APPENDIX C-1

Scranton/Wilkes-Barre Area
An Explanation of Methodology

Explanation of Methodology
May 2012

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INTRODUCTION

The purpose of this document is to explain how the Pennsylvania Department of Environmental Protection (Department) estimates emissions from highway vehicles for inclusion in its emission inventories and State Implementation Plans.

Overview of Emissions Inventories

The Department's inventories generally categorize emissions into four categories:

- Highway vehicles.
- Stationary sources (major industrial, commercial and utility sources).
- Area sources (smaller industrial/commercial sources, consumer products).
- Nonroad mobile sources (including construction and agricultural equipment, lawn and garden equipment).

An evaluation of emissions from point, area, and mobile sources is needed to develop a complete inventory needed for a maintenance demonstration plan. This documentation addresses the mobile source activity and emissions for base and future years used to support such a demonstration.

Of all of the sources of air pollution, only the emissions of some stationary sources are measured directly and continuously through instrumentation. Emissions from all other sources must be modeled based on available local data, including those from highway vehicles. In their very simplest form, estimates of emissions follow the following pattern:

Emission rate x activity level = emissions per time period (usually day or year)

Most emission rates have been developed by the U.S. Environmental Protection Agency (EPA), in cooperation with industry and states, and are compiled and documented into key references or emission models. These include Compilation of Air Pollution Emission Factors (AP-42), the Motor Vehicle Emission Simulator (MOVES) model, and the NONROAD model. Adding up the products of the emission rates and activity levels for all sources of a given pollutant constitutes the emission inventory for that pollutant.

Highway Vehicle Emission Inventories

Highway vehicles contribute significantly to air pollution, particularly to ground-level ozone, which is the most persistent air pollutant in Pennsylvania. Ground-level ozone is not emitted directly to the atmosphere, but is formed by photochemical reactions between volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) in the presence of sunlight. The long, hot, humid days of summer are particularly conducive to ozone formation, so ozone levels are of concern primarily during the months of May through September. Both VOCs and NOx are emitted from highway vehicles. Pennsylvania's ozone-related emission inventory efforts focus on these two types of pollutants.

Obviously, direct measurement of emission levels from all vehicles in use is impossible. In comparison to highway vehicles, estimating residential heating emissions is a fairly simple calculation because there is a constant emission rate and a fairly simple measure of activity. However, for highway vehicles

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 vehicle miles traveled (VMT) to estimate total emissions. But 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 and fuel characteristics. The inventory must also account for non-exhaust or evaporative emissions. In addition, the fleet is composed of several generations and types of vehicles with different emission control technologies. This requires the estimation algorithm include the composition of the fleet (vehicle ages and types).

In order to estimate both the rate at which emissions are being generated and to calculate vehicle miles traveled (activity level), Pennsylvania examines its road network and fleet to estimate vehicle activity. For ozone-related inventories, this is done for a typical summer weekday. For carbon monoxide (CO) and particulate matter (PM) emission inventories, this may be done for a typical winter weekday, summer weekday and/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 Commonwealth's roadway system. The models also generate emissions rates (also called 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. The key models used to generate this mobile source emissions inventory are:

MOVES: EPA's MOVES model was officially released on March 2, 2010 and was followed with a revised version (MOVES2010a) in August 2010. The MOVES model provides a more robust estimate of emissions as compared to its predecessor MOBILE6.2. MOVES calculates average in-use fleet emissions for each of thirteen 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.

For this mobile source inventory, Pennsylvania used MOVES2010a as approved by EPA. MOVES can be used to estimate national, state, and county level inventories of criteria air pollutants, precursors, greenhouse gas emissions, and some mobile source air toxics from highway vehicles. Additionally, MOVES can make projections for energy consumption (total, petroleum-based, and fossil-based).

PPSUITE: For the Department's highway emissions inventory, a post processor named PPSUITE (formerly named PPAQ - Post Processor for Air Quality) is used, which consists of a set of programs that perform the following functions:

- Analyzes highway operating conditions.
- Calculates highway speeds.
- Compiles vehicle miles of travel (VMT) and vehicle type mix data.
- Prepares MOVES runs and processes MOVES outputs.

PPSUITE is a widely used and accepted tool for estimating speeds and processing emissions rates. The software is based upon accepted transportation engineering methodologies. For example, PPSUITE uses speed and delay estimation procedures based on planning methods provided in the *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.

The PPSUITE process is integral to producing key input files to the MOVES emission model. Exhibit 1 summarizes the key functions of PPSUITE and the traffic-related input files prepared for the MOVES County Data Manager (CDM).

