analyses of the transportation system.

PPSUITE plays a key role in the development of hourly roadway speed estimates, which are supplied as input to the MOBILE6.2 model. The software is also used to prepare the MOBILE6.2 input shell and to process the MOBILE6.2 outputs.

These two computer programs interact as shown in Figure 1.

Figure 1 Emission Calculation Process for the Baltimore Region



TRAFFIC DATA SOURCES

This section provides a summary of the key input data and analysis tools used for producing the Baltimore area emissions inventory. The key elements to the modeling protocol are described in the sections below.

Roadway Data

The roadway data input to emissions calculations for the Baltimore ozone non-attainment region uses information from the 2005 SHA highway database obtained directly from SHA and is referred to as the "Universal" highway database and named as "HMIS2005_Max.MDB". This data contains information on all state highways and arterials, most of the major collectors, and some minor collector and local roadways divided into links of varying lengths. Each of these link segments contains descriptive data that is used in the calculation of the congested speeds input to the MOBILE6.2 emissions model. The PPSUITE post processor calculates the congested speeds based on the following model network fields:

1. Number of Lanes
2. Distances
3. Volumes in Average Annual Daily Traffic (AADT)
4. Facility Type
5. Area Type (Urban/Rural)
6. Link free-flow speeds
7. Zones to relate each link to the county in which it belongs

SHA volumes and distances are used in calculating highway VMT totals for each county. As discussed in the next section, adjustments are needed to convert the volumes to an average July weekday. Lane and capacity values are an important input for determining the congestion and speeds for individual highway segments. Truck volumes are used in the speed determination process and are used to split volumes to the individual vehicle types used by the MOBILE6.2 software.

SHA data classifies its road segments by function, in addition to whether it is located in an urban or rural area, as indicated below in Figure 2. The urban/rural (UR) and functional classes (FC) are important indicators of the type and function of each roadway segment. The variables provide insights into other characteristics not contained in the SHA data that are used for speed and emission calculations. In addition, VMT and emission quantities are aggregated and reported using both UR and FC codes.

Figure 2 SHA-Based Process Classification Scheme

Urban/Rural and Facility Type Codes

Urban/Rural Code	1=Urban
	2=Rural

Functional Class	Rural Functional Classes Used For Rural Areas	Urban Functional Classes Used For Urban Areas
	1=Rural Freeway	11=Urban Freeway
	2=Rural Other Principal Arterial	12=Urban Expressway
	6=Rural Minor Arterial	14=Urban Principal Arterial
	7=Rural Major Collector	16=Urban Minor Arterial
	8=Rural Minor Collector	17=Urban Collector
	9=Rural Local	19=Urban Local

Additions and Adjustments to Roadway Data

Before the SHA data can be used by PPSUITE for speed and emission calculations, several adjustments and additions must be made to the roadway data.

HPMS Adjustments: According to EPA guidance, baseline inventory VMT computed from the 2005 SHA database must be adjusted to be consistent with Highway Performance Monitoring System (HPMS) VMT totals. Although it has some limitations, the HPMS system is currently used in all 50 states and is being improved under FHWA direction.

Adjustment factors are calculated which adjust the 2005 SHA data to be consistent with the 2005 HPMS data. 2005 HPMS adjustments are calculated as factors and are carried forward for future year runs. These factors are developed for each county, urban/rural code and facility group combination.

Seasonal Adjustments to Volumes: The 2005 SHA database contains volumes that represent an average of all days in the year including weekends and holidays. An ozone emission analysis, however, is based on a typical July weekday. Therefore, those volumes must be seasonally adjusted. Seasonal factors were developed for each functional class and urban/rural code using the traffic flow data available by day and month from *ATR Station Reports in the Traffic Trends System Report Module* from the SHA website These factors are applied to the existing SHA AADT volumes to produce the July volumes.

Additional Network Information: The PPSUITE software system allows for many additional variables other than those available in the SHA database. Using these variables improves the ability of Maryland to incorporate real roadway conditions into its estimates. The variables include information regarding signal characteristics and other physical roadway features that can affect a roadway's calculated congested speed. PPSUITE's ability to estimate congested speeds by road segment improves Maryland's emissions inventories because of the overwhelming role speed plays in emission rates. If specific information regarding these variables is known or obtained for areas, this information can be appended to the SHA database. Otherwise, default values are assumed based on information provided by the PPSUITE input speed / capacity lookup data, as described below.

Speed / capacity lookup data provides PPSUITE with initial (free-flow with no congestion) speeds and capacities for different urban/rural code and functional class groupings. The initial speeds and capacities are used by PPSUITE in determining the final congested speed for each roadway segment. Speeds can also be significantly impacted by traffic signals and other roadway features. As a result, this data provides default signal densities (average number of signals per mile for different functional classes), as well as default values for variables that determine the decay of speed with varying levels of congestion. As discussed above, values from the speed/capacity data can be overridden for specific links by directly

coding values to the roadway database segments. The speed / capacity data was developed from a combination of sources including the following:

1. Information contained in the 2000 Highway Capacity Manual
2. SHA information on speeds and signal densities
3. Engineering judgment

24-hour Pattern Data: Speeds and emissions vary considerably depending on the time of day (because of temperature) and traffic volumes, which may cause congestion. Therefore, it is important to estimate the pattern by which roadway volume varies by hour of the day. The 24-hour pattern data provides PPSUITE with information used to split the daily roadway segment volumes to each of the 24 hours in a day. Pattern data is in the form of a percentage of the daily volumes for each hour. Distributions are provided for each county and functional class grouping. This data was developed from the *Traffic Trends System Report Module* from the SHA website.

Vehicle Type Pattern Data: *Vehicle Type Mix* is a key input that has significant impacts on emissions. The vehicle mix data is used in combination with diesel sales fractions by MOBILE6.2 to develop a composite emission rate for all 28 output vehicle types. The vehicle mixes are input to PPSUITE as hourly distributions of vehicles by vehicle type.

The Vehicle Mix Pattern was based on the latest version of BMC's truck model which was calibrated to SHA count data. The functional classes from BMC data are different and thus were mapped to the 12 functional classes used within the SHA based emission process.

