APPENDIX A:
EMISSIONS ESTIMATION UTILITIES FOR MOVES-BASED EMISSIONS INVENTORIES

TTI EMISSIONS ESTIMATION UTILITY MODULES FOR MOVES4-BASED EMISSIONS INVENTORIES

The following is a summary of the utility modules developed by TTI (written in the Python programming language) for producing detailed, link-based, hourly, and 24-hour emissions estimates for on-road mobile sources using the latest version of EPA's MOVES model (MOVES4). These utility modules produce inputs used with the MOVES model, calculate the necessary activity (VMT and off-network activity), calculate hourly emission factors, make special adjustments to the emissions factors (when required), and multiply the emissions factors with travel model link-based or Highway Performance Monitoring System (HPMS)-based (virtual link) activity estimates to produce emissions at user specified temporal and spatial scales.

The release of MOVES4 and associated guidance documents introduces several changes to developing on-road emissions inventories. These changes require an overhaul of the previous MOVES3 TTI utilities.

Besides introducing updates based on new regulations and updates in default data, the most significant change involves the introduction of the modeling capability of electric vehicles and CNG for more types of cars in MOVES4. It further supported a variety of combinations of electric fuel types with MOVES source types compared to its previous version, suggesting that over time, data and methods will be required to incorporate these electric vehicles into regulatory EIs. At the same time, it keeps the changes brought by MOVES3 about the new ONI activity, new models for calculating vehicle starts, and a database system.

The new MOVES4 TTI Utilities were redeveloped based on using Python programming language to ensure:

- New MOVES4 features could be accurately incorporated into Texas' EI methods.
    - Modeling electric vehicles

- Keep the same algorithm for ONI activity calculations and start calculations introduced in the MOVES3 TTI utilities.
- Continue work on the principles to ensure the process of undertaking EIs is more efficient.
    - Folder structure, module design, and file format
- Updates on activity algorithm when necessary.

Figure 1 outlines the basic steps required to run the new MOVES3-based TTI utilities.

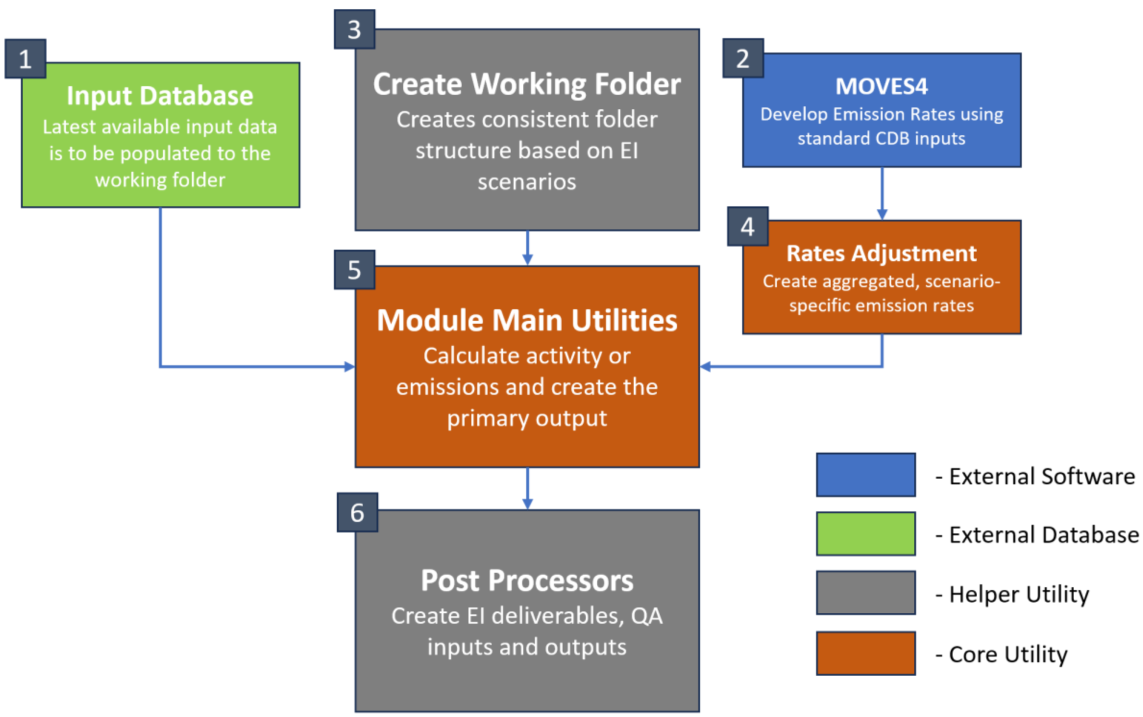

Figure 1. Basic steps required to develop an EI using the new TTI Utilities.

The numbered grey boxes indicate sequential steps and are described in the main text.

The following is a description of each step outlined in Figure 1:

1. The user prepares the activity and emission inputs for all the EI scenarios. The inputs will be loaded into working folders created in Step 3.
2. County Data Base (CDB) files are prepared and run using MOVES4 to obtain MOVES4 output databases for each scenario.