Exhibit 1: Summary of PPSUITE Process
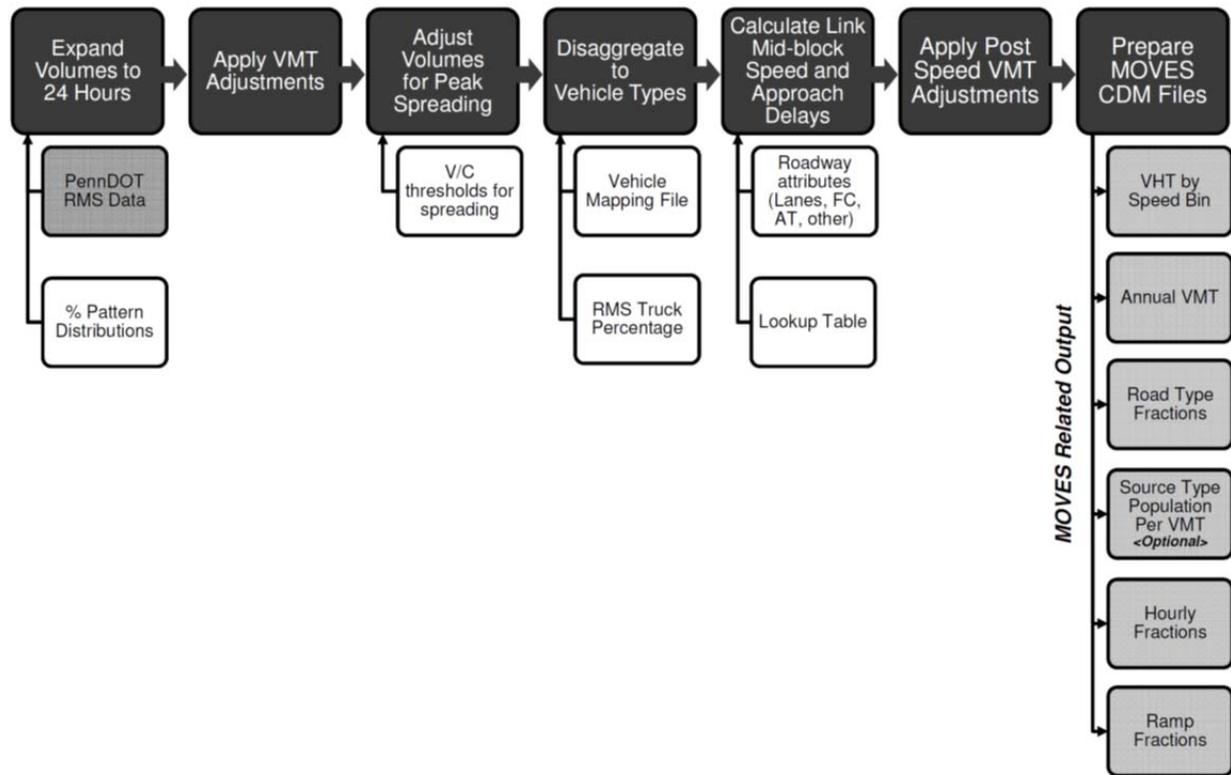
The following sections summarize the key data and methodologies used to produce the mobile source emissions inventory. This includes a summary of local data sources and a step-by-step review of the speed calculation process.   The emission data and process has been developed according to recommendations provided by EPA in key policy and technical guidance as provided below:

- *Policy Guidance on the Use of MOVES2010 for SIP Development, Transportation Conformity, and Other Purposes*, US EPA Office of Air and Radiation, EPA-420-B-09-046, December 2009.

- *Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity*, US EPA Office of Air and Radiation, and Office of Transportation and Air Quality, EPA-420-B-10-023,   April 2010.

The process has focused on developing an emissions inventory using the available tools and data to its fullest extent. This includes the use of available local data for items that have a significant impact on emissions and applying a robust calculation process to estimate hourly traffic speeds.
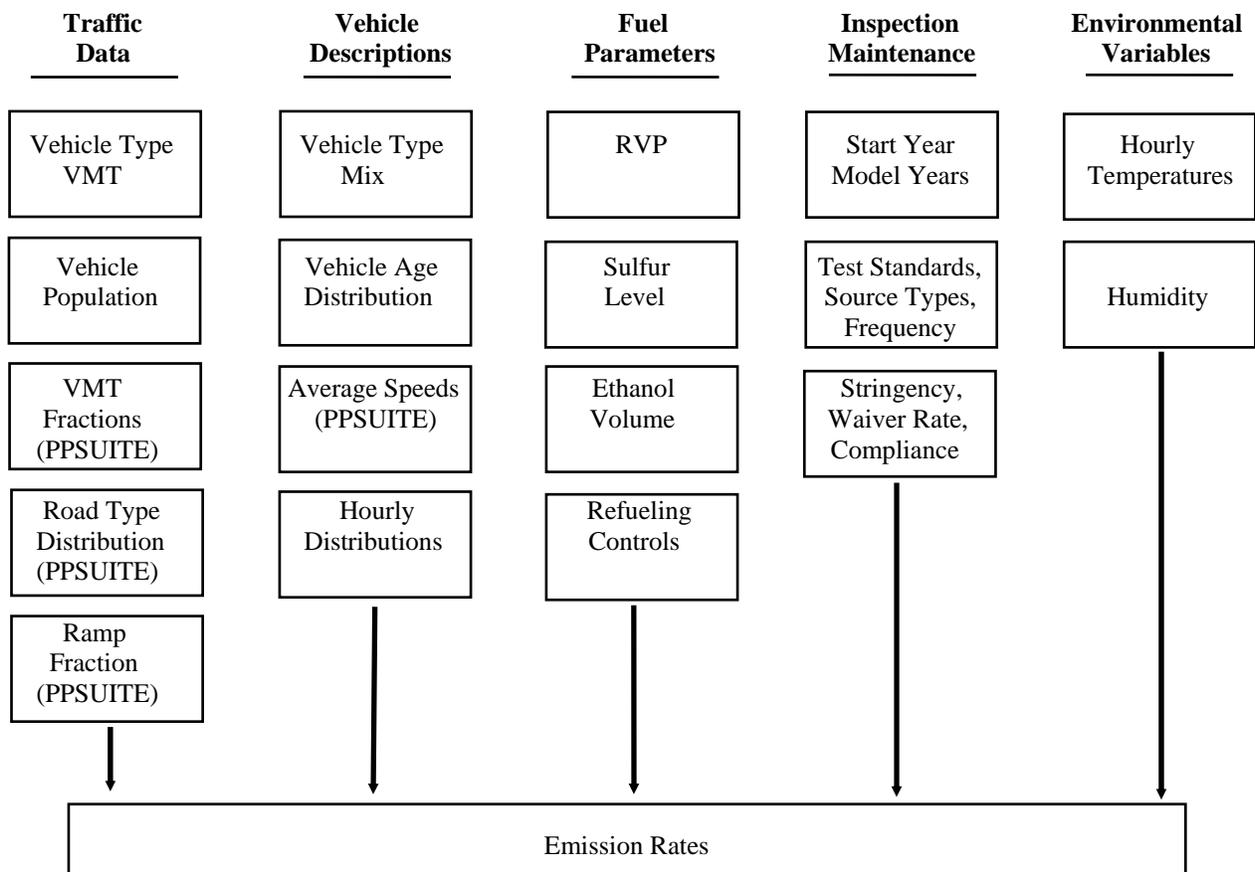
WHERE DOES PENNSYLVANIA OBTAIN ITS DATA?

