Appendix E

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Appendix E1

2017 Base Year Mobile Source Emissions Documentation

MOVES3 Model Platform

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Prepared by:

Maryland Department of the Environment

Appendix E1

2017 Base Year Mobile Source Emissions Documentation

MOVES3 Model Platform

State Implementation Plan (SIP)

For the 0.070 ppm National Ambient Air Quality Standard for Ozone

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1.0 ONROAD MOBILE SOURCES

1.1 OVERVIEW

The purpose of this section is to explain how Maryland (MD) estimates emissions from highway vehicles for inclusion in its emission inventories and State Implementation Plans (SIP). This emission inventory relates to the Baltimore ozone non-attainment Area of MD and Cecil County of MD-Philadelphia ozone non-attainment Area for the 2015 Ozone NAAQS.

In accordance with the standard methodology for the development of highway vehicle emissions inventories, all emissions estimates documented herein are based on emission factors developed using the latest version of the United States Environmental Protection Agency's (EPA's) Motor Vehicle Emission Simulator (MOVES/MOVES3.03 version) model. In addition, appropriate traffic input parameters such as vehicle miles traveled (VMT), developed from the vehicle count data maintained by the Maryland Department of Transportation State Highway Administration (MDOT SHA) and vehicle population (VPOP) developed from the vehicle registration data obtained from the Maryland Department of Transportation Motor Vehicle Administration (MDOT MVA), were used in this work.

1.1.1 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 Volatile Organic Compounds (VOCs), and Oxides of Nitrogen (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. Ozone season summertime VOC and NOx emission units for this inventory are in tons per day.

Estimating emission rate and activity levels of all vehicles on the road during a typical day is a complicated endeavor. While running, if every vehicle emitted the same amount of pollution all the time, one could simply multiply emission rates (grams per mile) by the number of miles driven (VMT) to estimate total running emissions. During vehicle starts, (whether cold or hot), if every vehicle emitted the same amount of pollution all the time, one could simply multiply those emission rates (grams per vehicle) times the number of vehicles (VPOP) to estimate total start emissions. But there are many other emissions by processes to account for such as evaporative, extended idling, refueling, spillage, and so on.

The fact is that emission rates from all vehicles vary over the entire range of conditions under which they operate. These variables include ambient air temperature, speed, traffic conditions, road types, road topography, operating mode (whether started cold or started hot, whether accelerating or decelerating) and fuel. 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.

To estimate both the rate at which emissions are being generated and to calculate vehicle miles traveled (VMT), MD examines its road network and fleet to estimate vehicle activity. For the 2017 summer weekday baseline summertime inventory of VOC and NOx, July was chosen as the month of evaluation as per EPA's guidance.

Computer models have been developed to perform these calculations by simulating the travel of vehicles on the Maryland's roadway system. These models then generate emission factors for different vehicle types for specific conditions by jurisdiction and then combine them in a summary form. These conditions include fleet characteristics such as vehicle population and vehicle age distribution, roadway and travel characteristics, meteorology, control programs in place, mandated fuel requirements, etc.

1.1.2 2017 BASELINE EMISSION INVENTORY METHODOLOGY

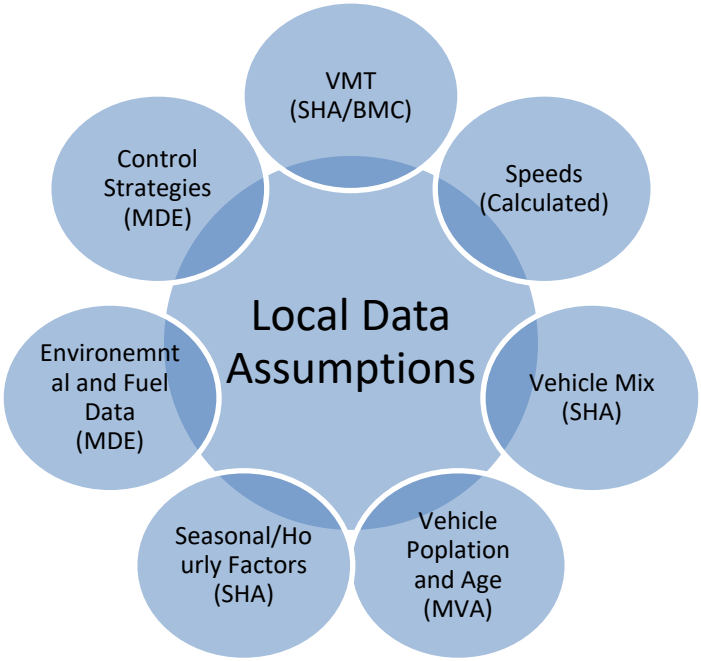
The following guidance documents released by U.S. EPA were used to develop the highway emissions inventory:

Policy Guidance on the Use of MOVES3 for SIP Development, Transportation Conformity, and Other Purposes, US Environmental Protection Agency (EPA-420-B20-044, November 2020).

MOVES3 Technical Guidance; Using MOVES to Prepare Emission Inventers for the State Implementation Plans and Transportation Conformity (EPA-420-B20-052, November 2020).

The methodologies used to produce the emissions data conform to the recommendations provided in EPA's technical guidance. A mix of local data and national default (internal to the MOVES3 model) data has been used for this work. As illustrated in Figure 1-1, local data has been used for the primary data items that have a significant impact on emissions. Local data inputs to the analysis process reflect the latest available planning assumptions using data obtained from the Maryland Department of Environment (MDE), MDOT MVA, MDOT SHA, Baltimore Metropolitan Council (BMC), and other local/national sources.

Figure 1-1: Local Data Inputs Used for Emissions Inventory



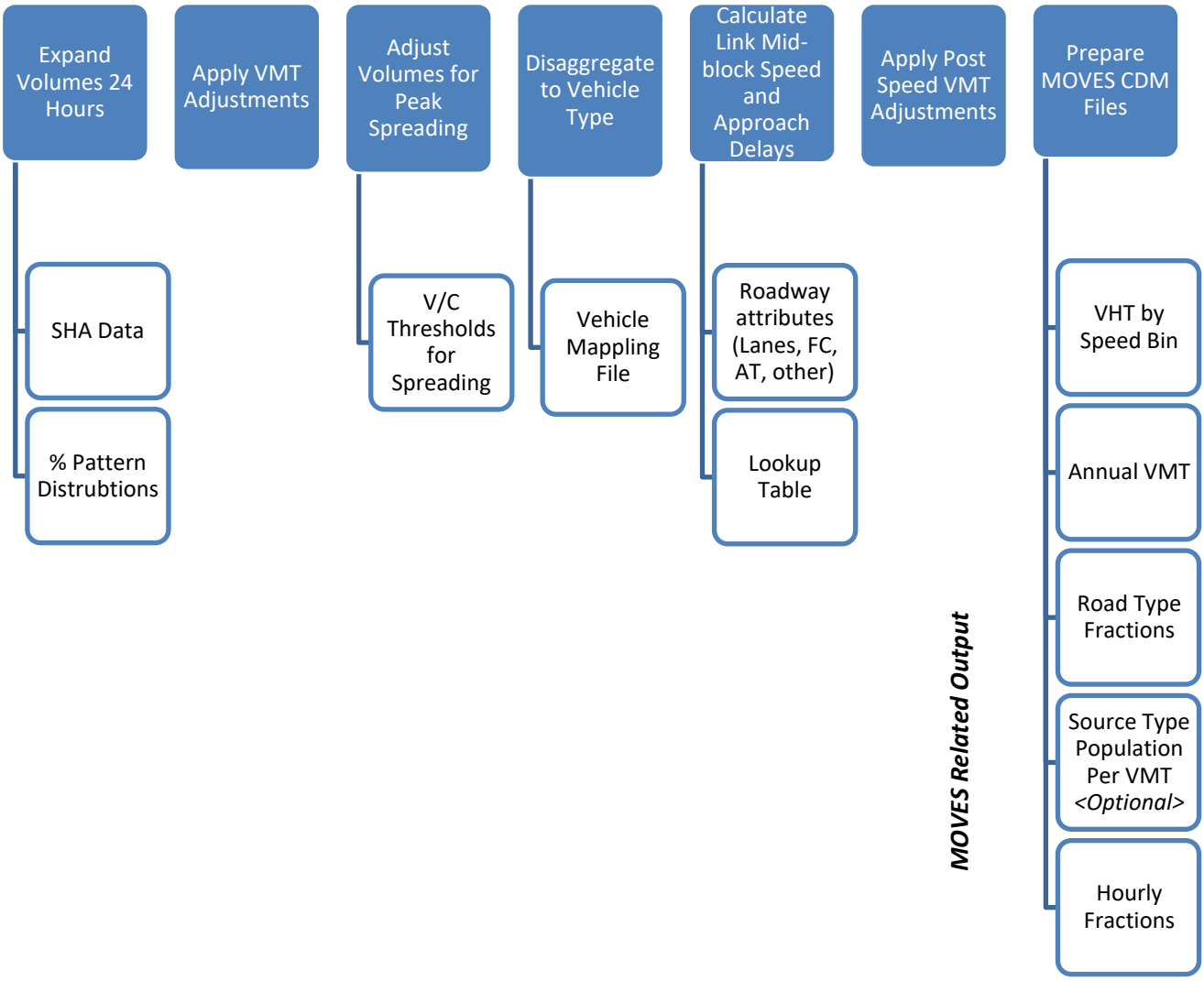
The analysis methodology is consistent with past statewide inventory efforts including the EPA mandated triennial National Emissions Inventory (NEI) submission. This includes the use of statewide traffic roadway data and a custom pre-processing and post-processing software suite (PPSUITE) to calculate hourly speeds and prepare key traffic input files to the MOVES emission model. PPSUITE 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 inputs, invokes MOVES runs and processes MOVES outputs.