Basic emission rates may differ by vehicle type. These types are listed below in Figure 3.

Figure 3 MOBILE6.2 Vehicle Classes

MOBILE6.2 Input		Composite Vehicle Classes
1.	LDV	- Light-Duty Vehicles (Passenger Cars)
2.	LDT1	- Light-Duty Trucks 1 (<6,000 lbs)
3.	LDT2	- Light-Duty Trucks 2 (<6,000 lbs, LVW=3,751-5,750)
4.	LDT3	- Light-Duty Trucks 3 (6,001-8,500 lbs)
5.	LDT4	- Light-Duty Trucks 4 (6,001-8,500 lbs, LVW>5,751)
6.	HDV2B	- Class 2b Heavy Duty Vehicles
7.	HDV3	- Class 3 Heavy Duty Vehicles
8.	HDV4	- Class 4 Heavy Duty Vehicles
9.	HDV5	- Class 5 Heavy Duty Vehicles
10.	HDV6	- Class 6 Heavy Duty Vehicles
11.	HDV7	- Class 7 Heavy Duty Vehicles
12.	HDV8A	- Class 8a Heavy Duty Vehicles
13.	HDV8B	- Class 8b Heavy Duty Vehicles
14.	HDBS	- School Buses
15.	HDBT	- Transit and Urban Buses
16.	MC	- Motorcycles

MOBILE summary reports by vehicle type are also useful in knowing what kinds of vehicles generate emissions. The vehicle type pattern data is used by PPSUITE to divide the hourly roadway segment volumes to the sixteen MOBILE6.2 (MOBILE5 had eight) vehicle types. Similar to the 24-hour pattern data, this data contains percentage splits to each vehicle type for every hour of the day. The vehicle type pattern data was developed from several sources of information:

- Vehicle Mix Patterns for light-duty vehicles, heavy-duty vehicles, buses and motorcycles based on latest version of BMC's truck model.
- MOBILE6.2 default vehicle type break downs for the analysis year(s)

The vehicle type pattern data is developed for each county and functional class combination. Using the percentage volumes for light-duty vehicles, heavy-duty vehicles, buses and motorcycles by county, functional class grouping based on latest version of BMC's truck model, the total roadway volume for any segment could be divided to these four vehicle type categories. However, these percentages do not yet enable volumes to be divided to each of the sixteen MOBILE6.2 vehicle types. As a result, MOBILE6.2 default vehicle type breakdowns are then used to divide the four categories, calculated above, to each specific MOBILE6.2 vehicle type. Note that the defaults used vary by analysis year; as a result, each forecast year will utilize a unique vehicle mix distribution. SHA hourly distributions for trucks and total traffic are then used to create vehicle type percentage breakdowns for each hour of the day.

Vehicle Type Capacity Analysis Factors: Vehicle type percentages are provided to the capacity analysis section of PPSUITE to adjust the speeds in response to trucks. That is, a given number of larger trucks take up more roadway space than a given number of cars, and this must be accounted for in the model. Capacity is adjusted based on the factors provided in this data. Values are developed from information in the 2000 Highway Capacity Manual and are specific to the various facility types.

Producing Future Year Volumes

Traffic growth forecasting plays a pivotal role in estimating future year emissions for the region. In the past, separate factors were derived for each county and highway functional class based on 1990-2002 HPMS VMT data. The factors were then applied to base year traffic volumes (in this case 2002) on each highway segment in the SHA network database. This inventory utilizes growth rates based on new 2005 HPMS VMT data.

The resulting forecasting system includes the development of VMT forecasts and growth rates for the total of 12 functional classifications including urban and rural area types for each of the six Baltimore counties. The forecasts use statistical relationships based on historic HPMS VMT trends. The following table summarizes the assumed projected growth of VMT for future analysis year.

Table 3 Baltimore Area VMT Growth Assumptions

Analysis Year	Total Growth From 2002	Annualized Growth From Previous Analysis Year
2002	-----	-----
2009	10.96%	1.57%

MOBILE6.2 INPUT DATA

Overview of Emission Rates

Two major types of information are written into the MOBILE6.2 model by EPA: basic emission rates and travel weighting rates. EPA's Office of Mobile Sources obtains this information from a number of sources, including its new vehicle certification program, in-use vehicle random sample studies and special studies (including information from some state I/M programs). For more information on MOBILE, a user's guide and various documents (as well as the model itself) are available through EPA's website (http://www.epa.gov/OMSWWW/models.htm).

Basic emission rates are those which are produced under very standardized conditions. The model then modifies (corrects and/or weights) these rates based on other model or input parameters. Rates are incorporated for model year and vehicle type. MOBILE also calculates the EPA-estimated increase in emissions rates as vehicles accumulate mileage.

In addition to exhaust emissions, evaporative VOC emission sources from gasoline-powered vehicles are also included[1]:

1. Diurnal emissions (evaporated gasoline emissions generated by the rise in temperature over the course of a day when the vehicle is not being driven),
2. Hot soak emissions (evaporated gasoline emissions occurring after the end of a vehicle trip, due to the heating of the fuel, fuel lines, fuel vapors),
3. Running loss emissions (evaporated gasoline emissions occurring while a vehicle is driven, due to the heating of the fuel and fuel lines),
4. Resting loss emissions (small but continuous seepage and minor leakage of gasoline vapor through faulty connections, permeable hoses and other materials in the fuel system).

Evaporative emissions are very dependent on temperature and fuel volatility as well as vehicle model year.

Research has found that newer cars tend to be driven more. The model reflects this, using state-specific vehicle age distributions from registration data. The model also contains assumptions about trips per day and miles per day by age of the vehicle. This is important for exhaust emissions because these emissions are greater when the vehicle is not warmed up (cold start). Also, this information helps characterize evaporative emissions.

[1] Some states use MOBILE to estimate refueling emissions (gasoline vapor emissions generated by the refueling of vehicles, where in the absence of controls the vapor in the vehicle fuel tank is displaced by the incoming liquid fuel and released to the atmosphere). Maryland includes these emissions in the area source inventory.