Summary of MOVES Inputs

A large number of inputs to MOVES are needed to fully account for the numerous vehicle and environmental parameters that affect emissions. These include traffic flow characteristics (as determined from the PPSUITE software), vehicle descriptions, fuel parameters, inspection/maintenance program parameters, and environmental variables. MOVES includes a default national database of meteorology, vehicle fleet, vehicle activity, fuel, and emission control program data for every county; but EPA cannot certify that the default data is the most current or best available information for any specific area. As a result, local data is recommended for use for analyses supporting state implementation plans (SIPs).

A mix of local and default data is used for this inventory. Local data sources are used for all inputs that have a significant impact on calculated emission rates. Exhibit 2 summarizes Pennsylvania-specific inputs assembled and used for this inventory. These data items are discussed in the following sections.

Exhibit 2: MOVES Local Data Input Summary

Traffic Data	Vehicle Descriptions	Fuel Parameters	Inspection Maintenance	Environmental Variables
Vehicle Type VMT	Vehicle Type Mix	RVP	Start Year Model Years	Hourly Temperatures
Vehicle Population	Vehicle Age Distribution	Sulfur Level	Test Standards, Source Types, Frequency	Humidity
VMT Fractions (PPSUITE)	Average Speeds (PPSUITE)	Ethanol Volume	Stringency, Waiver Rate, Compliance	
Road Type Distribution (PPSUITE)	Hourly Distributions	Refueling Controls		
Ramp Fraction (PPSUITE)				

Emission Rates

Vehicle Miles of Travel (VMT)

The VMT input to emissions calculations for Pennsylvania is based on information from the Roadway Management System (RMS) maintained by the Pennsylvania Department of Transportation's (PennDOT's) Bureau of Planning and Research (BPR). PennDOT obtains this information from periodic visual and electronic traffic counts. RMS data is dynamic, since it is continually reviewed and updated from new traffic counts and field visits conducted by PennDOT. Information on roadways included in the National Highway System is reviewed at least annually, while information on other roadways is reviewed at least biennially.

On a triennial basis, a current "snapshot" of the RMS database is taken and downloaded to provide an up-to-date record of the Commonwealth's highway system for estimating emissions. This emissions inventory is based on the most current snapshot of the RMS data.

The RMS database contains all state highways, including the Pennsylvania Turnpike, divided into segments approximately 0.5 miles in length. These segments are usually divided at important intersections or locations where there is a change in the physical characteristics of the roadway (e.g. the number of lanes changes). There are approximately 99,000 state highway segments for the 67 Pennsylvania counties contained in the RMS. Each of these segments contains an abundance of descriptive data, but only the following information is extracted for emission calculations:

- Lanes.
- Distances.
- Volumes representing Average Annual Daily Traffic (AADT).
- Truck percentages.
- PennDOT urban/rural classifications.
- PennDOT functional class codes.
- Number of signals (based on linkage to PennDOT GIS signal location data).

RMS 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 summer weekday, winter weekday, and monthly day. In addition, the traffic volumes must be forecast to support future year emission inventories. Lane values and traffic signals are an important input for determining the congestion and speeds for individual highway segments. Truck percentages are used in the speed determination process and are used to split volumes to individual vehicle types used by the MOVES software.

Road segments are classified by function, as well as whether it is located in an urban, small urban or rural area, as indicated below in Exhibit 3. The PennDOT 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 RMS data that are used for speed and emission calculations.

Exhibit 3: PennDOT Urban/Rural and Functional Class Codes

Urban/Rural Code	1=Rural 2=Small Urban 3=Urban

Functional Class	Rural Functional Classes Used For Rural Areas	Urban Functional Classes Used For Small Urban and 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

Additional Network Information: The PPSUITE software system allows for many additional variables other than those available in the RMS database. Using these variables improves the ability of the Department to incorporate real roadway conditions into its estimates. The variables include information regarding free-flow speeds and capacities, signal characteristics and other physical roadway features that can affect a roadway's calculated congested speed. This data can be determined from lookup tables based on a roadway segment's urban/rural code and functional class. Much of the lookup table data was developed from information contained in the *Highway Capacity Manual*, PennDOT information on speeds and signal densities, and other engineering judgment.

MOVES Traffic Inputs: The PPSUITE software uses RMS traffic data to prepare key inputs to the MOVES emission model including:

- VMT.
- Travel speeds.
- Road type distributions.
- Ramp fractions.

VMT is the primary traffic input that affects emission results. The roadway segment distances and traffic volumes are used to prepare estimates of VMT. PPSUITE performs these calculations and outputs the MOVES annual VMT input file to the County Data Manager (CDM).

Emissions for many pollutants (including both VOC and NOx) vary significantly with travel speed. While VOCs generally decrease as speed increases, NOx decreases at the low speed range and increases at higher speeds, as illustrated in Exhibit 4. To obtain the best estimate of vehicle speeds, the Department 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 MOVES input files. The PPSUITE software prepares the MOVES vehicle hours of travel (VHT) by speed bin file which summarizes the distribution of speeds across all links into each of 16 MOVES speed bins for each hour of the day. This robust process ensures that MOVES emission rates are used to the fullest extent and is consistent with the methods and recommendations provided in EPA's *Technical Guidance on the Use of MOVES2010 for Emissions Inventory Preparation in State Implementation Plans and Transportation Conformity*.