3. The user creates the working folder based on the number of EI scenarios to run. Scenarios are specified by area, analysis year, season, and day type. Analysts can calculate emissions for a single multi-county area or create multiple areas based on individual counties (or another relevant jurisdiction). Scenarios are defined through a YAML (a type of JavaScript Object Notation) file that defines the scope of the EIs to be run (this file is also used during Steps 4-6). A "Create Working Folder" utility uses the YAML file to create a project workspace containing empty folders that will become populated with input data required to run an EI and outputs for each scenario-driven EI (i.e., during Steps 4-6).
4. The TTI "Rates Adjustment" utility locates the MOVES4 output database for each modeled scenario. It makes necessary emission rate adjustments based on the county Low Emission Diesel (LED) factor and inspection maintenance programs and electric vehicles. Other MOVES default and local values (defined in the input CDB) are also extracted from the MOVES database and transferred to the working folder. This is the only time the new TTI Utilities interact with MOVES4 databases.
5. The "Module Main Utility" utility calculates and aggregates primary activity and emission inventory inputs by each category, on-network activity calculation, off-network activity calculation, and emission calculation. Options required for running EI Main are specified in another YAML control file called Utility_Control.yaml. The Main inventory works sequentially through each scenario defined in an EI project. It begins by calculating on-network and off-network activities. The EI Main Utility then works through each pollutant specified in the EI scenario and multiplies on- and off-network activities by the appropriate emission rates derived from Step 4. The EI Main utility produces simple, highly consistent output in tab-delimited text files (depending on runtime specifications, the user can specify whether to output EI results as link-by-link or county-scale summary files).
6. After the EI leading utility has been run, outputs are organized consistently in each of the specific EI scenario working folders. At this point, the analyst can choose from various post-processing utilities designed to QA EI inputs and outputs and create formatted data files suitable for reporting EI results for various downstream air quality planning purposes.

Compared to MOVES3 utilities, it eliminated the data convert helper utility and replaced the input database. This helps TTI maintain version control of the utility inputs and track changes among emission inventory projects. Here is the list of modules (included as Deliverable 4.3 of the project in the new MOVES4 TTI Utilities:

- Input database,
- XAML control file,
- Folder Structure Creating Utility,
- Core Utilities
    - On-network Activity Estimation Utility,
    - Off-network Activity Estimation Utility,
    - Rates Adjustment Utility,
    - Emission Estimation Utility
- Post-processing Utilities
    - Tab and tab totals and XML Post-processing Utility,
    - Link Emission Post-processing Utility,
    - Inventory mode CDB Activity Input Build Post-processing Utility,
    - Inventory mode CDB, MRS Post-processing Utility

On-network Activity Estimation Utility

TDM-Based Link VMT Module

The TDM-Based Link VMT Module(TRANSVMT) utility module post-processes travel demand models (TDMs) to produce hourly, on-road vehicle, seasonal and day-of-week specific, directional link VMT, and speed estimates. The TRANSVMT utility module processes a TDM traffic assignment by multiplying the link volumes by the appropriate HPMS, seasonal, or other VMT factors. Hourly factors are then used to distribute the link VMT to each hour of the day. The TTI speed model estimates the operational time-of-day link speeds for each direction. Since intrazonal links are not included in the TDM, special intrazonal links are created, and the VMT and speeds for these special links are estimated using the intrazonal trips from the trip matrix and the zonal radii.

The utility module then distributes the hourly HPMS functional class/area type VMT to each SUT/fuel type using the VMT mix and the HPMS roadway type designations. For each HPMS functional class/area type, the appropriate VMT mix road type is selected from the HPMS roadway type designations and the VMT mix for that VMT mix road type is applied to the hourly HPMS functional/area type VMT. If the 24-hour VMT mix is used, each hour uses the same VMT mix data set. If the time period VMT mix is used, each hour is assigned a time period based on the time period designations, and the appropriate time period VMT mix data set is used.

The utility module then calculates the hourly VMT by MOVES road type and SUT/fuel type. For each hour, the HPMS functional class/area type combinations are assigned a MOVES road type using the HPMS roadway type designations, and the hourly VMT is aggregated across MOVES road types to produce the county-level hourly VMT by MOVES road type and SUT/fuel type.

The link VMT and speeds produced by TRANSVMT are subsequently input to the EmsCalc utility for applying the MOVES-based emissions factors (as well as with other utilities to develop off-network activity estimates).

HPMS-Based Link VMT Module

The HPMS-based Link VMT calculation module processes analysis scenario (by year, season, day type) county-level VMT control totals to produce analysis scenario county-level hourly VMT by MOVES road type and SUT/FT. The main inputs to this module:

- County-level, 24-hour analysis scenario VMT control totals.
- County HPMS data sets, which include AADT VMT, centerline miles, and lane miles by HPMS area type and functional class.
- Hourly VMT distributions.
- 24-hour or time period VMT mix by roadway type, MOVES source type, and MOVES fuel type.
- Time period designations (only if time period VMT mix is used); and
- HPMS roadway type designations, which list associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types.