PPSUITE is a widely used and accepted tool for estimating speeds and processing emissions rates. It has been used for past SIP highway inventories in MD, Pennsylvania, and New Jersey. 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 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. Figure 1-2 summarizes the key functions of PPSUITE and the traffic-related input files prepared for MOVES.

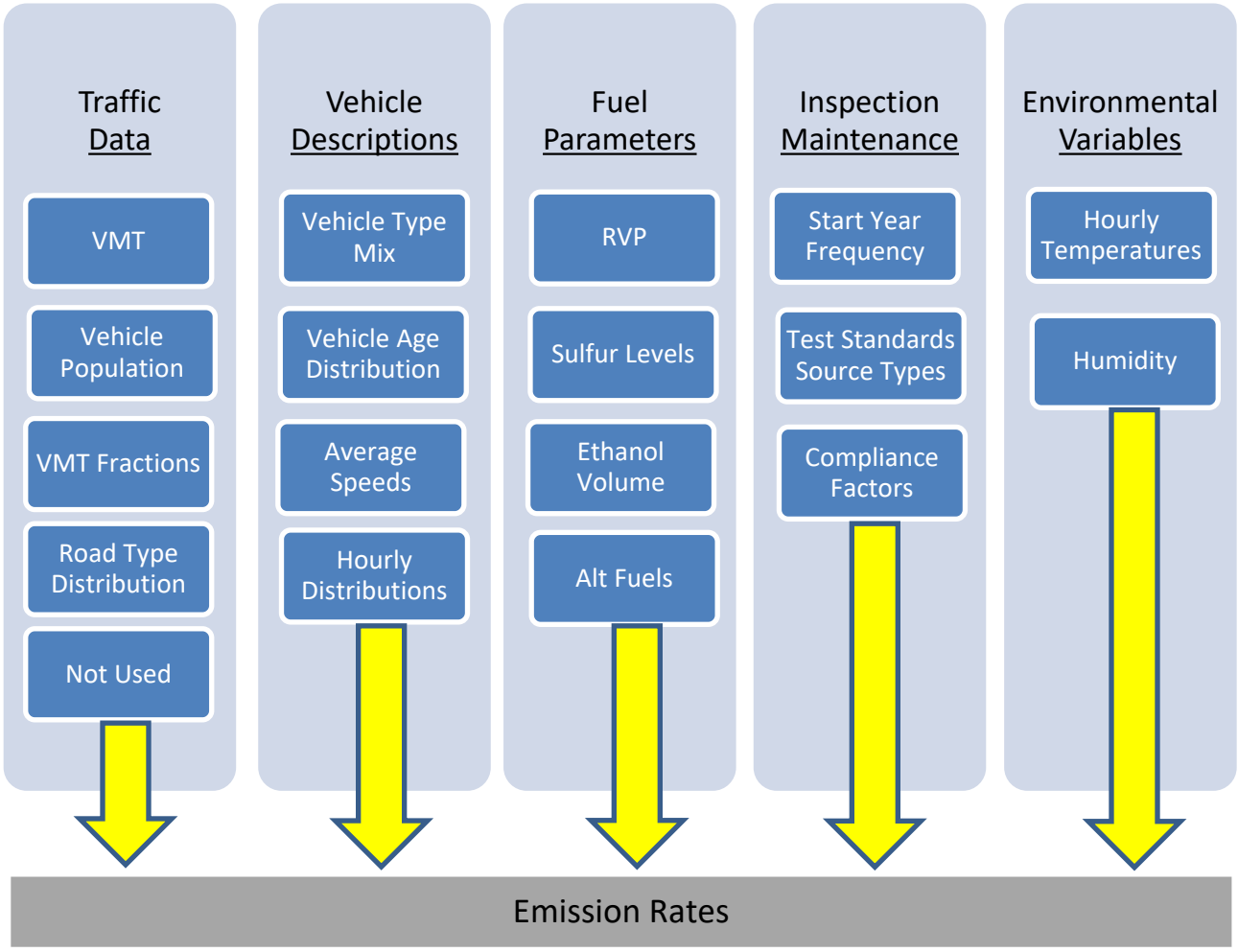
Figure 1-2: Emissions Calculation Process



1.2 DATA SOURCES

Many inputs to MOVES are needed to fully account for the numerous vehicle and environmental parameters that affect emissions levels. These include traffic flow characteristics, vehicle descriptions, fuel parameters, inspection/maintenance program parameters, and environmental variables as shown in Figure 1-3.

Figure 1-3: Examples of Key MOVES Input Data



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 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. These data items are discussed in the following sections.

1.2.1 ROADWAY DATA

The roadway data input to emissions calculations for this inventory is based on information from the "universal" highway database maintained by the MD's SHA which obtains this information from periodic visual and electronic traffic counts. The SHA data is dynamic since it is continually reviewed and updated

from new traffic counts. 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 SHA database is taken and downloaded to provide an up-to-date record of the state's highway system for estimating emissions. This emissions inventory is based on 2017 data which is the most current "snapshot" of the SHA data. The following information is extracted from the database for emission calculations:

- Lanes and distances
- volumes representing Average Annual Daily Traffic (AADT)
- urban/rural classifications
- functional class codes

The 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. The lane values, area type, and functional class are important inputs 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.

Maryland classifies its road segments by function, as well as whether it is in an urban or rural area, as indicated below in Figure 1-4. The urban/rural (UR) and functional classes (FC) are important indicators of the type and function of each roadway segment. These values are also used to determine the MOVES Road Type classification that has an important impact on the emission factors for each roadway segment. Equivalencies between the SHA and MOVES indices are discussed in later sections.

Figure 1-4: MDOT Urban/Rural and Functional Class Codes

Urban/Rural Code

1	=	Rural
2	=	Small Urban
3	=	Urban

Functional Class — Functional Roadway Classification Codes for each of the Rural/Urban Areas:

1	=	Intestate
2	=	Principal Arterial, Other Freeways and Expressways
3	=	Principal Arterial Other
4	=	Minor Arterial
5	=	Major Collector
6	=	Minor Collector
7	=	Local

1.2.2 OTHER SUPPORTING TRAFFIC DATA

Other traffic data is used to adjust and disaggregate traffic volumes. Key sources used in these processes include the following:

HPMS VMT: According to EPA guidance, baseline inventory VMT computed from the SHA highway segment volumes must be adjusted to be consistent with HPMS VMT totals. Although it has some limitations, the HPMS system is currently in use in all 50 states and is being improved under FHWA direction. Adjustment factors are calculated which adjust the base year 2017 SHA download VMT to be consistent with the reported 2017 HPMS totals for that year. These factors are applied to all county, urban/rural code, and facility group combinations within the region. These adjustments are important for accounting for missing local roadway VMT that is not contained within or represented by the state-owned roadway system.

Hourly Patterns: 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. Pattern data is in the form of a percentage of the daily volumes for each hour. Distributions are provided for all the counties within the region and by each facility type grouping. This data was developed from the 2017 24-hour count data obtained from the SHA website. The same factors are also used to develop the MOVES hourly fraction file.

1.2.3 VEHICLE CLASS DATA

Emission rates within MOVES model 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 five HPMS vehicle groups. Figure 1-5 summarizes the distinction between each classification scheme.