Local Inputs to MOBILE6.2

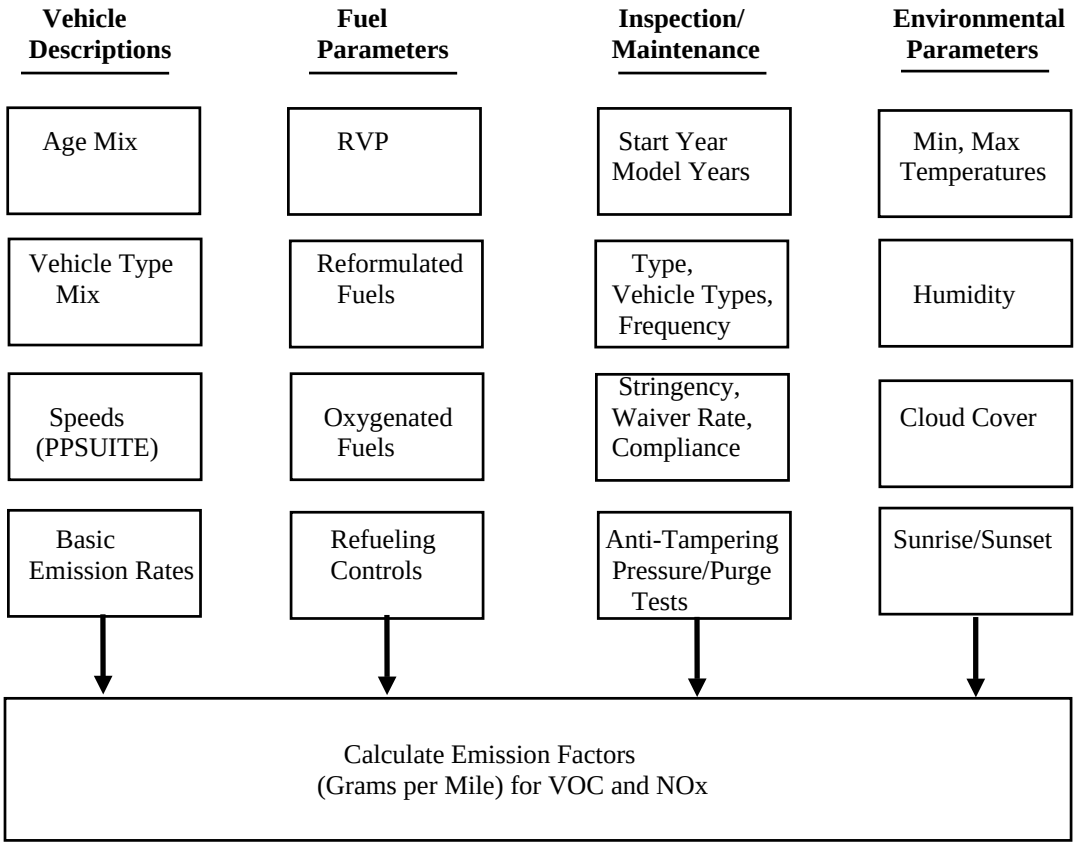
Federal Programs

Federal vehicle emissions control and fuel programs are incorporated into the MOBILE6.2 software. The programs include:

- The Federal Motor Vehicle Control Program (FMVCP) including the National Low Emission Vehicle Program (NLEV) and federal Tier II / Low Sulfur Fuel Program;
- Emissions standards for medium and heavy duty vehicles in 2002, 2004 and 2007;
- Stage II and Onboard Refueling Vapor Recovery (ORVR)[2].

A large number of inputs to MOBILE6.2 are needed to fully account for the numerous vehicle and environmental parameters that affect emissions including traffic flow characteristics (as determined from the PPSUITE software), vehicle descriptions, fuel parameters, inspection/maintenance program parameters, and environmental variables as shown in Figure 4. With some input parameters, MOBILE6.2 allows the user to choose default values, while others require area-specific inputs.

Figure 4 MOBILE6.2 Inputs



[2]*Maryland considers emissions from refueling operations an area source category. While MOBILE6.2 is employed to calculate emissions factors for that source category, refueling emissions are not included in highway vehicle emissions estimations.*

For an emissions inventory, area-specific inputs are used for all of the items shown in **Error! Reference source not found.** except for the basic emission rates, which are MOBILE6.2 defaults. In addition, Maryland uses the MOBILE6.2 default starts-per-day data and soak distributions that are used to calculate the number of starts in cold and hot start modes. EPA requires that the number of starts occurring per vehicle be determined from instrumented vehicle counts. Since such local data is not available, the MOBILE6.2 national defaults are used for the Maryland analyses. A vehicle will generate more emissions when it is first operated (cold start). It generates emissions at a different rate when it is stopped and then started again within a short period of time (hot start). Soak distributions are used to determine the time between when an engine is turned off to the next time it is restarted.

Vehicle Descriptions

Vehicle Age Distributions are input to MOBILE6.2 for the Baltimore region based on registered vehicles reflecting July 1 summer conditions. The data is obtained from the Maryland Motor Vehicle Administration's vehicle registration database. These distributions reflect the percentage of vehicles in the fleet up to 25 years old and are listed by the 16 MOBILE6.2 vehicle types. The Vehicle Type Mix for Baltimore region was based on the latest version of BMC's truck model which was calibrated to SHA count data. (See also the discussion of Vehicle Type Pattern Data in the next section). Speeds are discussed extensively in the next section.