The utility module initially calculates the HPMS functional class/area type VMT distribution from the county HPMS data sets by dividing the HPMS functional class/area type AADT VMT by the county total HPMS AADT VMT. The county-level, 24-hour analysis scenario VMT is then distributed to each HPMS functional class/area type by multiplying this distribution by the county-level, 24-hour VMT control total. The 24-hour HPMS functional class/area type VMT is then distributed to each hour of the day using the hourly VMT distribution.

The utility module then distributes the hourly HPMS functional class/area type VMT to each SUT/fuel type using the VMT mix and the HPMS roadway type designations. For each HPMS functional class/area type, the appropriate VMT mix road type is selected from the HPMS roadway type designations and the VMT mix for that VMT mix road type is applied to the hourly HPMS functional/area type VMT. If the 24-hour VMT mix is used, each hour uses the same VMT mix data set. If the time period VMT mix is used, each hour is assigned a time period based on the time period designations, and the appropriate time period VMT mix data set is used.

The utility module then calculates the hourly VMT by MOVES road type and SUT/fuel type. For each hour, the HPMS functional class/area type combinations are assigned a MOVES road type using the HPMS roadway type designations, and the hourly VMT is aggregated across MOVES road types to produce the county-level hourly VMT by MOVES road type and SUT/fuel type.

The link VMT and speeds produced by the HPMS-Based Link VMT Module are subsequently input to the EmsCalc utility for applying the MOVES-based emissions factors (as well as with other utilities to develop off-network activity estimates).

Vehicle Population Build Module

The Vehicle Population Build (VehPopBuild) utility module builds the sourcetypeyear data files in a format consistent with the MOVES input database table. It also builds the SUT/fuel type population input file to estimate emissions or the off-network activity module to estimate starts and SHP) using the VMT mix and the Texas Department of Motor Vehicles (TxDMV) registration data sets. The TxDMV registration data sets are three sets of registration data (an age registration data file, a gas trucks registration data file, and a diesel trucks registration data file) that list 31 years of registration data. The primary inputs to this utility are:

- County ID file, which specifies the county for which the output will be calculated;

- Age registration data file, which lists 31 years of registration data for Passenger Vehicle, Motorcycles, Trucks <=6000, Trucks >6000 <=8500, Total Trucks <=8500, Gas Trucks >8500, Diesel Trucks >8500, TotalTrucks >8500, and Total All Trucks vehicle categories;
- Gas trucks registration data file, which lists 31 years of registration data for the Gas >8500, Gas >10000, Gas >14000, Gas >16000, Gas >19500, Gas >26000, Gas >33000, Gas >60000, and Gas Totals gas truck categories;
- Diesel trucks registration data file, which lists 31 years of registration data for the Diesel >8500, Diesel >10000, Diesel >14000, Diesel >16000, Diesel >19500, Diesel >26000, Diesel >33000, Diesel >60000, and Diesel Totals diesel truck categories;
- No roadtype VMT mix by TxDOT district, MOVES SUT, and MOVES fuel type;
- TxDOT district name file, which specifies the VMT mix TxDOT district;
- MOVES default database; and
- Population scaling factor file (optional);

For the desired county (from the county ID file), the age registration data (for the Passenger Vehicle, Motorcycles, Trucks <=6000, Trucks >6000 <=8500, and Total Trucks <=8500 vehicle categories) are saved in an age registration data array. The gas truck registration data (for the Gas >8500, Gas >10000, Gas >14000, Gas >16000, Gas >19500, Gas >26000, Gas >33000, and Gas >60000 gas truck categories) are saved in the gas truck section of the diesel/gas registration data array. The diesel truck registration data (for the Diesel >8500, Diesel >10000, Diesel >14000, Diesel >16000, Diesel >19500, Diesel >26000, Diesel >33000, and Diesel >60000 diesel truck categories) are saved in the diesel truck section of the diesel/gas registration data array. The age registration data array and the diesel/gas registration data array are combined to form the registration category data array (seven categories for 31 years of data and the total) using the combinations.

The registration category data array is used to fill the SUT population array (by SUT and fuel type) for all vehicles except long-haul trucks. Each SUT/fuel type combination is assigned the total registrations from one or more of the registration categories in the registration category data array:

- SUT 11 to Registration Category 2,

- SUT 21 to Registration Category 1,
- SUT 31 and 32 to Registration Category 3,
- SUT 41, 42, 43, 51, 52, 54 to Registration Category 4 and 6,
- SUT 61 to Registration Category 5 and 7.

SUT population factors are calculated, by SUT/fuel type using the data from the VMT mix input[1] for all SUTs except motorcycles (SUT 11) and the long-haul trucks (SUTs 53 and 62), and saved in the SUT population factors array. For SUT 21, each fuel type VMT mix fraction is divided by the total VMT mix for SUT 21. For SUT 31, each fuel type VMT mix fraction is divided by the total VMT mix for SUTs 31 and 32. The same process applies to SUT 32. For SUT 41, each fuel type VMT mix fraction is divided by the total VMT mix for SUTs 41, 42, 43, 51, 52, and 54. The same process applies to SUTs 42, 43, 51, 52, and 54. For SUT 61, each fuel type VMT mix fraction is divided by the total VMT mix for SUT 61.