Figure 1-5: MOVES Source Types and HPMS Vehicle Groups

SOURCE TYPES		HPMS Class Groups	
11	Motorcycle	10	Motorcycle
21	Passenger Car	25	Light Duty Vehicle
31	Passenger Truck	40	Bus
32	Light Commercial Truck	50	Single Unit Truck
41	Other Bus	60	Combination Truck
42	Transit Bus		
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		

For this regional inventory, vehicle type pattern data was developed for each county and functional class combination based on SHA classification counts and internal MOVES defaults. As the first step, SHA count data was used to develop percentage splits to the following four vehicle groups:

- Autos
- Heavy trucks
- Motorcycles
- Buses

Following procedures used for previous SIP efforts, the vehicle groups were expanded to the 13 Source Use Types (MOVES vehicle types) using procedures provided in EPA technical guidance.

The vehicle type percentages are also 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.

1.2.4 VEHICLE AGES

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 vehicle age distributions were prepared by MDE based on information obtained from MVA registration data.

The vehicle age distributions are based on 2017 MVA registration data. The development process includes cleaning of duplicate, expired, and non-emitting vehicles such as truck trailers and the farm tractors (which are accounted for in the Area Source category of emissions). The data was subjected to VIN decoding to obtain vehicle information at a greater resolution and then transformed into vehicle age mixes following the EPA's guidance. SAS (network server based) and MS-Access (PC) systems were deployed for this project.

1.2.5 VEHICLE POPULATION DATA

The information on the vehicle fleet including the number and age of vehicles impacts forecasted start and evaporative emissions within MOVES. MOVES model requires the population of vehicles by the thirteen source type categories. This data was prepared in-house by MDE for the analysis year 2017 utilizing SAS-based computer program and MS-Office (PC) systems like the one discussed in the previous vehicle age section. This data was used to estimate vehicle population for light-duty and medium duty vehicles for all counties in the region. To include through trips of heavy-duty vehicles on MD's Interstate/other highway systems, VPOP for MOVES heavy-duty vehicle types 52, 53, 61 and 62 were developed based on modeled VMT and default VMT/VPOP per EPA's guidance.

1.2.6 ENVIRONMENTAL AND FUEL DATA

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

Meteorological Data: Meteorological hourly average MOVES inputs of temperature and relative humidity are always compiled on a triennial basis for every county in MD. The 2017 month by month raw hourly-data sets came from the National Climate Data Center of NOAA based on weather data collected at the airport situated closest to the county modeled. Hourly average temperature and humidity computations were developed from the 24-hourly values for every day in each month. For the Baltimore Area, since the data source is one for the entire area (BWI Airport situated in Anne Arundel County of MD), the same set of data was used for all the constituent city/counties of the Baltimore Area. For the Cecil County the data source is Philadelphia International (PHL) Airport situated in Philadelphia, PA.

Fuel Data: Usually MDE obtains monthly fuel data reports from the MD Fuel Laboratory which is under the jurisdiction of MD Fuel Tax Division of the Office of the Comptroller of MD. These fuel reports are generated by testing samples collected in the field (gas stations) for the purpose of fuel regulation enforcement. The 2017 retail sample fuel data was compiled, and fuel data parameters were developed separately for the 14 MD counties with EPA mandates to dispense only reformulated gasoline requirements and the 10 remaining counties dispensing conventional gasoline. This was true for the 2017 periodic inventory of VOC and NOx developed using MOVES2014a model.

However, the fuel parameters have changed in MOVES3 model. For lack of time and resources, MDE opted to deploy all MOVES3 default fuel files for this 2017 baseline inventory modeling of VOC/NOx.

This includes the Alternate Vehicle & Fuel Technology (AVFT) tables developed from the MOVES3 defaults – individually for each modeled jurisdiction.

1.2.7 OTHER VEHICLE TECHNOLOGY AND CONTROL STRATEGY DATA

The MOVES default I/M data was reviewed and updated by MDE for all the I&M counties in the region. The current I/M program known as Vehicle Emission Inspection Program (VEIP) assumed for the analysis year 2017 is described below.

MD Vehicle Emission Inspection Program:

This program tests gasoline powered vehicles weighing up to 26,000 lb. The following vehicles receive the OBD test: (1) MY 1996 and newer light duty vehicles (up to 8,500) lbs and (2) 2008 and newer vehicles (between 8,501 and 14,000 lbs).

The following vehicles receive the Idle test: (1) MY 1977- 2007 vehicles (between 8,501-14,000 lbs) and (2) 1977 and newer vehicles (between 14,001 and 26,000 lbs). The idle test includes a gas cap pressure test and a visual check for the presence of a catalytic converter. The VEIP test is done biennially, and on change of ownership.

There is a 24-month delay, after titling and registration, from emissions testing for new vehicles and qualified hybrids.

The compliance factors reflect the observed failure and waiver rates observed in the program, combined with an assumed 96% compliance rate for vehicles showing up for testing. Heavy duty vehicles have an additional factor, reflecting the fraction of vehicles in the weight range covered by the program. This was derived from documentation comparing the MOVES and MOBILE vehicle classes. The significantly higher compliance rate for the gas cap check reflects the much higher retest pass rate for this check.

Federal Programs: Current federal vehicle emissions control and fuel programs are incorporated into the MOVES software. These include the National Program standards. Modifications of default emission rates are required to reflect the early implementation of the National Low Emission Vehicle Program (NLEV) program in Maryland. To reflect these impacts, EPA has released instructions and input files that can be used to model these impacts in the Technical Guidance

1.2.8 STATE VEHICLE TECHNOLOGY PROGRAMS

Maryland Clean Car Program: Maryland adopted California's Advanced Clean Car Programs (formerly the CAL-LEV II and CAL-LEV III programs) in 2007 and 2012, respectively. The Advanced Clean Car Program (CAL-LEV II) became effective in model year 2011 and was made more stringent (CAL-LEV III) effective with the model year 2015-2025 vehicles. The Advanced Clean Car Program includes a Zero Emissions Vehicle (ZEV) mandate. These programs were included in the modeling process following the guidelines provided in the MOVES3 Technical Guidance.

1.3 ANALYSIS METHODOLOGY

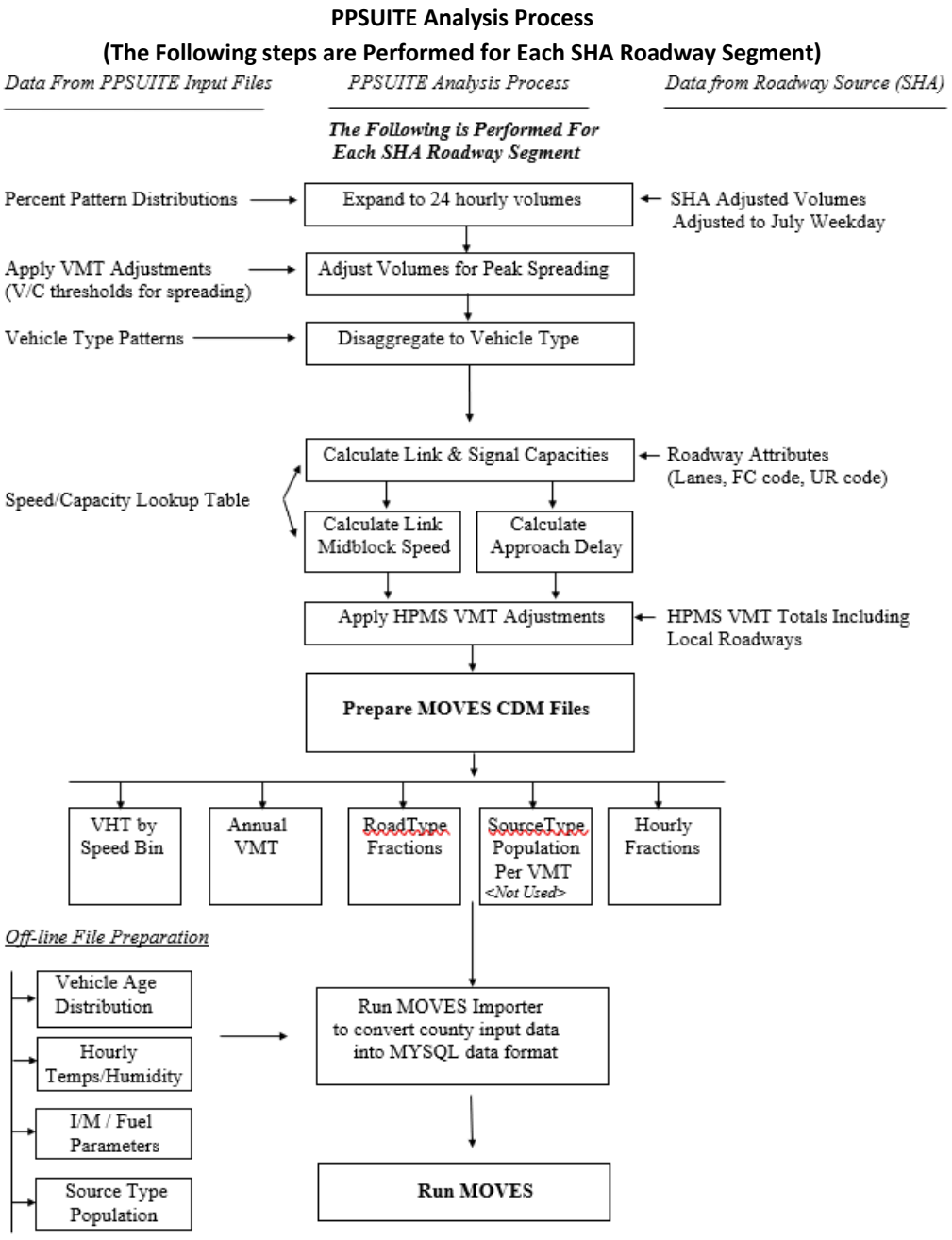
The previous sections have summarized the input data used for computing speeds and emission rates for this highway emissions inventory. This section explains how PPSUITE and MOVES uses that input data to produce emission estimates. Figure 1-6 provides a more detailed overview of the PPSUITE analysis procedure using the available traffic data information described previously.