Exhibit 4: Emission Factor vs. Speed Variances (NOx)
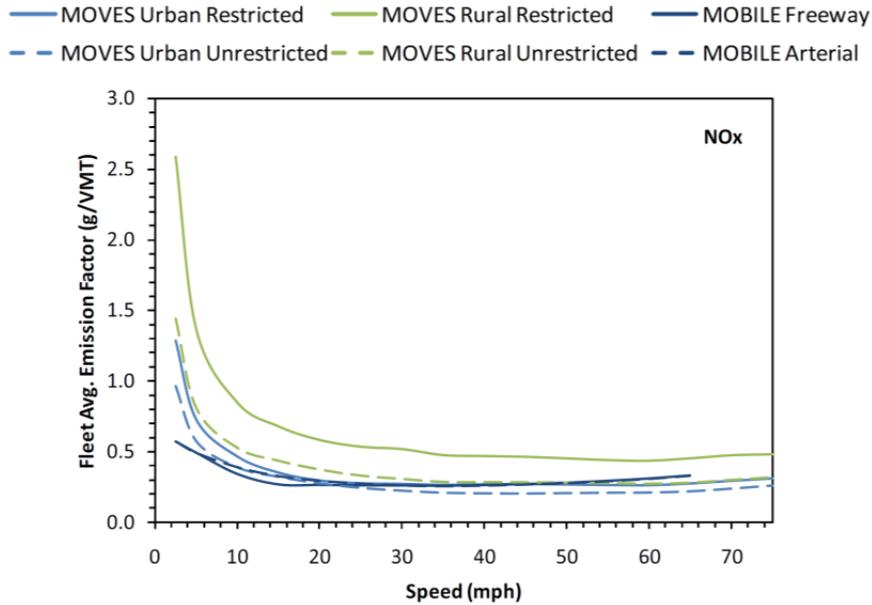
*Source: Figure 3 from Implications of the MOVES2010 Model on Mobile
Source Emission Estimates, Air & Waste Management Association, July 2010.*

In MOVES, typical drive cycles and associated operating conditions vary by the type of roadway. MOVES defines five different road types as follows:

1   Off-Network.
2   Rural Restricted Access.
3   Rural Unrestricted Access.
4   Urban Restricted Access.
5   Urban Unrestricted Access.

The off-network road type includes emissions from vehicle starts, extended idle activity, and evaporative emissions. Off-network activity in MOVES is primarily determined by the Source Type Population input, as discussed in a following section. The remaining distribution among road types is determined by equating the PennDOT functional class with each MOVES road type as follows:

- MOVES Road Type (2) = PennDOT Functional Class (1).
- MOVES Road Type (3) = PennDOT Functional Class (2,6,7,8,9).
- MOVES Road Type (4) = PennDOT Functional Class (11,12).
- MOVES Road Type (5) = PennDOT Functional Class (14,16,17,19).

For this inventory, the MOVES road type distribution file is automatically generated by PPSUITE using the defined equivalencies.

Since ramps are not directly represented within the RMS database information, it is assumed that 8% of the Freeway VHT is Ramp VHT. This is consistent with the recommendations provided in EPA's technical guidance.

Adjustments to Roadway Data

Before the RMS data can be used by PPSUITE for speed and emission calculations, several adjustments and additions must be made to the roadway data. These adjustments are summarized below.

HPMS Adjustments: According to EPA guidance, baseline inventory VMT computed from the RMS highway segment volumes must be adjusted to be consistent with Highway Performance Monitoring System (HPMS) VMT totals. The HPMS VMT reported for Pennsylvania is a subsystem of the RMS established to meet the data reporting requirements of the Federal Highway Administration (FHWA) and to serve as PennDOT's official source of highway information. Although it has some limitations, the HPMS system is currently in use in all 50 states and is being improved under FHWA direction.

Although the HPMS VMT and the roadway data used for an inventory emissions analysis are both based on data from the RMS system, differences do exist between them and include the following. First, the HPMS and inventory roadway data are "snapshots" of the RMS data taken at different times. Since the RMS is dynamic, changing constantly due to new data, differences will result between the data used for calculating HPMS VMT totals and the inventory data used for an emissions analysis. Second, since the RMS does not contain many of the local roadways, <u>local</u> road estimates of HPMS VMT are obtained through alternative procedures developed by PennDOT. To account for such differences, adjustment factors are calculated and used to adjust the inventory roadway data to the reported HPMS VMT totals submitted to FHWA. The VMT contained in the HPMS reports are considered to represent average annual daily traffic (AADT).

Adjustment factors are calculated which adjust the base year RMS download VMT to the reported HPMS totals for that year. These factors are developed for each county and functional class combination and are also applied to all future year runs. Adjustments for the "higher" functional classes (e.g. Freeway, Arterials - major routes) are close to 1.000 since HPMS VMT is derived from RMS information, and the only difference in the data is that the "snapshot" for the emission calculations is taken at a different time than for the HPMS. "Lower" classes (e.g. local roads) require greater adjustment since a large part of the local system is not under state jurisdiction and is not in the RMS database. There is, of course, a significant amount of local road mileage in the state. It is assumed that those local streets that are in RMS are representative of all local streets in their area with respect to volume and speed, so that roadway mileage adjustment is appropriate.

Seasonal Adjustments to Volumes: The RMS contains AADT volumes that are an average of all days in the year, including weekends and holidays. An ozone emission analysis, however, is based on a typical July or summer weekday. PM and CO analyses require volumes representing a typical summer or winter weekday and monthly average conditions (needed for producing annual totals). Therefore, the RMS volumes must be seasonally adjusted. Seasonal factors were developed for each functional class and urban/rural code based on yearly count information prepared by PennDOT's BPR. These factors are applied to the existing RMS AADT volumes to produce the July volumes. The same factors are also used to develop the MOVES daily and monthly VMT fraction files.

Hourly Adjustments: Speeds and emissions vary considerably depending on the time of day. 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 is developed from 24-hour count data compiled by PennDOT's BPR, according to the process in the agencies annual traffic data reports. The same factors are also used to develop the MOVES hourly fraction file.

Traffic Volume Forecasts: Traffic growth forecasting plays a pivotal role in estimating future year emissions for the region. There are many uncertainties affecting projections of traffic growth, including the current economic conditions, potential fuel prices, the impacts of Marcellus Shale activities in many counties throughout the state, and the future growth in population and employment. Growth rates for the Department's emissions inventories are based on an assessment of available data sources which include:

- PennDOT BPR growth rate forecasting system.
- Regional travel model, if available.
- Estimates of Marcellus Shale related activity growth, if applicable.