For SUT 11, the SUT population factor for fuel type 1 (gasoline) is set to 1 with all other factors set to 0. For SUT 53, the SUT population factors by fuel type are calculated by dividing each fuel type VMT mix fraction for SUT 53 by the fuel type VMT mix for SUT 52. For SUT 62, the SUT population factors by fuel type are calculated by dividing each fuel type VMT mix fraction for SUT 62 by the fuel type VMT mix for SUT 61, therefore creating a ratio of long-haul and short-haul trucks. The SUT population factors are applied to the SUT population array for all SUTs except SUT 53 and 62. For SUT 53, the SUT population factors for SUT 53 are applied to the SUT population array for SUT 52. For SUT 62, the SUT population factors for SUT 62 are applied to the SUT population array for SUT 61.

Off-network Activity Calculation Module (OffNetActCalc)

The Off-network activity utility module (OffNetActCalc) calculates the analysis scenario off-network activity (ONI, Adjusted SHP, starts, SHEI and APU hours activity) by hour and SUT/fuel type (SHEI and APU hours activity are for SUT 62, fuel type 2 [CLhT_Diesel] and SUT 62, fuel type 9 [CLhT_Electricity] only).

[1] The VMT Mix for MOVES4 includes the fractions of gasoline, diesel and electric vehicles. The factions of electric vehicles are coming from MOVES4 default and local EV study from Clean Vehicles.

The ONI is calculated for each hour of the day using the following formula:

$$ONI\ Hours = (SHO_{network} \times TIF - SHI_{network})/(1 - TIF)$$

Where:

$SHO_{network}$ = the SHO on each link. This is calculated by dividing the VMT associated with each link by the link's congested speed.

$SHI_{network}$ = the total SHI that occurs on the network (idling that occurs as a component of drive cycles) and is calculated by multiplying $SHO_{network}$ by an RIF. RIF is the proportion of idling (in units of time) that occurs within a drive cycle at a specified operational speed. Default values for RIF are used as defined in the MOVES data table *roadidlefraction*.

TIF = the total idle fraction, i.e., the ratio of total source hours idling and total source hours operating. TIF default values are used as defined in the MOVES database table *totalidlefraction* (three-month seasonal averages for the summer weekday scenario and 12-month averages for the annual scenario).

The Adjusted SHP is calculated using hourly MOVES road type and SUT/fuel type VMT, an average speed distribution (same format as the MOVES default average speed distribution), and the SUT/fuel type population, and ONI activity. To calculate the Adjusted SHP activity, the utility first calculates the hourly MOVES road type and SUT average speed by applying the average speed distribution to the average speed bin speeds from MOVES and summing across the average speed bins. The utility then calculates the VHT (or SHO) by SUT/fuel type by dividing the hourly MOVES road type and SUT/fuel type VMT by the hourly MOVES road type and SUT average speed and aggregating across the MOVES road types; thus producing hourly SUT/fuel type SHO. The hourly SUT/fuel type SHP is calculated by subtracting the hourly SUT/fuel type SHO from the hourly SUT/fuel type total hours (since these are hourly calculations, total hours are set equal to the vehicle population). If the calculated SHP is negative (i.e., SHO is greater than the total hours), the SHP is set to 0. Adjusted SHP is then calculated by subtracting ONI hours from the previously calculated SHP.

Vehicle starts are estimated using county-level vehicle type populations and data from MOVES representing the average number of vehicle starts per vehicle type per hour. The starts per vehicle are calculated using the applicable MOVES algorithm with data on the age distribution and fuel fractions of the local fleet[2]. Local age distributions and fuel fractions inputs to MOVES are combined with MOVES default parameters (startsageadjustment, startsmonthadjust [three-month seasonal average for summer weekday scenario and 12-month average for annual scenario], and startspervehicle) to produce 24-hour starts per vehicle output representative of each seasonal period. The MOVES output provides the scenario-specific starts per vehicle defined by the study scope. For each hour of the day, the starts per vehicle data calculated by the MOVES algorithm are multiplied by the local vehicle type population estimates to produce the total number of starts by vehicle type per hour.

The SHEI and APU hours activity are a function of hotelling hours and are calculated using base data (24-hour hoteling and hourly MOVES road type and SUT/fuel type VMT), the analysis scenario data used to calculate the SHP, and the analysis scenario SHP. The utility also aggregates the SHP across hours to produce the daily SUT/fuel Type SHP. The utility module first calculates the 24-hour base CLhT_Diesel VMT from the base hourly MOVES road type and SUT/fuel type VMT and the analysis scenario CLhT_Diesel and CLhT_Electricity VMT from the base hourly MOVES road type and SUT/fuel type VMT. The 24-hour analysis scenario CLhT_Diesel VMT and CLhT_Electricity is then divided by the 24-hour base CLhT_Diesel VMT and CLhT_Electricity VMT to create a scaling factor, which is then applied to the base 24-hour hotelling hours to calculate the analysis scenario 24-hour hotelling hours. The utility then calculates the analysis scenario hourly hotelling hours. The analysis scenario hourly CLhT_Diesel and CLhT_Electricity SHO (from the SHP calculation process) is converted to hourly VHT fractions. The hourly hotelling fractions are calculated as the inverse of the hourly VHT fractions. The hourly hotelling fractions are then applied to the analysis scenario 24-hour hotelling hours to calculate the hourly hotelling hours. For each hour, the hourly hotelling hours are then compared to the hourly CLhT_Diesel SHP. For those hours where the hotelling hours are greater than the SHP, hotelling hours are set to the SHP for that hour. The utility then calculates the SHEI fraction and the APU hours fraction using the source type age distribution (same distribution used in the MOVES runs), the relative mileage accumulation rates, and the hotelling activity distribution. Travel fractions for source type 62 (CLhT) by ageID (0 through 30) are calculated by multiplying the age distribution by the appropriate relative mileage accumulation rate, which is then turned into a distribution by dividing the individual travel fraction (ageID 0 through 30)