1.3.1 VMT PREPARATION

Producing an emissions inventory with PPSUITE requires a complex process of disaggregation and aggregation of vehicle activities. Data is available and used on a very small scale individual half-a-mile roadway segments for each of the 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 the input VMT to the MOVES emission model. As an example: key steps in the preparation of VMT for a summer daily run include:

- *Apply Seasonal Adjustments* - PPSUITE takes the input daily volumes from SHA (which represents AADT traffic) 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. This is useful in developing summertime emission inventories of VOC and NOx and wintertime emission inventories of carbon monoxide (CO).
- *Disaggregate to 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 MOVES.
- *Peak Spreading* - 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 Types* - EPA requires VMT estimates to be prepared by source type, reflecting specific local characteristics. As a result, for Maryland’s emission inventory runs, the hourly volumes are disaggregated to the five HPMS MOVES vehicle grouping based on count data assembled by SHA in combination with MOVES defaults as described in the previous section.
- *Apply HPMS VMT Adjustments* – Traffic volumes must also be adjusted to account for differences with the HPMS VMT totals (as benchmark), 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/ subtracted to the SHA database assumes the speeds calculated using the original volumes for each roadway segment for each hour of the day.

Figure 1-6: PPSUITE Speed/Emission Estimation Procedure



1.3.2 SPEED ESTIMATION

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.

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 exceeds that recommendation. Speeds are individually calculated for each roadway segment and hour and include the estimated 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 highway emissions inventory, distributions of speeds are input to MOVES by road type and source type by each hour of the day.

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

1.3.3 DEVELOPING THE MOVES TRAFFIC INPUT FILES

The PPSUITE software is responsible for producing the many activity-based MOVES input files during any analysis run. Some examples are as follows:

- VMT by HPMS vehicle class
- VHT by speed bin
- Road type distributions
- Average speed distribution

These files are text formatted files with a *.csv extension. The files are provided as inputs within the MOVES county data importer.

VMT Input File: 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).

VHT by Speed Bin File: As described in the previous section, the PPSUITE software prepares the MOVES 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 by road type. This robust process ensures that MOVES emission rates are fully used and is consistent with the methods and recommendations provided in EPA's technical guidance.

Road Type Distributions: In MOVES, typical drive cycles and associated operating conditions vary by the type of roadway. MOVES define 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

For this inventory, the MOVES road type distribution file is automatically generated by PPSUITE using defined equivalencies. 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. The remaining distribution among road types is determined by equating the functional class with each MOVES road type as follows:

Road Types in MOVES3		
Road Type ID	**Description**	**FHWA Functional Type**
1	Off Network	Off Network
2	Rural Restricted Access	Rural Restricted Access Rural Interstate & Rural Freeway/Expressway
3	Rural Unrestricted Access	Rural Other Principal Arterial, Minor Arterial, Major Collector, Minor Collector & Local
4	Urban Restricted Access	Urban Restricted AccessUrban Interstate & Urban Freeway/Expressway
5	Urban Unrestricted Access	Urban Other Principal Arterial, Minor Arterial, Major Collector, Minor Collector & Local

1.3.4 MOVES RUNS

After computing speeds and aggregating VMT and VHT, PPSUITE prepares traffic-related inputs needed to run EPA's MOVES software. Additional required MOVES inputs are prepared external to the processing software and include temperatures, I/M program parameters, fuel characteristics, vehicle fleet age distributions and source type population.

The MOVES model's county importer is run in batch mode. This program converts all data files into the Maria DB 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.

1.4 SUMMER WEEKDAY INVENTORY OF VOC AND NOX

The 2017 baseline inventory summaries for the Baltimore Area and Cecil County, MD are provided in Table 1-1.

1.4.1 EMISSION ESTIMATES

Table 1-1: 2017 Summer Weekday Highway Vehicle Emissions Inventories

2017 Baltimore Area	NOx (tpd)	VOC (tpd)	VMT (mi-miles)
Anne Arundel County	11.70	5.24	
Baltimore County	16.67	6.89	
Carroll County	2.94	1.75	
Harford County	4.98	2.30	
Howard County	7.55	2.64	
Baltimore City	7.31	3.19	
Area Total	51.15	22.01	78.93

2017 Cecil County	NOx (tpd)	VOC (tpd)	VMT (mi-miles)
Area Total	4.04	1.15	3.92

tpd = tons per day
mi-miles = million miles

1.5 EMISSION INVENTORY SAMPLE INPUTS/OUTPUTS

The 2017 baseline inventory inputs and outputs based on and developed using MOVES3 model are too large to be exhibited here. They can be provided in electronic format upon request. However, a sample MOVES Run Specification (MRS) file for Baltimore County, representing the Baltimore Area is appended hereunder.

MOVES3 Sample Input Files

2017 Summer Weekday MOVES Run Specification (MRS)

Baltimore Area, 2017 represented by Baltimore County.

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Maryland
Department of
the Environment

Larry Hogan, Governor
Boyd K. Rutherford, Lt. Governor

Horacio Tablada, Secretary
Suzanne E. Dorsey, Deputy Secretary

Appendix E2

Cecil County, MD Mobile Source Emissions Technical Support Documentation MOVES3 Model Platform

An Explanation of Methodology

Prepared for:

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Baltimore, MD 21230

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February 2023

Appendix E2

Cecil County, MD Mobile Source Emissions
Technical Support Documentation
MOVES3 Model Platform
State Implementation Plan (SIP)
For the 0.070 ppm National Ambient Air Quality Standard for Ozone

Cecil County, MD: Mobile Source Emissions
Technical Support Document
February 2023

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OVERVIEW

The purpose of this technical document is to explain how Maryland estimates emissions from highway vehicles using EPA's Motor Vehicle Emission Simulator (MOVES) model for inclusion in its emission inventories and State Implementation Plans (SIP). The document includes a summary of the methodology and data assumptions used for the analysis. As shown in Exhibit 1, appendices have been provided with additional detail regarding the MOVES input parameters, sample input files, vehicle miles of travel (VMT) and emission results for the nonattainment area.

Exhibit 1: Summary of Appendices

Appendix	Title	Description
E-3	MOVES Input Parameter Summary	Provides a summary of input parameters related to traffic data sources, fuel, weather, I/M, and other MOVES related input data.
E-4	MOVES Sample Input Files	Provides example of the MOVES input run specification files.
E-5	Ozone (VOC, NOx) Emission Results	Provides emission exhibits by county, road type, and source type categories for a July weekday in 2023.

Background:

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.

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.

This inventory was developed using MOVES3 model, EPA's latest official version of Motor Vehicle Emission Simulator (MOVES) for estimating emissions from highway vehicles. MOVES3, released in January 2021, incorporates the latest data on vehicle populations, travel activity and emission rates as well as updated fuel data at the county level.

Highway Emissions:

Exhibit 2 summarizes the highway emissions inventory for Cecil County, MD. Both VOC and NOx emission estimates have been developed using the MOVES3 emission model and latest planning assumptions. Emissions have been estimated for the 2023 analysis year.