Significant changes have occurred in the MOBILE6.2 model as compared to previous releases. Some of the information previously applied by the post processor after running MOBILE can now be input directly to the MOBILE6.2 model run. This includes information on the hourly distribution of VMT and the hourly speeds that occur during the day. Another important change in MOBILE6.2 is the influence of facility type on output emission factors. For example, MOBILE6.2 assumes that an average speed on a freeway results in a different emission factor than the same speed on an arterial roadway. Thus MOBILE6.2 is indirectly accounting for the accelerations and decelerations that typically occur on such roadways. MOBILE6.2 has four distinct facility types: Freeway, Arterial, Local, and Ramp. For any emission analysis, the input functional classes to be analyzed must be mapped to the above facility types. The following mapping scheme was used for the Maryland runs:

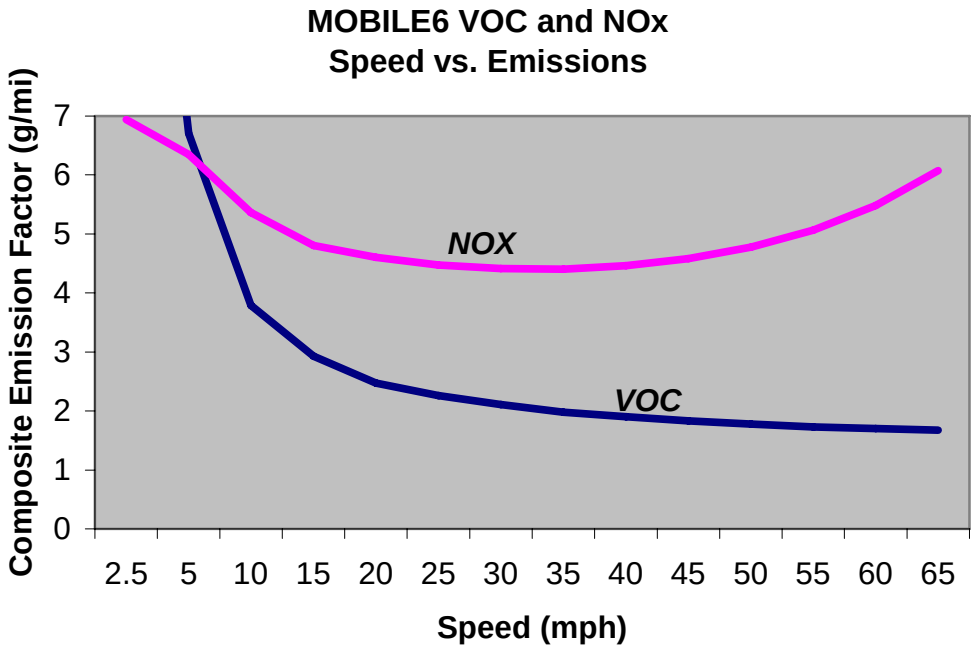
Maryland Functional Classes	***MOBILE6.2 Facility Type***
1,11,12	Freeway
2,6,7,8,14,16,17	Arterial
9,19	Local

Since ramps are not directly represented within the SHA highway database information, it is assumed that 8% of the Freeway VMT is Ramp VMT. This is consistent with the recommendations provided in EPA's Technical Guidance on the Use of MOBILE6.2 for Emissions Inventory Preparation.

Emission and Speed Relationships. Of all the user-supplied input parameters, perhaps the most important is vehicle speed. Emissions of both VOC and NOx vary significantly with speed, but the relationships are not linear, as shown in Figure 5. While VOCs generally decrease as speed increases, NOx decreases only at the low speed range and increases steeply at higher speeds.

To obtain the best estimate of vehicle speeds, Baltimore uses the PPSUITE set of programs, whose primary function is to calculate speeds and to organize and simplify the handling of large amounts of data needed for calculating speeds and for preparing MOBILE6.2 input files.

Figure 5 MOBILE6.2 Speed and Emissions Curves



Fuel Parameters

The same vehicle will produce different emissions using a different type of gasoline. Fuel control strategies can be powerful emission reduction mechanisms. An important variable in fuels for VOC emissions is its evaporability, measured by Reid Vapor Pressure.

MOBILE6.2 allows the user to choose among conventional, federal reformulated, oxygenated and low Reid Vapor Pressure (RVP) gasoline. Maryland chooses the MOBILE6.2 inputs appropriate to the year, season, and control strategy for the area being modeled. The Baltimore region uses reformulated gasoline with a RVP of 6.8.

MOBILE6.2 also allows users to calculate refueling emissions, the emissions created when vehicles are refueled at service stations. Maryland includes refueling emissions in its area source inventory and not in its highway vehicle inventory. However, that calculation uses a grams per gallon emission rate generated by MOBILE6.2.

Vehicle Emission Inspection/Maintenance Parameters (VEIP)

MOBILE6.2 allows users to vary inputs depending on the I/M program in place for the particular analysis year. The inputs include:

- program start year
- stringency level
- first and last model years subject to the program
- waiver rates
- compliance rates

- program type (test-only, test-and-repair, etc.) and effectiveness
- frequency of inspection (annual, biennial)
- vehicle type coverage
- test type (idle, loaded, etc.)
- pass/fail standards or "cutpoints"
- technician training program

Baltimore area uses VEIP program for years beyond 2002 and the program parameters include:

Table 4 Summary of VEIP Program Parameters

Model Years	Program Parameters
1996 & newer	OBDII
1977-1983 (Light-Duty) 1977-2050 (Heavy-Duty)	Idle
1984-1995	IM240
1977-1983	ATP

Some cutpoints (the emissions at which vehicles are failed) are contained in MOBILE6.2, while others must be put in by the model user. Maryland uses the parameters specific for the geographic area and year for which the modeling is being performed.

Environmental Parameters

Evaporative emissions are influenced significantly by the temperatures of the surrounding air. Hourly temperature, absolute humidity and barometric pressure assumptions have been compiled for the Baltimore region based on information from the National Weather Service's meteorological stations. A summary of the weather data inputs used for the emissions inventory is shown in Table 5 and also the detailed MOBILE6.2 input file is attached with the submission.