[2] Previously with MOVES2014, TTI used MOVES default start per vehicle (which varied only by MOVES day type) in combination with local vehicle populations to estimate vehicle starts activity. In MOVES4, vehicle starts per hour also vary by county (because age distributions also vary by county).

by the sum of the travel fractions. These travel fractions are then applied, by model year, to each pertinent operating mode fraction (e.g., for SHEI and APU hours [operating mode IDs 200 and 201]), from the MOVES hotelling activity distribution (also by model year), and summed by operating mode to calculate the composite operating mode fractions (e.g., for operating modes 200 and 201). For each hour the analysis scenario hotelling hours are multiplied by the SHEI fraction to calculate the analysis scenario hourly SHEI activity and by the APU hours fraction to calculate the analysis scenario hourly APU hours activity. The utility also aggregates the hoteling, SHEI, and APU hours activity across hours to produce the daily hoteling, SHEI, and APU hours activity.

Rates Adjustment Module

The Rates Adjustment utility module consists of two utilities:

- RatesCalc module. The module calculates emission rates in terms of the rate/SHP for the evaporative emissions process using the data in the CDB in the MOVES emission rates run and the MOVES default database,
- and RatesAdj Module. The module applies emission rate adjustments to an emission rate database table if necessary.

The RatesCalc module creates copies of the rateperdistance, rateperhour, and rateperstart emission rates tables to include the units for each pollutant. If not specified, emission rates are assembled for each pollutant and process combination (excluding total energy and the refueling emissions processes) in the MOVES emission rates tables. The utility also uses the movesrun database table, along with a pollutant energy or mass lookup table (mass or gmole), to determine the units of the emission rates, which are added to the emission rates tables, which will allow the user to specify any of the units available in MOVES for the MOVES emission rates run. The type of activity used for the emission rate calculations is determined by the process, as Table 1 shows.

Table 1. MOVES Emissions Process and Corresponding Activity for Rate-per-Activity Emission rates

MOVES3 Emissions Process	Activity	Emission rate Units
Running Exhaust	Miles Traveled	Rate/Mile
Crankcase Running Exhaust	Miles Traveled	Rate/Mile
Start Exhaust	Starts	Rate/Start
Crankcase Start Exhaust	Starts	Rate/Start

MOVES3 Emissions Process	Activity	Emission rate Units
Extended Idle Exhaust	Extended Idle Hours	Rate/Extended Idle Hour
Crankcase Extended Idle Exhaust	Extended Idle Hours	Rate/Extended Idle Hour
Auxiliary Power Exhaust	APU Hours	Rate/APU Hour
Off-network Idling Exhaust[1]	ONI Hours	Rate/ONI Hour
Evaporative Permeation	Miles Traveled Source Hours Parked	Rate/Mile Rate/SHP
Evaporative Fuel Vapor Venting	Miles Traveled Source Hours Parked	Rate/Mile Rate/SHP
Evaporative Fuel Leaks	Miles Traveled Source Hours Parked	Rate/Mile Rate/SHP
Brake Wear	Miles Traveled	Rate/Mile
Tire Wear	Miles Traveled	Rate/Mile

1 The ONI emission rates have the same processID as running exhaust, with roadTypeID = 1.

For the rateperdistance (rate/mile emission rates) emission rate table, the utility creates a copy of the emission rates in the specified output database with the table name ttirateperdistance. If specific pollutants are specified, only the emission rates for those pollutants are copied to the ttirateperdistance table. Otherwise, the entire rateperdistance table is copied to the ttirateperdistance table. The utility also adds a "Units_Per_Activity" field to the ttirateperdistance table and fills that field based on the pollutant's energy or mass designation. For those pollutants designated as mass, the mass units from the movesrun table are added to the "Units_Per_Activity" field. For those pollutants designated as gmole, the mass units from the movesrun table, along with the text "-mole" (i.e., pound-mole or gram-mole) are added to the "Units_Per_Activity" field. No unit conversions are performed in this utility. The rateperstart and rateperhour, emission rate tables are processed similarly to produce the ttirateperstart and ttirateperhour, emission rate tables.