All SIP mobile source highway inventories include the review and assessment of county-specific growth rates from a PennDOT study originally completed in 2005 and documented in the report, *Statistical Evaluation of Projected Traffic Growth, Traffic Growth Forecasting System: Final Report, March 14, 2005*. As part of that study, a statewide traffic growth forecasting system was developed that incorporates traffic data from PennDOT's Traffic Information System and socioeconomic forecasts. That forecasting system is maintained by the PennDOT BPR and is updated on a periodic basis to develop new statistical relationships between historic VMT growth and population and updated demographic forecasts from Woods and Poole, Inc. The growth rates from the PennDOT BPR forecasting system are evaluated against other available data including travel model growth and other insights.

Vehicle Type Processing

Emission rates within MOVES vary significantly by the type of vehicle. The MOVES model produces emissions and rates by thirteen MOVES vehicle source types. However, VMT is input to MOVES by six HPMS vehicle groups. Exhibit 5 summarizes the distinction between each classification scheme.

Exhibit 5: MOVES Source Types and HPMS Vehicle Groups

SOURCE TYPES		HPMS Class Groups	
11	Motorcycle	10	Motorcycle
21	Passenger Car	20	Passenger Car
31	Passenger Truck	30	Passenger/Light Truck
32	Light Commercial Truck	40	Buses
41	Intercity Bus	50	Single Unit Trucks
42	Transit Bus	60	Combination Trucks
43	School bus		
51	Refuse Truck		
52	Single Unit Short-haul Truck		
53	Single Unit Long-haul Truck		
54	Motor Home		
61	Combination Short-haul Truck		
62	Combination Long-haul Truck		

The process used for this inventory includes a method to disaggregate the RMS traffic volumes to the thirteen source types and then to recombine the estimates to the six HPMS vehicle classes. Vehicle type pattern data is used by PPSUITE to divide the hourly roadway segment volumes to the thirteen MOVES source types. Similar to the 24-hour pattern data, this data contains percentage splits to each source type for every hour of the day. The vehicle type pattern data for this inventory is developed from several sources of information:

- PennDOT truck percentages from the RMS database.
- Hourly distributions for trucks and total traffic compiled by PennDOT's BPR.
- Transit data from PennDOT and the National Transit Database.
- School bus registration data from PennDOT's Bureau of Motor Vehicles Registration Database.

The vehicle type pattern data is developed for each county and functional class combination. First, RMS truck percentages are averaged for all roadways within a county and functional class grouping. Using this percentage data, the total roadway volume for any segment is divided to auto and truck vehicle type categories. The transit data and school bus data is used to further disaggregate trucks, resulting in four vehicle groups (light-duty, school, transit, and other heavy-duty).

From these groups, MOVES default Pennsylvania county VMT distributions by source type are used to divide the four groups into each of the MOVES source types. PennDOT hourly distributions for trucks and total traffic are used to create source 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 is accounted for in the speed estimation process by adjusting capacity using information from the *Highway Capacity Manual*.

Vehicle Fleet and Population Data

The information on the vehicle fleet including the number and age of vehicles has a significant impact on forecasted start and evaporative emissions within MOVES. The MOVES Model requires the population of vehicles by the thirteen source type categories. Pennsylvania county vehicle registration data is used to estimate vehicle population for light-duty vehicles and school buses. The data is split to source types using MOVES2010a default Pennsylvania county population data. For transit buses, data from PennDOT and the National Transit Database (NTD) is used to estimate county transit bus totals. Other heavy-duty vehicle population values are based on VMT for each source type using the vehicle mix and pattern data discussed previously. The PPSUITE software automatically applies default MOVES2010a ratios of VMT and source type population (e.g. the number of miles per vehicle by source type) to the local VMT estimates to produce vehicle population.

Vehicle population is forecast based on projected household and population growth from Woods and Poole Inc. for each Pennsylvania county. The growth rate methodology includes:

- Choosing the highest growth rate between population and households.
- Limiting growth as to not exceed the VMT growth assumptions.

Vehicle Age: Vehicle age distributions are input to MOVES for each county by the thirteen source types. The distributions reflect the percentage of vehicles in the fleet up to 31 years old. The most recent available registration download from PennDOT's Bureau of Motor Vehicles Registration Database has been used for the inventory. Due to insufficient data, only information for light-duty vehicles are used as local inputs; and, heavy-duty vehicles use the internal MOVES2010a national defaults. The registration data download is based on MOBILE6.2 vehicle categories. As a result, the data was converted to source types using the EPA convertor spreadsheets provided with the MOVES2010a emission model.

Environmental, Fuel and Technology Assumptions

Information on environmental, fuel, vehicle technology and other control strategy assumptions were determined based on a review of MOVES2010a default information by the PaDEP.

Fuel Parameters: The same vehicle will produce different emissions using a different type of gasoline. Fuel control strategies can be powerful emission reduction mechanisms. The MOVES2010a default fuel formulation and fuel supply data were reviewed and updated based on available local volumetric fuel property information. The gasohol market penetration and RVP values were updated for all the counties. MOVES2010a default data was used for the rest of the parameters.

Refueling Emissions: MOVES also allows users to calculate refueling emissions, the emissions created when vehicles are refueled at service stations. Pennsylvania includes refueling emissions in its area source inventory and not in its highway vehicle inventory. Refueling emissions are not included in the highway emissions inventory.

Vehicle Emission Inspection/Maintenance (I/M) Parameters: MOVES allows users to vary inputs depending on the I/M program in place for the area. 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.)

The MOVES2010a default Pennsylvania assumptions were reviewed and modifications were made per actual program parameters.

Environmental Variables: Evaporative emissions are influenced significantly by the temperatures of the surrounding air. Hourly temperatures have been compiled for each county based on information from WeatherBank, Inc. to specify temperatures from nine airports within the state. Ozone analysis temperature and humidity values were determined using the procedures documented in EPA's technical guidance. Minimum and maximum temperatures for each month were converted to hourly temperatures using EPA convertors supplied with the MOVES2010a model.