Table 5 Summary of Weather Data

Weather Data	Data Used
Hourly Temperatures	74.61 77.35 79.61 81.20 82.68 83.79 84.33 84.91 85.04 84.88 83.93 82.40 80.11 77.98 76.67 75.58 74.51 73.78 72.87 71.93 71.36 71.22 70.81 71.81
Relative Humidity	81.00 74.48 68.58 63.65 61.00 58.42 58.00 56.58 56.84 56.74 58.77 62.81 68.13 73.26 76.16 77.94 80.77 81.90 84.61 85.90 87.06 87.90 88.35 87.10
Barometric Pressure	29.83
Cloud Cover	M6 Default (0%)
Peak Sun	M6 Default
Sunrise / Sunset	M6 Default (6 9)

SPEED/EMISSION ESTIMATION PROCEDURE

The previous sections have summarized the input data used for computing speeds and emission rates for Baltimore non-attainment region. This section explains how PPSUITE and MOBILE6.2 use that input data to produce emission estimates. Figure 6 on the following page summarizes PPSUITE's analysis procedure used for each of the nearly 15,000 roadway links in the region.

Producing an emissions inventory with PPSUITE requires a process of disaggregation and aggregation. Data is available and used on a very small scale -- individual ½ mile roadway segments for each of the 24 hours of the day. This data needs to first be aggregated into categories so that a reasonable number of MOBILE6.2 scenarios can be run, and then further aggregated and/or re-sorted into summary information that is useful for emission inventory reporting.

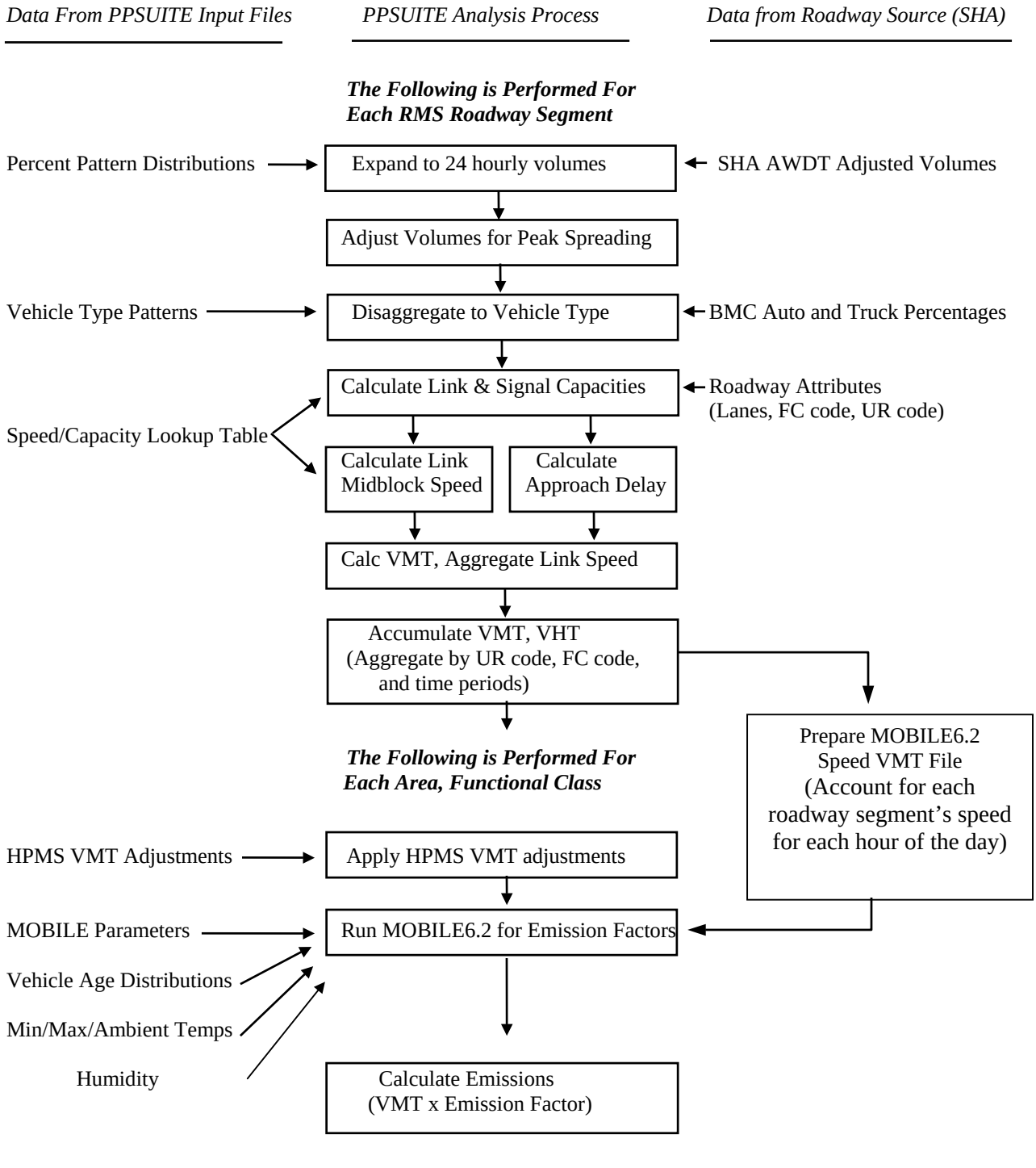
One of the major enhancements of MOBILE6.2 is the increased detail of traffic that can be input to the emissions model. The PPSUITE post processor calculates hourly speeds for each roadway segment. Since previous versions of MOBILE only allowed one average speed as input for each scenario, the post-processed speeds had to be aggregated and run through MOBILE with scenarios representing four separate time periods. MOBILE6.2 allows for direct input of the 24 hourly speeds as well as options to account for each link's speed separately. These added features utilize the full extent of the information output from the speed processing programs and provide for more accurate emission estimates of the available traffic data.

Volume/VMT Development

Before speeds can be calculated and MOBILE6.2 run, volumes acquired from SHA data must be adjusted and disaggregated. Such adjustments include factoring to future years, seasonal adjustments, and disaggregating daily volumes to each hour of the day and to each of the sixteen MOBILE6.2 vehicle types.