For the evaporative emission rates, the utility uses the CDB from the MOVES run and the MOVES default database to replicate the MOVES vehicle population and SHP calculation process. Using the emission rates from the rateperprofile and ratepervehicle emission rate tables, the utility calculates the rate-per-SHP emission rates by multiplying the emission rate by the appropriate vehicle population and dividing it by the appropriate SHP value. These rate-per-SHP emission rates are then saved in the ttiratepershp emission rate table. Similar to the previous RatesCalc emission rate tables, the "Units_Per_Activity" field is added to the ttiratepershp table and filled based on the pollutant's energy or mass designation.

The RatesAdj module applies emission rate adjustments to an emission rate database table produced by the RatesCalc module (ttirateperdistance, ttirateperstart, ttirateperhour, or ttiratepershp) or by this utility to produce a new emission rate database table in the same format as the input emission rate database table. The emission rate adjustments can be linear adjustments that are applied to all emission rates or can be applied by SUT, fuel type, pollutant, and process (adjustments may also include roadway type, average speed bin, and hour). The user has the option of selecting which pollutants will be in the new emission rate database table, along with the output units of the emission rates. This allows the user to perform any unit conversions between mass units (i.e., pounds to grams or pound-mole to gram-mole) without providing any additional adjustment factors. Unit conversions between unit types (i.e., gram-moles to grams or TEQ to grams) are not performed internally by the utility. These types of conversions must be made using the emission rate adjustment factors. The utility also has the option for combining multiple emission rate database tables into one new emission rate database table, if the input emission rate database tables are in the same format.

For the first input emission rate database table, the utility extracts the emission rates for the specified pollutants (or all the pollutants if not specified) from the input database emission rate table, applies the emission rate adjustments (if necessary), and any unit conversion adjustments, and saves these adjusted emission rates. If more than one emission rate database table is input, then the utility performs a similar calculation process to the first input emission rate database table for each input emission rate database table. If pollutants are found in more than one input emission rate database table, the adjusted emission rates are summed to produce one emissions rate.

After processing all of the input emission rate database tables, the utility creates a new emission rate database table in the same format as the first input emission rate database table and writes the adjusted emission rates to this new emission rate database table. Using MySQL code, the utility also creates a minimum and maximum emission rate summary for each input emission rate table and the output emission rate table by pollutant, process, and source type/fuel type, which is written to a tab-delimited file specified by the user.

Emission Calculation Module

The Emission Calculation utility (EmsCalc) module estimates the hourly link emissions for one user-specified county using the emissions factors (either from RatesCalc or

RatesAdj), the 24-hour or time period VMT mix, the hourly link VMT and speeds activity estimates (either from TRANSVMT or HMPS VMT), and the off-network activity (SHP, ONI hours, starts, and SHEI and APU hours). The primary inputs to this module are:

- Emissions factors from Rates Adjustment utility.
- Link-based hourly VMT and speeds developed with the TRANSVMT or HPMS VMT utility module. For each link, the following information is input to EmsCalc: link start node, link end node, link county number, link roadway type number, link area type number, link VMT, and link operational speed estimate;
- 24-hour or time period VMT mix by roadway type, MOVES SUT, and MOVES fuel type;
- Off-network activity (SHP, starts, ONI hours, SHEI, and APU hours) by hour and SUT/fuel type;
- VMT roadway type designations, which list associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types;
- The pollutants input file specifies which pollutant/process combinations for which the emissions calculations will be performed and their respective units in the tab-delimited output.

The emissions estimation can be categorized into two basic types based on the type of emissions factors: roadway-based emissions and off-network-based emissions. For the roadway-based emissions (ttirateperdistance emissions factors), the VMT for each link is distributed to each of the SUT/fuel type combinations listed in the VMT mix by roadway type (as designated in the VMT roadway type designations). If the time period VMT mix is input, each hour is assigned a time period by the user. Otherwise, the 24-hour VMT mix is used for all hours. For each pollutant/process combination in the pollutants input file, the emissions factors are selected based on the emission rate roadway type (as designated in the VMT roadway type designations) and the link speed for each SUT/fuel type combination listed in the VMT mix.

For link speeds greater than 75 mph, the emissions factors for 75 mph are used. For link speeds less than 2.5 mph, the emissions factors for 2.5 mph are used. For those link speeds that fall between the 16 MOVES speeds, the emissions factors are interpolated using the emissions factor interpolation methodology in the following section. These

SUT/fuel type combination-specific emissions factors are multiplied by the SUT/fuel type combination-specific VMT to estimate the mobile source emissions for that link by SUT/fuel type combination. If the activity and emissions by SCC are to be created, the activity and emissions are also aggregated by SCC using the SCC input file and by SCC pollutant using the SCC pollutants input file (thus allowing the user the option to combine multiple MOVES pollutants into one more aggregate pollutant).

For the off-network emissions, the ttirateperstart, ttirateperhour, and ttiratepershp emission rates(by SUT/fuel type) are multiplied by the appropriate activity, which is determined by the emissions process (see Table 1).

Emissions Factor Interpolation Methodology

To calculate emissions factors for link speeds that fall between two of the 16 MOVES speed bin speeds, an interpolation methodology similar to the methodology used with MOBILE6 is used. This methodology interpolates each emissions factor using a factor developed from the inverse link speed and the inverse high and low bounding speed bin speeds. The following is an example of a link speed of 41.2 mph.