Exhibit 2: Summary of Highway Emissions Inventory (Cecil County, MD)

Area	*Emissions (Short Tons/Day)*	
	2023	
	VOC	NOx
Cecil County	**0.92**	**2.64**

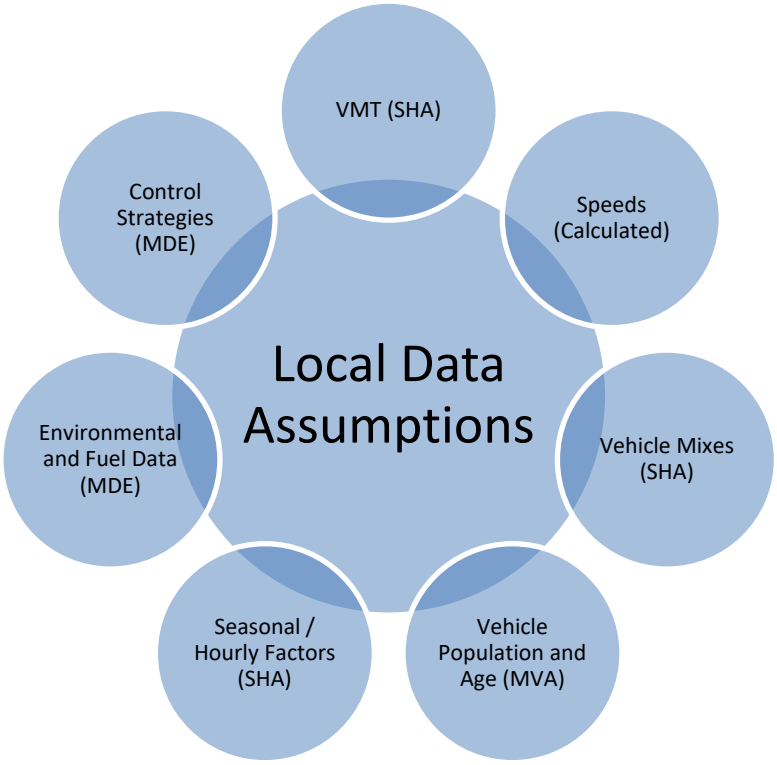
Analysis Methodology:

Guidance documents from EPA were used to develop the highway emissions inventory. They include:

- *Policy Guidance on the Use of MOVES3 for State Implementation Plan Development, Transportation Conformity, General Conformity, and Other Purposes,* US EPA Office of Transportation and Air Quality, EPA-420-B-20-044, November 2020.
- *MOVES3 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity,* US EPA Office of Transportation and Air Quality, EPA-420-B-20-052, November 2020.

The methodologies used to produce the emission data conform to the recommendations provided in EPA's technical guidance. A mix of local data and national default (internal to MOVES3) data has been used for this submission. As illustrated in Exhibit 3, local data has been used for the primary data items that have a significant impact on emissions. Local data inputs to the analysis process reflect the latest available planning assumptions using data obtained from the Maryland Department of Environment (MDE), Motor Vehicle Administration (MVA), Maryland State Highway Administration (SHA), and other local/national sources.

Exhibit 3: Local Data Inputs Used for Emissions Inventory



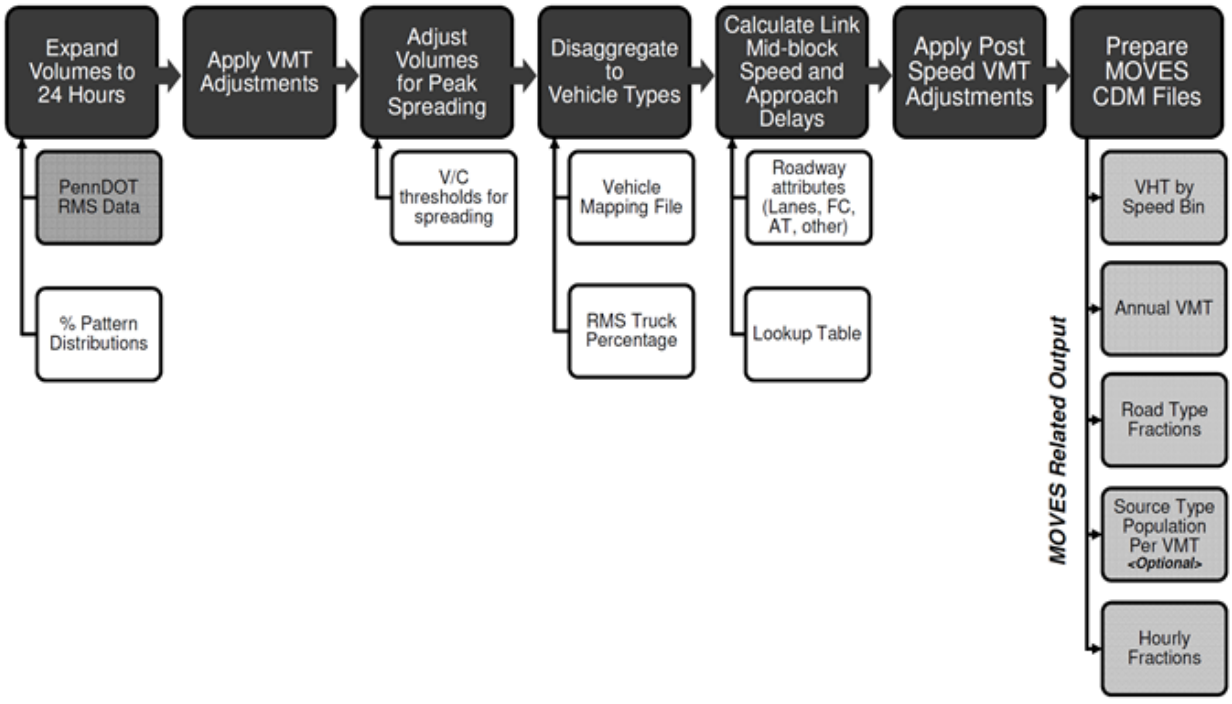
The analysis methodology is consistent with past statewide inventory efforts including the 2020 National Emissions Inventory (NEI) submission. This includes the use of statewide traffic roadway data and custom post-processing software (PPSUITE) to calculate hourly speeds and prepare key traffic input files to the MOVES3 emission model. PPSUITE 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. It is has been used for past SIP highway inventories in Maryland, Pennsylvania, and New Jersey. 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 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 4 summarizes the key functions of PPSUITE and the traffic-related input files prepared for MOVES.