A summary of the MOVES related inputs used for the inventory and future year estimates are attached with the submission.

SPEED/EMISSION ESTIMATION PROCEDURE

The previous sections have summarized the input data used for computing speeds and emissions for Pennsylvania. This section explains how PPSUITE and MOVES uses that input data to produce emission estimates. Exhibit 6 summarizes PPSUITE's analysis procedure used for each of the RMS highway segments in the state.

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 24 hours of the day. This data needs to be processed individually to determine the distribution of vehicle hours of travel (VHT) by speed and then aggregated by vehicle class to determine input VMT to the MOVES emission model.

Volume/VMT Development

Before speeds can be calculated and MOVES run, volumes acquired from RMS 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 thirteen MOVES source types.

Determine Future Year Volumes: The RMS database contains up-to-date current year volumes. However, to conduct a future year analysis, these volumes must be factored to the year being analyzed. Growth factors have been prepared for each county and functional class grouping. These growth factors are applied to the base year RMS volumes to obtain future year estimates that can be utilized by PPSUITE.

Example:

A typical freeway link in the RMS database is I-80 segment 2500 in Luzerne County, Pennsylvania. This link has an urban/rural code=1 which indicates the link is in a rural area, and a functional class=1 indicating a rural freeway.
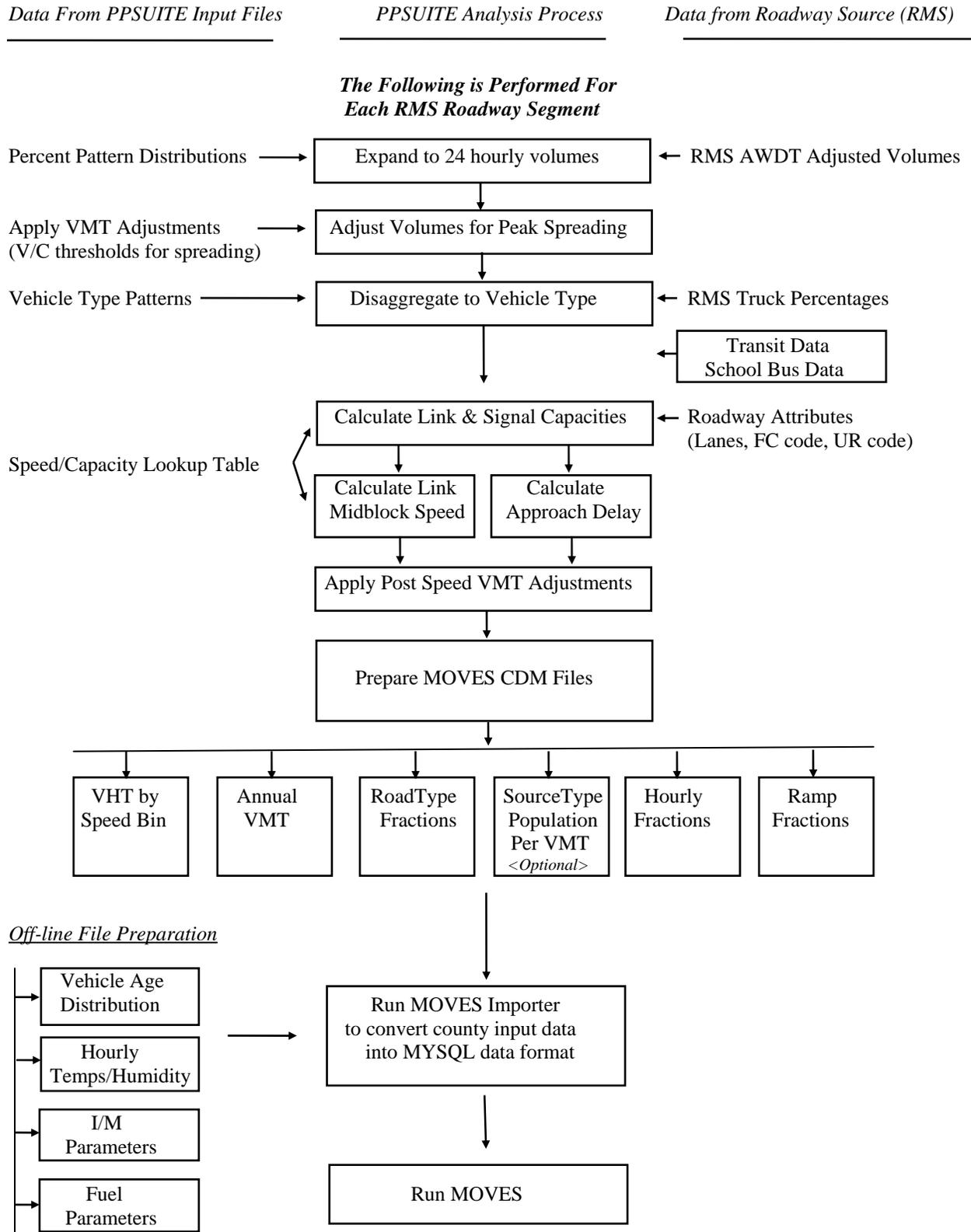
The average annual daily traffic (AADT) from the RMS database for this link in 2008 is 12,077 vehicles/day.