The interpolated emissions factor (EF_{Interp}) is expressed as:

$$EF_{Interp} = EF_{LowSpeed} - FAC_{Interp} \times (EF_{LowSpeed} - EF_{HighSpeed})$$

Where:

$EF_{LowSpeed}$	= emissions factor (EF) corresponding to the speed below the link speed;
$EF_{HighSpeed}$	= EF corresponding to the speed above the link speed; and
FAC_{Interp}	= (1/ $Speed_{link}$ - 1/ $Speed_{low}$)/ (1/ $Speed_{high}$ - 1/ $Speed_{low}$)

Given that:

$EF_{LowSpeed}$	=	0.7413 g/mi;
$EF_{HighSpeed}$	=	0.7274 g/mi;
Speedlink	=	41.2 mph;
$Speed_{low}$	=	40 mph; and
$Speed_{high}$	=	45 mph.

$$FAC_{Interp} = (1/41.2\ - 1/40\ )/(1/45\ - 1/40)\ = 0.26214$$

$$EF_{Interp} = 0.7413\ g/mile\ \ - 0.26214 \times (0.7413\ g/mile\ - 0.7274 g/mile) = 0.7377\ g/mile$$

MOVES CDB ACTIVITY INPUT BUILD MODULE

The MOVES CDB Activity Input Build utility builds the roadtypedistribution, hourvmtfraction, avgspeeddistribution, roadtype, hpmsvtypeday, sourcetypedayvmt, year, state, zone, zoneroadtype, monthvmtfraction, and dayvmtfraction data files in a format consistent with the MOVES input database tables using the link-based hourly VMT and speeds developed with the TRANSVMT or HPMS VMT utility, the VMT mix, and the MOVES defaults. The utility also has the option of building the sourcetypepopulation (adjusted to reflect the 24-hour VMT mix), starts, and hotellinghours data files in a format consistent with the MOVES input database tables using the output from the OffNetActCalc utility, along with inputs from the MOVES runs and the MOVES defaults. The primary inputs to this utility are:

- Link-based hourly VMT and speeds developed with the TRANSVMT or HPMS VMT utility;
- County ID file which specifies the county number in the link-based hourly VMT and speeds for which the output will be calculated;
- VMT roadway type designations, which lists associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types (same as used with the Emission Calculation utility module);
- 24-hour or time period VMT mix by roadway type, MOVES source type, and MOVES fuel type (same as used with the Emission Calculation utility module);
- Day ID, which specifies the MOVES day ID for calculating the output;
- Year ID, which specifies the year for calculating the output;
- Link/Ramp designations, which designates each link roadway type/area type combination to either ramp or non-ramp;
- MOVES default database;
- Month ID, which specifies the month for calculating the output;

- sourcetypeyear, SUT age, and sourcetypeage inputs from the MOVES runs (optional, only if sourcetypeage table output is to be created);
- Starts output from the OffNetActCalc utility (optional, only if starts table output is to be created); and
- Hotelling, extended idle, and APU hours output from the OffNetActCalc utility (optional, only if hotelling table output is to be created).

For each link in the link-based hourly VMT and speeds in which the county number matches the desired county ID, the link VMT is saved in a VMT summary array based on hour, link functional class, and link area type. The link VHT (link VMT/link speed) is saved in a VHT summary array based on hour, link functional class, link area type, and MOVES average speed bin ID (determined using the MOVES average speed bins and the link speed). The link VHT is also saved in a road type VHT array based on link functional class and link area type, and, if the link is specified as ramp by the link/ramp designations specified by the user, the VHT is additionally saved in the ramp segment of the road type VHT array.

A MOVES roadway type array by MOVES roadway type (roadTypeID codes 2 through 5) is also created using the data in the VMT summary array and VMT roadway type designations. An hourly VMT array (by MOVES SUT, MOVES roadway type, and hour) is formed using the data in the VMT summary array, the VMT roadway type designations, and the VMT mix. If the time period VMT mix is used, each hour is assigned a time period by the user. Otherwise, the same 24-hour VMT mix is used for all hours. An average speed distribution array (by MOVES SUT, MOVES roadway type, hour, and MOVES speed bin) is created using the VHT summary array and the VMT mix. Using the appropriate MySQL code, the MOVES roadtypedistribution, hourvmtfraction, and avgspeeddistribution default values are extracted and saved for later use.

The VMT in the MOVES roadway type array is used to produce the roadway type distribution array by MOVES SUT and MOVES roadway type. This VMT is converted to a distribution by MOVES SUT (i.e., the total for a SUT over the five MOVES roadway types should equal 1), with the distribution value for MOVES roadway type 0 (Off-Network) equal to 0. The utility writes the tab-delimited roadtypedistribution table output (optional).

The VMT in the hourly VMT array is added to the hourly VMT fraction array (by SUT, MOVES roadway type, and hour) and for those roadway types where the VMT for all hours is greater than 0, this VMT is converted to hourly distribution. For those roadway types where the VMT is equal to 0, a value of 1 is placed in the first hour, followed by 0 in the remaining hours. The utility writes the tab-delimited hourvmtfraction table output (optional). For those SUTs where the VMT mix is greater than 0, the hourly VMT fraction array is used. Otherwise, the MOVES hourvmtfraction default values are used.