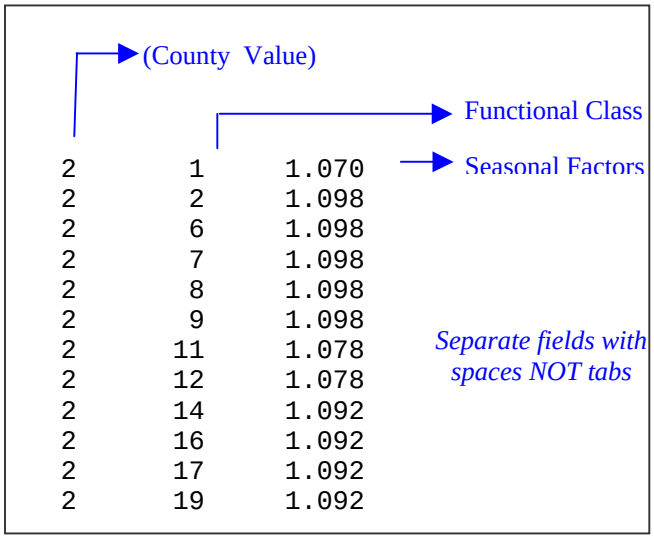
Future Year Volumes: The SHA database contains up-to-date current year volumes. However, to produce inventory forecasts, emission budgets, and conduct conformity analyses, these volumes must be factored to the year being analyzed. The historical growth factors have been prepared for each county and functional class grouping based on 2005 HPMS VMT. These growth factors are applied to the base year 2005 SHA volumes to obtain future year estimates that can be utilized by PPSUITE.

Figure 6 PPSUITE Speed/Emission Estimation Procedure



Seasonal Adjustments: PPSUITE takes the input daily volumes from SHA which represent AADT and seasonally adjusts the volumes to an average weekday in July. This adjustment utilizes factors developed for each functional class and urban/rural code. The above factors are coded into ASCII files, which are input to PPSUITE in the format shown in **Figure 7**. VMT can then be calculated for each link using the adjusted weekday volumes.

Figure 7 Sample Summer Seasonal Factor File

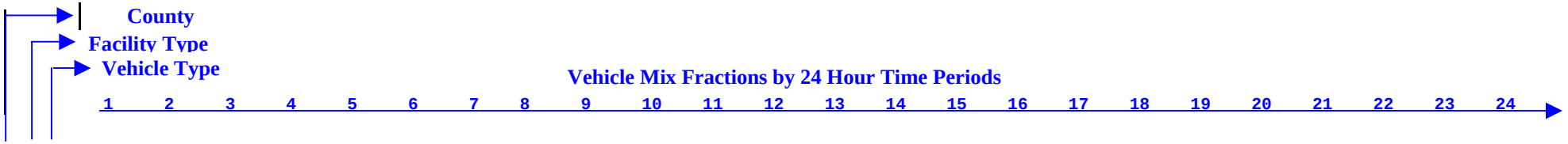


Disaggregation to 24 Hours: After seasonally adjusting the link volume, the volume is split to each hour of the day. This allows for more accurate speed calculations (effects of congested hours) and allows PPSUITE to prepare the hourly VMT and speeds for input to the MOBILE6.2 model.

After dividing the daily volumes to each hour of the day, PPSUITE identifies hours that are unreasonably congested. For those hours, PPSUITE then spreads a portion of the volume to other hours within the same peak period, thereby approximating the "peak spreading" that normally occurs in such over-capacity conditions.

Disaggregation to Vehicle Type: EPA requires VMT estimates to be prepared by vehicle type, reflecting specific local characteristics. As a result, for Baltimore area's emission inventory runs, the hourly volumes are disaggregated to the sixteen MOBILE6.2 vehicle types based on SHA class count data and BMC's truck model in combination with MOBILE6.2 defaults. The hourly volumes by four vehicle categories are contained in the vehicle pattern file which is an ASCII file with free format. A sample of the vehicle mix file is provided in Figure 8.