Growth factors have been developed to factor the 2008 volume to future years. For example, to factor the 2008 volume to the year 2014, a growth factor of 1.282 would yield:

2014 volume = 12,077 vehicles/day x 1.282 = 15,483 vehicles/day

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Exhibit 6: PPSUITE Speed / Emission Estimation Procedure

Data From PPSUITE Input Files	*PPSUITE Analysis Process*	*Data from Roadway Source (RMS)*

The Following is Performed For Each RMS Roadway Segment

Percent Pattern Distributions → **Expand to 24 hourly volumes** ← RMS AWDT Adjusted Volumes

Apply VMT Adjustments
(V/C thresholds for spreading) → **Adjust Volumes for Peak Spreading**

Vehicle Type Patterns → **Disaggregate to Vehicle Type** ← RMS Truck Percentages

← **Transit Data / School Bus Data**

Calculate Link & Signal Capacities ← Roadway Attributes (Lanes, FC code, UR code)

Speed/Capacity Lookup Table → **Calculate Link Midblock Speed** | **Calculate Approach Delay**

Apply Post Speed VMT Adjustments

Prepare MOVES CDM Files

| VHT by Speed Bin | Annual VMT | RoadType Fractions | SourceType Population Per VMT *<Optional>* | Hourly Fractions | Ramp Fractions |

Off-line File Preparation

- Vehicle Age Distribution
- Hourly Temps/Humidity
- I/M Parameters
- Fuel Parameters

→ **Run MOVES Importer to convert county input data into MYSQL data format**

Run MOVES

Seasonal Adjustments: PPSUITE takes the input daily volumes from RMS (which represents annual average daily traffic (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. VMT can then be calculated for each link using the adjusted weekday volumes.

Example:

Again, assume the rural freeway link: I-80 segment 2500 in Luzerne County, Pennsylvania. The AADT for this link in 2008 is 12,077 vehicles/day.

Seasonal factors have been developed for urban/rural code and functional class combinations. For an urban/rural code=1 and a functional class=1, the factor to convert from AADT to an average weekday in July is = 1.15.

Average Weekday July Volume = 12,077 x 1.15 = 13,889 vehicles/day.

Total VMT (daily) for this link is calculated as volume x distance. The distance of this link as obtained from RMS is 0.296 miles.

2008 VMT = 13,889 vehicles/day x 0.296 miles = 4,111 vehicle-miles / day.

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 MOVES model.

Example:

To support speed calculations and emission estimates by time of day, the July weekday volume is disaggregated to 24 hourly volumes. Temporal patterns were previously developed from PennDOT count data and input to PPSUITE. For the I-80 rural freeway link with morning peak volumes similar to evening peak hours (neutral), the following temporal pattern is applied:
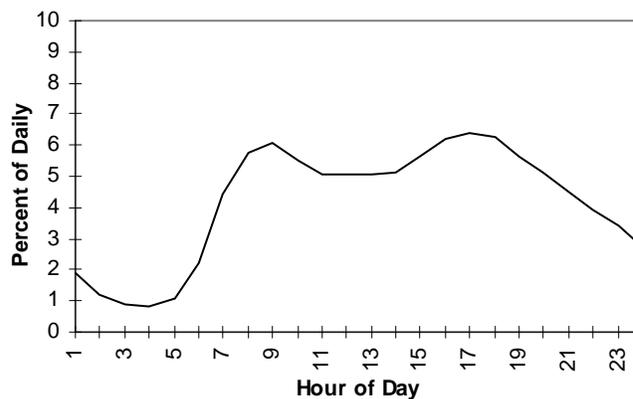
Using the I-80 segment, typical hourly volumes which result include:

8-9 a.m.	6.0% x (4,111 vehicle miles/ 0.296mi.) = 833 vehicles/hour (vph)
12-1 p.m.	5.0% x (4,111 vehicle .miles/ 0.296mi.) = 694 vph
5-6 p.m.	6.3% x (4,111 vehicle miles/ 0.296mi.) = 875 vph

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 source type, reflecting specific local characteristics. As a result, for Pennsylvania's emission inventory runs, the hourly volumes are disaggregated to the thirteen MOVES source types based on count data assembled by PennDOT in combination with MOVES defaults.

Example:

Disaggregation of the total I-80 VMT to the various source types would include the following:

Total Volume 8-9 am = 833 vph

Source Type Volume 8-9 am:

Motorcycle	11	0.5%	4 vph
Passenger Car	21	54.7%	456 vph
Passenger Truck	31	27.9%	232 vph
Light Commercial Truck	32	9.3%	78 vph
Intercity Bus	41	0.1%	1 vph
Transit Bus	42	0.1%	1 vph
School bus	43	0.1%	1 vph
Refuse Truck	51	0.0%	0 vph
Single Unit Short-haul Truck	52	2.2%	19 vph
Single Unit Long-haul Truck	53	0.3%	2 vph
Motor Home	54	0.1%	1 vph
Combination Short-haul Truck	61	1.9%	16 vph
Combination Long-haul Truck	62	2.6%	22 vph

Speed/Delay Determination

EPA recognizes that the estimation of vehicle speeds is a difficult and complex process. Because emissions are so sensitive to speeds, it 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 road type.

The computational framework used for this analysis meets and <u>exceeds</u> 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 a particular road type and calculating an average speed, each individual link hourly speed is represented in the MOVES vehicle hours of travel (VHT) by speed bin file. This MOVES input file allows the specification of a distribution of hourly speeds.

For example, if 5% of a county's arterial VHT operates at 5 mph during the AM peak hour and the remaining 95% operates at 65 mph, this can be represented in the MOVES speed input file. For the model runs, distributions of speeds are input to MOVES by road type and source type by each hour of the day; VMT and VHT 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. For areas with known characteristics, values can be directly coded to the RMS database and the speed/capacity data can be overridden. However, for most areas where known information is not available, the speed/capacity lookups provide valuable default information regarding speeds, capacities, signal characteristics, and other capacity adjustment information used for calculating congested delays and speeds. An effort has been made to enhance the RMS data with traffic signal locations using other GIS signal data available from PennDOT's Bureau of Highway Safety and Traffic Engineering.

Example:

The speed/capacity lookup table is used to obtain important data used for link speed calculations. For the I-80 link with an urban/rural code = 1 (rural) and a functional class = 1 (freeway), the lookup table provides information including the following:

> freeflow speed = 65 mph
> capacity = 1800 vph per lane
> number of signals = 0 (per RMS linkage to GIS traffic signal locations)

This information is used along with the physical characteristics of the roadway to calculate the delay (including congestion) to travel this link during each hour of the day:

For example: The I-80 link is calculated to have a travel time, including delay of 17.76 seconds for the 8-9am hour.