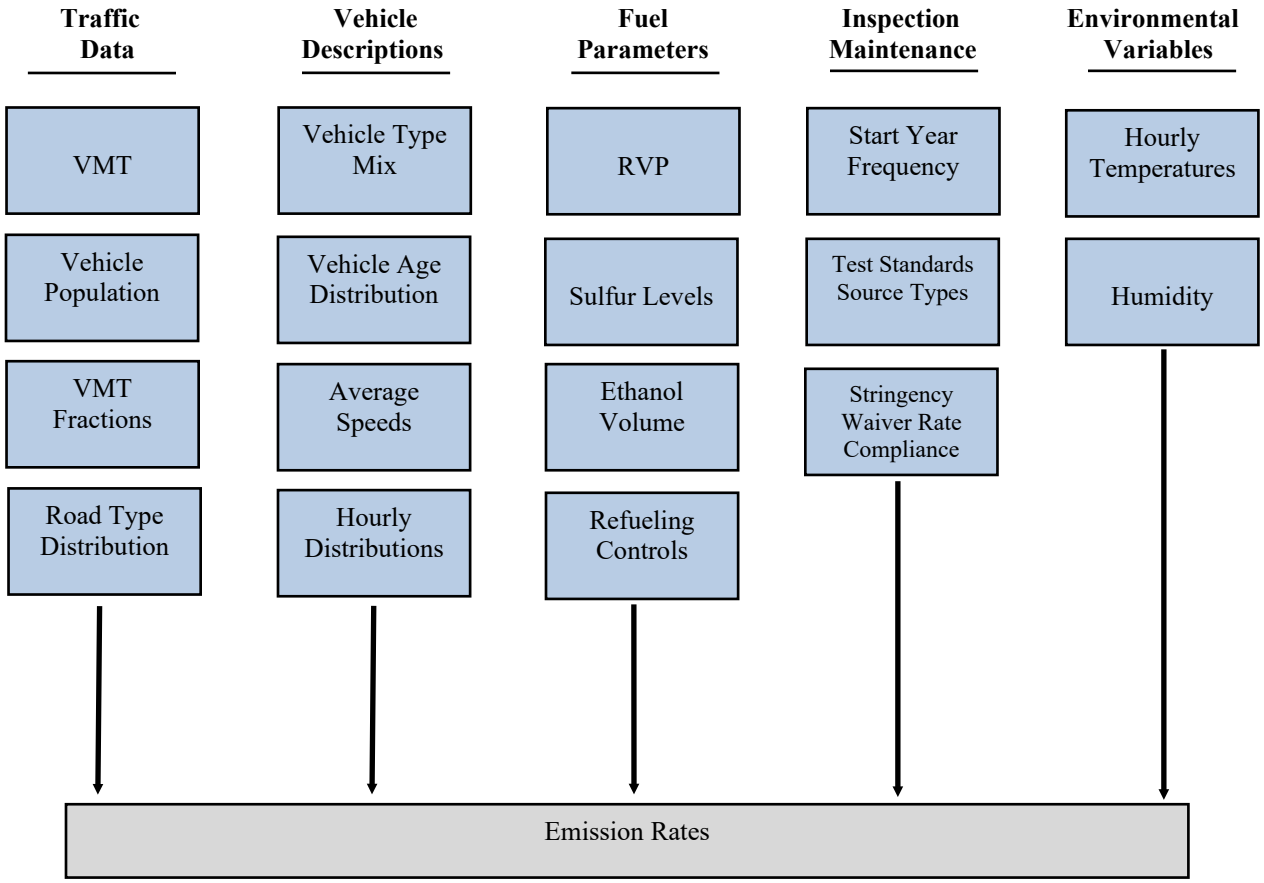
Exhibit 4: Emission Calculation Process



DESCRIPTION OF INPUT DATA

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, vehicle descriptions, fuel parameters, inspection/maintenance program parameters, and environmental variables as shown in Exhibit 5.

Exhibit 5: Examples of Key MOVES Input Data



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 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. These data items are discussed in the following sections.

Roadway Data:

The roadway data input to emissions calculations for this inventory is based on information from the "universal" highway database maintained by the Maryland SHA. SHA obtains this information from periodic visual and electronic traffic counts. The SHA data is dynamic, since it is continually reviewed and updated from new traffic counts.

On a triennial basis, a current "snapshot" of the SHA database is taken and downloaded to provide an up-to-date record of the state's highway system for estimating emissions. This emissions inventory is based on 2020 data which is the most current "snapshot" of the SHA data. The following information is extracted from the database for emission calculations:

- lanes
- distances
- volumes representing Average Annual Daily Traffic (AADT)
- truck percentages
- urban/rural classifications
- functional class codes

The 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 and to forecast to future years. The lane values, area type, and functional class are important inputs 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.

Maryland classifies its road segments by function, as well as whether it is located in an urban or rural area, as indicated below in Exhibit 6. The urban/rural (UR) and functional classes (FC) are important indicators of the type and function of each roadway segment. These values are also used to determine the MOVES Road Type classification that has an important impact on the emission factors for each roadway segment. Equivalencies between the SHA and MOVES indices are discussed in later sections.

Exhibit 6: MDOT Urban/Rural and Functional Class Codes

Urban/Rural Code	1=Rural 2=Small Urban 3=Urban
Functional Class	Functional Classes Used
	1=Interstate 2=Principal Arterial Other Freeways and Expressways 3=Principal Arterial Other 4=Minor Arterial 5=Major Collector 6=Minor Collector 7=Local

The PPSUITE processing software allows for many additional variables other than those available in the SHA database. Using these variables improves the calculation of congested speeds. Such variables

include information regarding free-flow speeds and capacities and other physical roadway features (e.g. traffic signals) 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.

Traffic Volumes Growth Rates:

Traffic volume projections are needed to support the forecast emission inventories. Growth factors are applied to the base year traffic volumes in the SHA database. These growth factors are determined through and assessment of:

- Historic VMT growth from the Highway Performance Monitoring System (HPMS)
- Assessment of other factors affecting regional growth not represented in the above sources

The development and selection of growth rates has included consultation between MDOT and MDE. Forecasted traffic volumes are used within the post-processing methodologies to estimate future year congested speeds.

Other Supporting Traffic Data:

Other traffic data is used to adjust and disaggregate traffic volumes. Key sources used in these processes include the following:

HPMS VMT: According to EPA guidance, baseline inventory VMT computed from the SHA highway segment volumes must be adjusted to be consistent with HPMS VMT totals. Although it has some limitations, the HPMS system is currently in use in all 50 states and is being improved under FHWA direction. Adjustment factors are calculated which adjust the base year 2020 SHA download VMT to be consistent with the reported 2020 HPMS totals for that year. These factors are applied to all county, urban/rural code, and facility group combinations within the region. These adjustments are important for accounting for missing local roadway VMT that is not contained within or represented by the state-owned roadway system.

Seasonal Factors: The SHA 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. Therefore, the SHA volumes must be seasonally adjusted. The seasonal factors were developed based on the 2020 report *Factors to Convert Volume to AADT* from the SHA Traffic Monitoring System website. These factors are utilized to convert the SHA AADT to produce July weekday volumes. The same factors are also used to develop the MOVES daily and monthly VMT fraction files.

Hourly Patterns: 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. Pattern data is in the form of a percentage of the daily volumes for each hour. Distributions are provided for all the counties within the region and by each facility type grouping. This data was developed from SHA 2020 24-hour count data. The same factors are also used to develop the MOVES hourly fraction file.

Vehicle Class Data:

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 five HPMS vehicle groups. Exhibit 7 summarizes the distinction between each classification scheme.

Exhibit 7: MOVES Source Types and HPMS Vehicle Groups

SOURCE TYPES		HPMS Class Groups	
11	Motorcycle	10	Motorcycle
21	Passenger Car	25	Light Duty Vehicles
31	Passenger Truck	40	Buses
32	Light Commercial Truck	50	Single Unit Trucks
41	Intercity Bus	60	Combination Trucks
42	Transit Bus		
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		

For this regional inventory, vehicle type pattern data was developed for each county and functional class combination based on SHA classification counts and internal MOVES defaults. As the first step, SHA count data was used to develop percentage splits to the following four vehicle groups:

- Autos
- Heavy trucks
- Motorcycles
- Buses

From these groups, MOVES default Maryland county VMT distributions by source type are used to divide the four groups into MOVES 13 source types.

The vehicle type percentages are also 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 Ages:

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 vehicle age distributions were prepared by MDE based on information obtained from 2020 MVA registration data.

The development process of the age distribution inputs includes removal of duplicate, expired, and non-emitting vehicles such as truck trailers and the farm tractors. The data was subjected to VIN decoding to obtain vehicle information at a finer resolution and then transformed into vehicle age mixes following the EPA's guidance. Mapping of vehicle classes from the registration data to the MOVES vehicle types was based on the EPA's MOVES3 technical guidance using the existing MVA data fields and fine-tuned data obtained via VIN decoding.

The age distributions for combination long-haul and short-haul trucks (source types 61 and 62) were developed using MOVES3 default data as it is difficult to distinguish short-haul and long-haul trucks in the MVA data.

Vehicle Population Data:

The information on the vehicle fleet including the number and age of vehicles impacts forecasted start and evaporative emissions within MOVES. MOVES model requires the population of vehicles by the thirteen source type categories. The 2020 baseline data was prepared and provided by MDE utilizing SAS-based computer program and MS-Access. Maryland county vehicle registration data was used to estimate vehicle population for light-duty, buses, refuse trucks and motor homes for all counties in the region. The vehicle population for heavy-duty trucks (source types 52, 53, 61 and 62) were estimated using county VMT and MOVES3 default VMT/population ratios for those source types.

For the analysis year 2023, the vehicle population was forecasted based on projected household and population growth obtained from state and MPO sources. The growth rate methodology included:

- Choosing the highest growth factors developed from Woods & Poole forecast data (e.g. population, households, or employment) and VMT growth.
- Default VMT/Population ratio for trucks, i.e., truck population growth based on Truck VMT.

Environmental and Fuel Data:

Information on environmental, fuel, vehicle technology and other control strategy assumptions were determined based on a review of MOVES3 default information by MDE.

Fuel Data: MDE obtains monthly fuel data reports regularly from the Maryland Fuel Laboratory, which is under the jurisdiction of Maryland Fuel Tax Division of the Office of the Comptroller of Maryland. In 2020, due to COVID-19 restrictions and subsequent lack of data for a few months, MDE decided to use the fuel data provided by the Maryland Comptroller's Office from Maryland's bulk terminals for all the counties in Maryland. The 2020 bulk terminal fuel data was compiled, and fuel data parameters were developed separately for all 14 counties required by EPA which use only reformulated gasoline and the remaining counties dispensing conventional gasoline.