Figure 8 Sample Vehicle Mix File




```
2  1 1  0.68  0.95  1.18  1.12  0.84  0.41  0.27  0.24  0.26  0.32  0.36  0.35  0.34  0.31  0.27  0.22  0.19  0.17  0.18  0.22  0.27  0.29  0.36  0.44
2  1 2 70.73 61.41 53.12 50.41 64.42 80.48 86.35 89.18 87.71 83.63 81.73 81.74 82.47 83.32 85.54 88.01 90.50 92.17 91.63 89.95 88.66 87.32 84.40 79.05
2  1 3  1.03  1.64  1.95  2.21  1.64  1.06  0.92  0.79  0.92  1.22  1.13  1.08  1.07  1.16  0.94  0.77  0.63  0.45  0.44  0.48  0.47  0.46  0.53  0.71
2  1 4 27.56 36.00 43.75 46.26 33.10 18.05 12.46  9.79 11.11 14.83 16.78 16.83 16.12 15.21 13.25 11.00  8.68  7.21  7.75  9.35 10.60 11.93 14.71 19.80
2  2 1  0.42  0.57  0.53  0.49  0.32  0.21  0.17  0.15  0.18  0.21  0.26  0.33  0.34  0.35  0.30  0.23  0.25  0.22  0.24  0.26  0.25  0.23  0.23  0.27
2  2 2 82.16 74.76 66.40 65.00 77.73 85.89 87.69 88.73 86.79 83.95 83.19 83.61 83.94 84.59 86.22 88.54 90.37 92.20 92.12 92.25 92.23 92.10 91.50 88.36
2  2 3  0.67  1.18  1.53  1.32  1.00  0.67  0.66  0.70  0.92  1.07  1.00  0.95  0.85  0.88  0.81  0.64  0.54  0.35  0.33  0.39  0.31  0.37  0.36  0.51
2  2 4 16.75 23.49 31.54 33.19 20.95 13.23 11.48 10.42 12.11 14.77 15.55 15.11 14.87 14.18 12.67 10.59  8.84  7.23  7.31  7.10  7.21  7.30  7.91 10.86
2  6 1  0.49  0.45  0.68  0.44  0.25  0.23  0.20  0.13  0.13  0.17  0.23  0.25  0.24  0.25  0.21  0.25  0.22  0.22  0.25  0.31  0.35  0.24  0.27  0.21
2  6 2 90.81 86.17 78.70 77.28 82.16 86.47 88.78 90.32 88.65 85.84 84.44 85.61 86.15 85.82 87.59 89.71 92.24 94.04 94.44 94.44 94.56 95.09 94.32 93.57
2  6 3  0.54  0.60  1.18  0.76  0.63  0.45  0.79  0.75  1.13  1.16  1.16  1.13  1.14  1.24  1.36  0.93  0.57  0.24  0.26  0.14  0.18  0.17  0.35  0.35
2  6 4  8.16 12.78 19.44 21.52 16.96 12.85 10.23  8.80 10.09 12.83 14.17 13.01 12.47 12.69 10.84  9.11  6.97  5.50  5.05  5.11  4.91  4.50  5.06  5.87


2 16 1  0.26  0.33  0.33  0.24  0.20  0.20  0.22  0.19  0.16  0.18  0.22  0.25  0.24  0.25  0.23  0.20  0.21  0.18  0.19  0.20  0.24  0.21  0.23  0.23
2 16 2 93.81 91.93 89.03 87.13 88.23 90.26 90.77 91.96 91.25 90.50 90.03 90.52 91.12 90.70 91.12 92.03 93.45 94.86 95.56 95.70 95.86 96.00 95.80 94.33
2 16 3  0.67  0.78  1.04  0.89  0.84  1.06  1.06  1.04  1.16  1.01  0.92  0.98  0.95  0.98  1.13  0.94  0.72  0.48  0.41  0.39  0.33  0.34  0.41  0.66
2 16 4  5.26  6.96  9.60 11.74 10.73  8.48  7.95  6.81  7.43  8.31  8.83  8.25  7.69  8.07  7.52  6.83  5.62  4.48  3.84  3.71  3.57  3.45  3.56  4.78
2 17 1  0.56  0.45  0.75  0.44  0.37  0.45  0.37  0.37  0.29  0.35  0.35  0.37  0.37  0.33  0.32  0.36  0.37  0.40  0.35  0.43  0.37  0.36  0.37  0.25
2 17 2 91.98 90.99 85.70 82.07 85.67 89.80 90.83 91.78 91.65 90.36 90.36 91.22 91.49 91.77 91.93 92.69 93.96 95.03 95.72 95.87 96.10 95.78 95.25 95.13
2 17 3  0.85  0.70  1.77  1.43  1.50  1.01  1.14  1.12  0.95  0.93  0.90  0.78  0.84  0.71  0.81  0.80  0.54  0.39  0.37  0.33  0.35  0.46  0.55  0.65
2 17 4  6.61  7.86 11.78 16.06 12.46  8.74  7.66  6.73  7.11  8.36  8.39  7.63  7.30  7.19  6.94  6.15  5.13  4.18  3.56  3.37  3.18  3.40  3.83  3.97
2 19 1  0.94  0.97  0.95  1.29  1.79  0.41  0.64  0.49  0.41  0.43  0.39  0.44  0.52  0.70  0.70  0.54  0.76  0.50  0.62  0.57  0.46  0.51  0.46  0.70
2 19 2 95.31 93.94 92.71 90.42 90.06 93.16 93.53 94.70 94.15 93.51 93.48 93.60 94.37 93.53 93.85 94.26 95.68 96.38 96.50 96.21 97.38 97.65 97.45 97.11
2 19 3  0.69  0.65  0.67  1.48  0.99  1.15  0.68  0.78  1.02  0.78  0.89  0.96  0.69  1.30  0.77  1.08  0.42  0.28  0.22  0.23  0.24  0.20  0.19  0.42
2 19 4  3.06  4.44  5.67  6.81  7.16  5.28  5.15  4.03  4.42  5.28  5.24  5.00  4.42  4.47  4.68  4.12  3.14  2.84  2.66  2.99  1.92  1.64  1.90  1.77
```

Speed/Delay Determination

EPA recognizes that the estimation of vehicle speeds is a difficult and complex process. Because VOC and NOx emissions are so sensitive to speeds, the agency recommends special attention be given to developing reasonable and consistent speed estimates; it also recommends that VMT be disaggregated into subsets that have roughly equal speed, with separate emission factors for each subset. At a minimum, speeds should be estimated separately by roadway functional class.

The computational framework used for this analysis meets and exceeds that recommendation. Speeds are individually calculated for each roadway segment and hour and include the delays encountered at signals. Rather than accumulating the roadway segments into area/functional groupings and calculating an average speed (as done in past), each individual link hourly speed is represented in the MOBILE6.2 speed VMT file. This represents a significant enhancement in the MOBILE model since past versions only allowed input of one average speed for each scenario. MOBILE6.2 allows the input of a distribution of hourly speeds. For example, if 5% of a county's arterial VMT operate at 5 mph during the AM peak hour and the remaining 95% operate at 55mph, this can be represented in the MOBILE6.2 speed input file. For the Baltimore runs, distributions of speeds are input to MOBILE6.2 for separate scenarios representing county and functional class groupings; VMT is accumulated by the same groupings for the application of the emission factors to produce resulting emission totals.

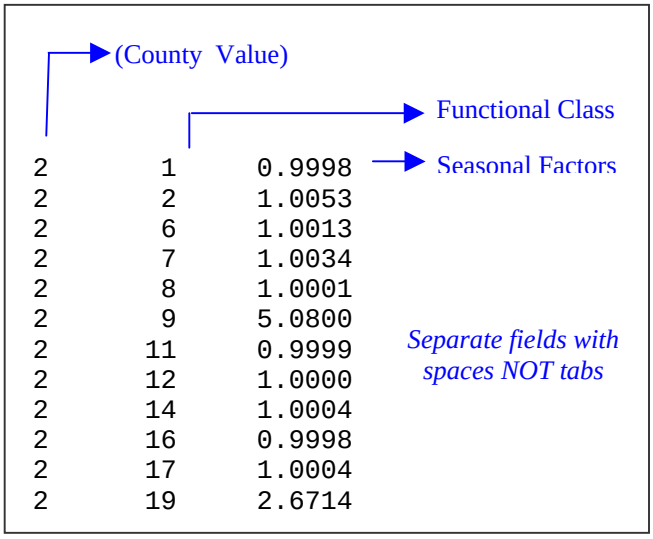
To calculate speeds, PPSUITE first obtains initial capacities (how much volume the roadway can serve before heavy congestion) and free-flow speeds (speeds assuming no congestion) from the speed/capacity lookup data. As described in previous sections, this data contains default roadway information indexed by the urban/rural code and functional class.