Total travel time, in vehicle hours, for the 8-9am hour is calculated as:

VHT (8-9am) = 17.76 seconds x 833vph / 3600 sec/hr = 4.12 vehicle hours.

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 the latest HPMS download (conducted triennially); however, they are also applied to any future year runs. The VMT added or subtracted to the RMS database assumes the speeds calculated using the original volumes for each roadway segment for each hour of the day.

Example:

Using the Luzerne County I-80 rural freeway link example, the daily assigned volume is adjusted to account for reconciliation with the HPMS VMT. RMS VMT (in AADT) for Luzerne County rural freeways totals 962,559 vehicle miles in 2008. HPMS VMT (in AADT) as supplied by PennDOT and reported to FHWA totals to 990,088 vehicle miles for the rural freeways. A factor is developed by dividing the HPMS VMT by the RMS VMT:

HPMS adjustment factor for Luzerne County rural freeways = 990,088 / 962,559 = 1.029.

This factor is held constant in all future years. As an example, this adjustment is made to the I-80 freeway link VMT for the 8-9am hour after speed calculations are made, and produces the final July weekday VMT for this hour used for Ozone runs.

I-80 Link VMT (8-9am) = 833vph x 0.296 miles x 1.029 = 254 vehicle miles.

MOVES Emissions Run

After computing speeds and aggregating VMT and VHT, PPSUITE prepares traffic-related inputs needed to run EPA's MOVES software, which is used to estimate emission factors in grams of pollutant per vehicle mile and to produce total emissions based on input VMT to the model. The process uses MOVES2010a, the officially released emissions model that was obtained directly from EPA.

The MOVES inputs prepared by PPSUITE include the following:

- Vehicle Type VMT.
- Vehicle Population.
- VMT fractions.
- Average speed distributions.
- Road Type Distribution.
- Ramp Fractions.

These files are text formatted files with a *.csv extension. The files are provided as inputs within the MOVES county data importer. In addition the remaining MOVES input data including temperatures, I/M programs, fuel and vehicle ages are prepared manually outside of the PPSUITE process.

The MOVES county importer is run in batch mode. This program converts all data files into the MYSQL formats used by the MOVES model. At that point a MOVES run specification file (*.mrs) is created which specifies options and key data locations for the run. MOVES is then executed in batch mode.

MOVES can be executed using either the *inventory* or *rate-based* approaches. For this highway emissions inventory, MOVES is applied using the *inventory-based* approach. Under this method, actual VMT and population are provided as inputs to the model; MOVES is responsible for producing the total emissions for the region. Under the rate-based approach, MOVES would produce emission factors, after which PPSUITE would apply the emission factors to the link data and calculate total regional emissions.

RESOURCES

MOVES model

Modeling Page within EPA's Office of Mobile Sources Website
(http://www.epa.gov/omswww/models.htm) contains a downloadable model, MOVES users guide and other information.

Motor Vehicle Emission Simulator, User Guide for MOVES2010a, EPA-420-B-10-036, August 2010.

Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity, US EPA Office of Air and Radiation, and Office of Transportation and Air Quality, EPA-420-B-10-023, April 2010.

Policy Guidance on the Use of MOVES2010 for SIP Development, Transportation Conformity, *and Other Purposes*, US EPA Office of Air and Radiation, EPA-420-B-09-046, December 2009.

Traffic Engineering

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

Traffic Data Collection and Factor Development Report, 2008 Data, Pennsylvania Department of Transportation, Bureau of Planning and Research.

Highway Vehicle Inventory Glossary

AADT: Average Annual Daily Traffic, average of ALL days.

AWDT: Average Weekday Daily Traffic.

Basic emission rates: MOBILE emission rates based on the applicable Federal emission standards and the emission control technologies characterizing the fleet in various model years.

Emission rate or factor: Expresses the amount of pollution emitted per unit of activity. For highway vehicles, usually in grams of pollutant emitted per mile driven.

FC: Functional code, applied in data management to road segments to identify their type (freeway, local, etc.).

Fuel volatility: The ability of fuel components to evaporate, thus entering the atmosphere as pollution. Fuel volatility is usually measured as Reid Vapor Pressure (RVP) in pounds per square inch. The lower the RVP, the less volatile the fuel.

Growth factor: Factor used to convert volumes to future years.

HPMS: Highway Performance Monitoring System, PENNDOT's official source of highway information and a subset of RMS.

I/M: Vehicle emissions inspection/maintenance programs ensure that vehicle emission controls are in good working order throughout the life of the vehicle. The programs require vehicles to be tested for emissions. Most vehicles that do not pass must be repaired.

MOBILE: The model EPA has developed and which Pennsylvania uses to estimate emissions from highway vehicles.

MOVES: The latest model EPA has developed with which Pennsylvania uses to estimate emissions from highway vehicles.

Pattern data: Extrapolations of traffic patterns (such as how traffic volume on road segment types varies by time of day, or what kinds of vehicles tend to use a road segment type) from segments with observed data to similar segments.

PPSUITE: Post-Processor for Air Quality, a set of programs that estimate speeds and processes MOBILE emission rates.

RMS: Roadway Management System, a database maintained by PENNDOT from traffic counts and field visits.

Segment (also referred to as link): Division of roadway in the PENNDOT Roadway Management System. Usually represents 0.5 mile segments of roadway.

UR: Urban/rural code, applied in data management to identify whether a road segment is urban, small urban or rural.

VHT: Vehicle hours traveled.

VMT: Vehicle miles traveled. In modeling terms, it is the simulated traffic volumes times link length.

Vehicle Type: One of eight types, distinguished primarily by fuel type and/or weight, used in MOBILE modeling.

Source Type: One of thirteen types, distinguished primarily by weight, used in MOVES modeling.

Road Type: Functional code, applied in data management to road segments to identify their type (rural/urban highways, rural/urban arterials, etc.)

County Data Manager: User interface developed to simplify importing specific local data for a single county or a user-defined custom domain without requiring direct interaction with the underlying MySQL database.