Three out of four sets of fuel data inputs (Fuel Formulation, Fuel Supply, and AVFT tables) required by MOVES model were developed by MDE for every county in MD. The fuel parameters changed from the MOVES3 defaults are as follows:

fuelFormulationID	Unique ID used for easy recognition
fuelSubtypeID	Selected per guidance based on ethanol content of gasoline
sulfurLevel	Computed from the local fuel data
ETOHVolume	Computed from the local fuel data
aromaticContent	Computed from the local fuel data
olefinContent	Computed from the local fuel data
benzineContent	Computed from the local fuel data
E200	Computed from the local fuel data
E300	Computed from the local fuel data

The Alternate Vehicle and Fuel Technology (AVFT) tables were developed individually for all the MD jurisdictions from the 2020 MVA data. They include vital information such as vehicle type, model year, fuel type, engine technology, and fuel engine fractions.

For the remaining fuel table 'Fuel Usage Fractions', MDE adopted MOVES3 defaults for lack of data on E85 vehicle fractions in the fleet.

Meteorological Data: Evaporative emissions are influenced significantly by the temperatures of the surrounding air. Meteorological data for MOVES inputs, including hourly average temperature and relative humidity, are compiled on a triennial basis for every county in MD. The data used for this analysis was prepared using the 2020 month by month raw hourly-data sets from the National Climate Data Center of NOAA based on weather data collected at the airport situated closest to the county modeled. Hourly average temps and humidity computations were developed from the 24-hourly values for every day in each month. The data source for Cecil County came from the NOAA station at the Philadelphia International (PHL).

Other Vehicle Technology and Control Strategy Data:

The MOVES3 default I/M data was reviewed and updated by MDE for all the I/M counties in the state. The current I/M program known as Vehicle Emission Inspection Program (VEIP) assumed for these analysis runs is described below.

MD Vehicle Emission Inspection Program: This program tests gasoline powered vehicles weighing up to 26,000 lb. The following vehicles receive the OBD test: (1) MY 1996 and newer light duty vehicles (up to 8,500) lbs and (2) 2008 and newer vehicles (between 8,501 and 14,000 lbs).

The following vehicles receive the Idle test: (1) MY 1977- 2007 vehicles (between 8,501-14,000 lbs) and (2) 1977 and newer vehicles (between 14,001 and 26,000 lbs). The idle test includes a gas cap pressure test and a visual check for the presence of a catalytic converter. The VEIP test is done biennially, and on change of ownership.

New vehicles and qualified hybrids are exempted from emissions testing for the first three years (36 months), after titling and registration.

The compliance factors reflect the observed failure and waiver rates observed in the program, combined with an assumed 96% compliance rate for vehicles showing up for testing. Heavy duty vehicles have an additional factor, reflecting the fraction of vehicles in the weight range covered by the program. This was derived from documentation comparing the MOVES and MOBILE vehicle classes. The significantly higher compliance rate for the gas cap check reflects the much higher retest pass rate for this check.

Federal Programs: Current federal vehicle emissions control and fuel programs are incorporated into the MOVES3 software. In addition to the federal programs included in the previous versions of MOVES (including National Program standards covering light duty vehicles through model year 2026, heavy duty greenhouse gas standards for model year 2014-2018 vehicles, and Tier 3 standards), MOVES3 incorporates the following new federal emission standard rules:

- *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2 (HD GHG2) Rule*: MOVES3 accounts for the HD GHG2 rule published in 2016. The rule set stricter fuel economy standards for HD vehicles which reduce CO_2 emissions, but also impact other pollutants through changes in glider sales, hoteling activity, vehicle mass and road load coefficients.

- *Safe Affordable Fuel Efficient (SAFE) Vehicles Rule*: MOVES3 also accounts for the March 2020 SAFE standards for light-duty vehicles. These standards were less stringent than the preceding fuel economy standards, and thus increased fuel consumption and CO_2 emissions.

Modifications of default emission rates are required to reflect the early implementation of the National Low Emission Vehicle Program (NLEV) program in Maryland. To reflect these impacts, EPA has

released instructions to develop input files that can be used to model these impacts. The NLEV input database was created for Maryland per EPA's instructions and was used for this inventory.

State Vehicle Technology Programs:

MD Clean Car Program: Maryland Clean Car Program: Maryland adopted California's Advanced Clean Car Programs (formerly the CAL-LEV II and CAL-LEV III programs) in 2007 and 2012, respectively. The Advanced Clean Car Program (CAL-LEV II) became effective in model year 2011 and was made more stringent (CAL-LEV III) effective with the model year 2015-2025 vehicles. The Advanced Clean Car Program includes a Zero Emissions Vehicle (ZEV) mandate. These programs were included in the modeling process following the guidelines provided in the MOVES3 Technical Guidance. A LEV input database was created to reflect a 2011 beginning model year for the State of Maryland.

ANALYSIS METHODOLOGY

The previous sections have summarized the input data used for computing speeds and emission rates for this highway emissions inventory. This section explains how PPSUITE and MOVES uses that input data to produce emission estimates. Exhibit 8 provides a more detailed overview of the PPSUITE analysis procedure using the available traffic data information described in the previous section.

VMT Preparation:

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 be processed individually to determine the distribution of vehicle hours of travel (VHT) by speed and then aggregated by vehicle class to determine the input VMT to the MOVES emission model. Key steps in the preparation of VMT include:

- *Apply Growth Factors* - The SHA database contains the base 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 SHA volumes to obtain future year estimates that can be utilized by PPSUITE.

- *Apply Seasonal Adjustments* - PPSUITE takes the input daily volumes from SHA (which represents AADT traffic) 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.

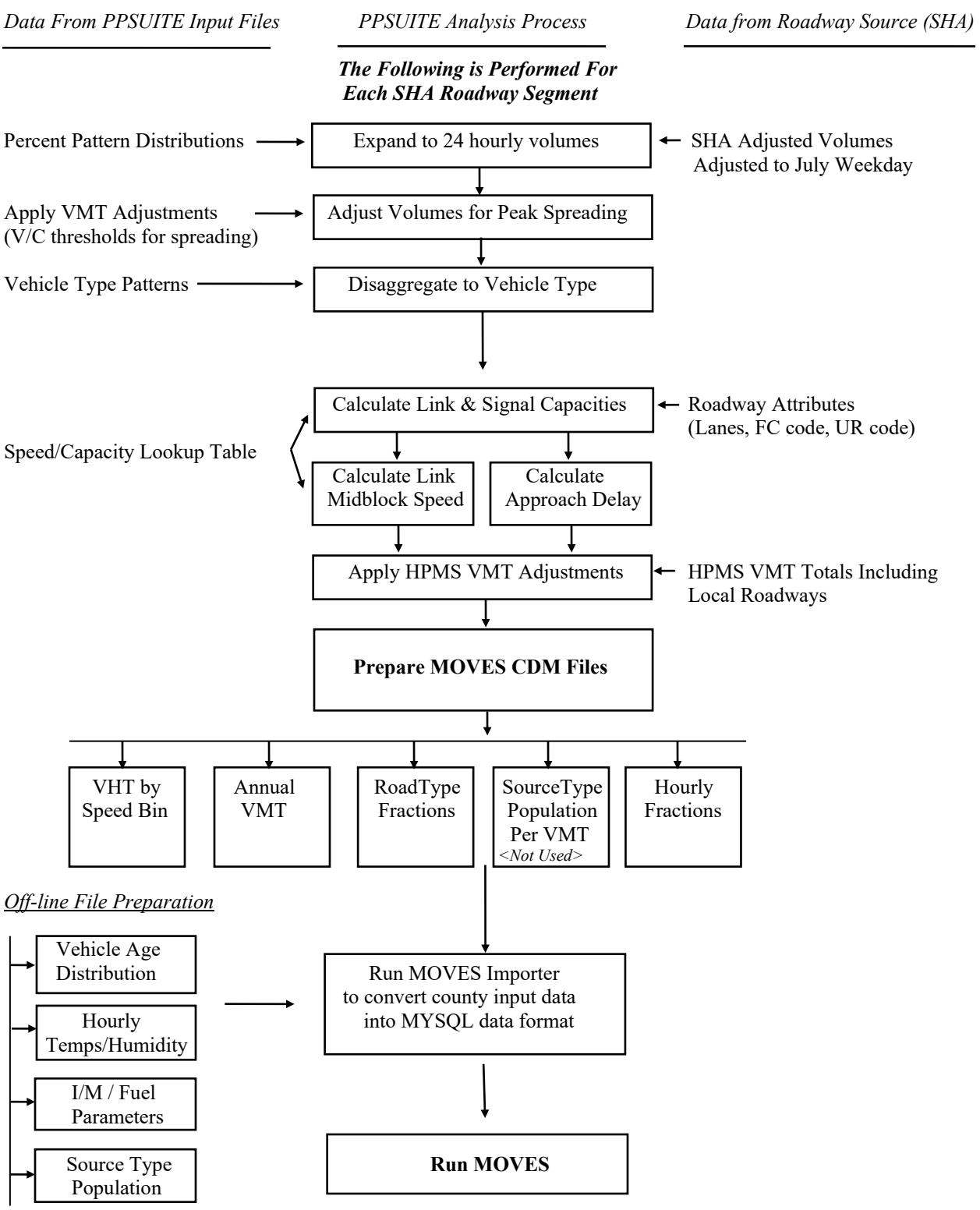
- *Disaggregate to Hours* - After seasonally adjusting the link volume, the volume is split to each hour of the day. This allows for more accurate speed calculations (effects of congested hours) and allows PPSUITE to prepare the hourly VMT and speeds for input to the MOVES model.