The result of this process is an estimated average travel time for each hour of the day for each highway segment. The average time can be multiplied by the volume to produce vehicle hours of travel (VHT).

HPMS and VMT Adjustments

Volumes must also be adjusted to account for differences with the HPMS VMT totals, as described previously. VMT adjustment factors are provided as input to PPSUITE, and are applied to each of the roadway segment volumes. These factors were developed from historical growth rates and 2005 HPMS data; however, they are also applied to any future year runs. The VMT added or subtracted to the SHA database assumes the speeds calculated using the original volumes for each roadway segment for each hour of the day. The HPMS factors are coded into ASCII files, which are input to PPSUITE in the format shown in Figure 9.

Figure 9 Sample HPMS Adjustment File



VMT and Speed Aggregation

As discussed in previous sections, MOBILE6.2's ability to handle input distributions of hourly speeds has eliminated the need to aggregate speed data. For the Baltimore runs, PPSUITE has been set up to automatically accumulate VMT and VHT by geographic area and highway functional class. The speed files input to MOBILE6.2 for each scenario contain the actual distribution of roadway speeds for that aggregation group. Figure 10 illustrates the scenario aggregation scheme used with MOBILE6.2.

Figure 10 VMT Aggregation Scheme

VMT/VHT Aggregation Scheme

County	1=Baltimore City 2=Baltimore County 5=Harford County	2=Anne Arundel County 4=Carroll County 6=Howard County	6 entries
Urban/Rural Code	1=Urban 2=Rural		
Functional Class	1=Rural Freeway 2=Rural Other Principal Arterial 6=Rural Minor Arterial 7=Rural Major Collector 8=Rural Minor Collector 9=Rural Local	11=Urban Freeway 12=Urban Expressway 14=Urban Principal Arterial 16=Urban Minor Arterial 17=Urban Collector 19=Urban Local	12 entries
			72 potential combinations

Geographic aggregation is performed by urban and rural areas of each county. Functional class aggregation is according to 12 functional classes respecting urban and rural definitions . For an individual county, this creates a potential for 12 possible combinations, each of which becomes an input MOBILE6.2 scenario. This allows each MOBILE6.2 scenario to represent the actual VMT mix and speed for that geographic / highway combination. Altogether then, there are potentially 72 combinations for which speeds and VMT are computed and emissions are calculated with MOBILE.

MOBILE6.2 Emissions Run

After computing speeds and aggregating VMT and VHT, PPSUITE prepares input files to be run in EPA's MOBILE6.2 program which is used to produce VOC and NOx emission factors in grams of pollutant per vehicle mile. The process uses an unmodified version of the MOBILE program that was obtained directly from EPA.

The MOBILE6.2 input file prepared by PPSUITE contains the following:

- MOBILE template containing appropriate parameters and program flags
- Temperature data specific to the county and season being run
- Vehicle age and diesel sales fraction data for the county being run
- Scenario data - contains VMT mix, speed distributions specific to scenario as produced by PPSUITE

Time of Day and Diurnal Emissions

Unlike in the past using MOBILE5, VMT and speeds are no longer aggregated as separate scenarios representing time periods. This was done in the past to account for the unique speeds encountered during each time period in the day. Since MOBILE6.2 allows for hourly roadway speeds to be represented in the speed VMT file, such a process is no longer needed. MOBILE6.2 will internally account for the emissions during each hour in the day and make the necessary diurnal calculations.

Process MOBILE6.2 Output

After MOBILE has been run, PPSUITE processes the MOBILE6.2 output files and compiles the emission factors for each scenario. Using the above methodology, it allocates daily diurnal emissions to each of the time periods. Using the MOBILE6.2 emission factors, PPSUITE calculates emission quantities by multiplying the emission factors by the aggregated VMT totals. PPSUITE then produces an emissions database summarizing VMT, VHT, VOC, and NOx emissions.

RESOURCES

Draft Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations, EPA, June, 2003

Consolidated Emissions Reporting, Federal Register, June 10, 2002

User's Guide to MOBILE6.1 and MOBILE6.2, Mobile Source Emission Factor Model, EPA420-R-02-028, dated October 2002.

Technical Guidance on the Use of MOBILE6.2 for Emission Inventory Preparation, US EPA Office of Transportation and Air Quality, August 2004.

Policy Guidance on the Use of MOBILE6 for Emission Inventory Preparation, US EPA Office of Air and Radiation, January 18, 2002.

Modeling Page within EPA's Office of Mobile Sources Website (http://www.epa.gov/omswww/models.htm) contains a downloadable model, MOBILE users guide and other information. It also contains documents relating to the next version of MOBILE (MOBILE6.2) expected in 1999.

"AP-42" document, "Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources," as updated by Supplement A (January 1991), available in hard-copy only. This material is also in the process of being revised and updated. Contact AP-42 Project, Test and Evaluation Branch, EPA, 2565 Plymouth Road, Ann Arbor, MI 48105.

Highway Vehicle Emission Estimates (June 1992) and *Highway Vehicle Emission Estimates II* (May 1995) discusses how EPA obtains data for MOBILE and some of the shortcomings in earlier models. Similar discussions of the present version's shortcomings are discussed in papers available at the website.

Traffic Engineering

2000 Highway Capacity Manual, Transportation Research Board, presents current knowledge and techniques for analyzing the transportation system.

2005 Traffic Volume Maps By County, Highway Information Services Division, Maryland State Highway Administration

Truck Volumes Maps By County 2000-2005, Highway Information Services Division, Maryland State Highway Administration

"Universal" Highway Database "HMIS2005_Max.MDB", Maryland State Highway Administration

*ATR Station Reports, Traffic Trends System Report Modul*e, Maryland State Highway Administration website