- *Peak Spreading* - 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 Types* - EPA requires VMT estimates to be prepared by source type, reflecting specific local characteristics. As a result, for Maryland's emission inventory runs, the hourly volumes are disaggregated to the five HPMS MOVES vehicle grouping based on count data assembled by SHA in combination with MOVES defaults as described in the previous section.

- *Apply HPMS 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 SHA database assumes the speeds calculated using the original volumes for each roadway segment for each hour of the day.

Exhibit 8: PPSUITE Speed/Emission Estimation Procedure



Speed Estimation:

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.

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 exceeds that recommendation. Speeds are individually calculated for each roadway segment and hour and include the estimated 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 highway emissions inventory, distributions of speeds are input to MOVES by road type and source type by each hour of the day.

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

Developing the MOVES Traffic Input Files:

The PPSUITE software is responsible for producing the following MOVES input files during any analysis run:

- VMT by HPMS vehicle class
- VHT by speed bin
- Road type distributions

These files are text formatted files with a *.csv extension. The files are provided as inputs within the MOVES county data importer.

VMT Input File: 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).

VHT by Speed Bin File: As described in the previous section, the PPSUITE software prepares the MOVES 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 by road type. 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.

Road Type Distributions: 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

For this inventory, the MOVES road type distribution file is automatically generated by PPSUITE using defined equivalencies. 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. The remaining distribution among road types is determined by equating the functional class with each MOVES road type as follows:

- MOVES Road Type (2) = SHA Rural Functional Class (1,2)
- MOVES Road Type (3) = SHA Rural Functional Class (3,4,5,6,7)
- MOVES Road Type (4) = SHA Urban Functional Class (1,2)
- MOVES Road Type (5) = SHA Urban Functional Class (3,4,5,6,7)

MOVES Runs:

After computing speeds and aggregating VMT and VHT, PPSUITE prepares traffic-related inputs needed to run EPA's MOVES3 software. Additional required MOVES inputs are prepared external to the processing software and include temperatures, I/M program parameters, fuel characteristics, vehicle fleet age distributions and source type population.

The MOVES county importer is run in batch mode. This program converts all data files into the MariaDB 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.

RESOURCES

MOVES model

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

Policy Guidance on the Use of MOVES3 for State Implementation Plan Development, Transportation Conformity, General Conformity, and Other Purposes, US EPA Office of Transportation and Air Quality, EPA-420-B-20-044, November 2022.

MOVES3 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, US EPA Office of Transportation and Air Quality, EPA-420-B-20-052, November 2020.

Traffic Engineering

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

Traffic Monitoring System, 2020 Data, State Highway Administration

Highway Vehicle Inventory Glossary

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

AWDT: Average Weekday Daily Traffic.

County Data Manager (CDM): 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.

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.).

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

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

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.

MOVES: The latest model EPA has developed with which Maryland 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.

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

Source Type: One of thirteen vehicle types used in MOVES modeling.

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.

APPENDIX E-3

Cecil County MOVES3 Input Parameter Summary

2023 MOVES3 Input Parameter Summary

Data Item	Inputs Assumptions
MOVES RunSpec	
Emission Model	MOVES3 (default database: MOVESDB20220105)
Scale/Calulation Type	County Scale Inventory Run
Analysis Years	2023
Analysis Season	July Weekday
Pollutants	VOC, NOx
Fuel Types	Gasoline, Diesel, CNG, Electricity, E-85
Traffic Data	
Highway Network	2020 SHA Universal Highway Database
Seasonal/Daily Adjustments	2020 SHA Traffic Trends Report
County HPMS VMT Adjustments	2020 HPMS Adjustments
Mapfile	Use MOVES3 national defaults VMT distributions for Maryland to dissagregate light duty vehicles/buses/trucks to MOVES13 source types
Hourly Patterns	Developed based on 2020 SHA 24-hour count data
Vehicle Mixes	1. 2020 Vehicle Classification by Functional Class 2. 2020 TMS & hourly distribution from SHA traffic count data
VMT Growth Forecast	2000-2019 HPMS trend growth, applying to 2019 HPMS Base Year
Vehicle Population Growth Forecast	1. Source Type 11, 21, 31, 32, 41, 42, 43 & 54: max of population, household and VMT growth 2. Source Type 51: max of population, household, employment and VMT growth 3. Trucks (source type 52, 53 ,61 & 62): Estimated by using MD VMT and MOVES3 national default VMT and population ratios
MOVES Inputs	
Month VMT Fractions	Calculated based on 2020 seasonal adjustment factors
Day VMT Fractions	Calculated based on 2020 seasonal adjustment factors
Hourly VMT Fractions	Calculated by PPSUITE
Average Speed Distribution	Calculated by PPSUITE
Source Type Population	1. Source Type 11, 21, 31, 32, 41, 42, 43, 51 & 54: Apply VPOP growth to 2020 base year inputs (2020 base year inputs provided by MDE) 2. Trucks (source type 52, 53 ,61 & 62): Estimated by using MD VMT and MOVES3 national default VMT and population ratios
Vehicle Age Distribution	Provided by MDE (Consistent with 2020 NEI): 1) 2020 Jul 01 MVA vehicle registration database, VIN-decoded by ESP. 2) Source types 61 & 62: Use MOVES3 national default age distribution inputs
Fuel Supply	MOVES3 inputs provided by MDE
Fuel Formulation	MOVES3 inputs provided by MDE
Fuel Usage Fraction	MOVES3 inputs provided by MDE
Temperatures/Humidity	2020 inputs provided by MDE
I/M Parameters	VEIP Reinvention Program provided by MDE
Early NLEV / CALLEV	Early NLEV and CALEV program databases developed with MOVES3 per EPA guidance.
AVFT	Provided by MDE for MOVES3
Federal Fuel & Emissions Standards	Controlled Measures included in MOVES3

APPENDIX E-4

Cecil County MOVES Sample Input Files

July Weekday MOVES Run Specification File Settings

Sample xml file format

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Sample mrs file format

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APPENDIX E-5: Cecil County VMT and Emission Summary

2023 July Weekday

County	Summer Daily VMT	Speed (mph)	Emissions (Tons/Day)	
			VOC	NOx
Cecil	4,176,631	37.0	0.92	2.64

Cecil County VMT and Emission Summary By Road Type

2023 July Weekday

County	Road Type	Summer Daily VMT	Speed (mph)	Emissions (Tons/Day)	
				VOC	NOx
Cecil	Off-Network	N/A	N/A	0.60	0.38
	Rural Restricted	668,228	68.5	0.04	0.45
	Rural UnRestricted	1,084,584	44.9	0.09	0.58
	Urban Restricted	936,691	64.9	0.06	0.45
	Urban UnRestricted	1,487,128	39.4	0.13	0.78
Region Total		**4,176,631**		**0.92**	**2.64**

Cecil County VMT and Emission Summary By Source Type

2023 July Weekday

County	Source Type	SourceTypeID	Summer Daily VMT	Emissions (Tons/Day)	
				VOC	NOx
Cecil	Motorcycle	11	20,593	0.06	0.01
	Passenger Car	21	1,243,988	0.30	0.21
	Passenger Truck	31	2,182,177	0.41	0.49
	Light Commercial Truck	32	106,833	0.02	0.03
	Intercity Bus	41	32,693	0.02	0.20
	Transit Bus	42	2,218	0.00	0.00
	School Bus	43	8,821	0.00	0.01
	Refuse Truck	51	346	0.00	0.00
	Single Unit Short-haul Truck	52	218,867	0.05	0.31
	Single Unit Long-haul Truck	53	14,371	0.00	0.02
	Motor Home	54	4,849	0.00	0.01
	Combination Short-haul Truck	61	68,206	0.01	0.25
	Combination Long-haul Truck	62	272,669	0.04	1.10
Region Total			**4,176,631**	**0.92**	**2.64**