The VHT in the average speed distribution array is converted to a distribution by SUT, MOVES roadway type, hour/day (combination of hour and the day ID specified by the user), and MOVES average speed bin. The utility writes the tab-delimited avgspeeddistribution table output (optional). For those SUTs where the VMT mix is greater than 0, the average speed distribution array is used. Otherwise, the MOVES avgspeeddistribution default values are used.

The VHT in the road type VHT array is converted to a proportion of ramp VHT by dividing the ramp segment of the road type VHT array by the total VHT for the road type in the road type VHT. The utility writes the tab-delimited roadtype table output (optional).

The VMT in the hourly VMT array is aggregated to create the 24-hour HPMS vehicle-type VMT array. Each SUT is assigned an HPMS vehicle type (SUT 11 is HPMS vehicle type 10; SUTs 21, 31, and 32 are HPMS vehicle type 25; SUTs 41, 42, and 43 are HPMS vehicle type 40; SUTs 51, 52, 53, and 54 are HPMS vehicle type 50; and SUTs 61 and 62 are HPMS vehicle type 60). The utility writes the tab-delimited hpmsvtypeday table output (optional).

The VMT in the hourly VMT array is also aggregated by SUT to create the 24-hour SUT VMT array. Using this VMT data, the utility writes the tab-delimited sourcetypedayvmt output table (optional) in a format consistent with the MOVES input.

Using the appropriate MySQL code, the fuel year ID is extracted from the MOVES default year database table for the user-supplied year ID. The tab-delimited year table output is written (optional) using the user-supplied year ID and the extracted fuel year ID. The "isbaseYear" data is written as well (automatically set to "Y").

The utility also produces two tab-delimited summary output files. A tab-delimited VMT summary is output by hour, link road type, and link area type for the user-specified county. A tab-delimited VHT summary is output by hour, link road type, link area type, and MOVES average speed bin for the user-specified county.

The utility creates five other tab-delimited outputs (state, zone, zoneroadtype, monthvmtfraction, and dayvmtfraction tables) using the user-supplied inputs. For the state table (optional), the utility extracts the data from the MOVES default state database table where the state ID is 48 and writes this data to the tab-delimited state table output. For the zone table (optional), the utility extracts the data from the MOVES default zone data for the county ID greater than 48000 and county ID less than 49000 and writes this data to the tab-delimited zone table output with the start allocation factors, idle allocation factors, and SHP allocation factors replaced with values of 1.

For the zoneroadtype table (optional), the utility extracts the MOVES default zoneroadtype data where the zone ID greater than 480000 and zone ID less than 490000 and writes this data to the tab-delimited zoneroadtype table output, with the SHO allocation factors replaced with values of 1. For the monthvmtfraction table (optional), the utility extracts the data from the MOVES default monthvmtfraction table and writes the data to the tab-delimited monthvmtfraction table output with the month VMT fraction set to 1 for the user-supplied monthID and 0 for all other months. For the dayvmtfraction table (optional), the utility extracts the data from the MOVES default dayvmtfraction table and writes this data to the tab-delimited dayvmtfraction table output with the day VMT fraction is set to 1 for the user-supplied day ID and 0 for all other months.

For the sourcetypeage table output (optional, also needed if the hoteling hours table output is to be created), the utility calculates the adjusted relative mileage accumulation rates (MAR) by multiplying the input relative MAR (categorized by SUT and age from the sourcetypeage input) by the SUT-specific relative MAR adjustment factors (one factor per SUT applied across all age categories). These adjustment factors are calculated using inventory SUT VMT fractions within each HPMS vehicle type and the sum of the SUT-specific normalized travel fractions within each HPMS vehicle type. The inventory SUT VMT fractions within each HPMS vehicle type are calculated by dividing the 24-hour SUT VMT by the 24-hour HPMS vehicle type VMT for the respective SUT.

For the sum of the SUT-specific normalized travel fractions within each HPMS vehicle type, the utility uses the same calculation procedures used by MOVES to calculate the normalized travel fractions. The SUT vehicle population is distributed to each age category using the SUT age distribution input. Using the sum of the vehicle population by HPMS vehicle type, the SUT population fraction for each age category within each HPMS vehicle type is calculated by dividing the SUT vehicle population by age by the sum of the vehicle population by HPMS vehicle type. The utility then calculates the initial travel fractions (by SUT and age) by multiplying the SUT population fraction for each age category within each HPMS vehicle type by the relative MAR input.

These initial travel fractions are then normalized within each HPMS vehicle type to produce the SUT and age-specific normalized travel fractions within each HPMS vehicle type. The utility then calculates the SUT-specific relative MAR adjustment factors by dividing the inventory SUT VMT fractions within each HPMS vehicle type by the sum of the SUT and age-specific normalized travel fractions (i.e., aggregated across the age category for each SUT); resulting in one SUT-specific relative MAR adjustment factor for each SUT.

For the starts table output (optional), the utility aggregates the SUT/fuel type hourly starts input (output from the OffNetActCalc utility) by SUT and multiplies the SUT hourly starts by the SUT age distribution (by SUT) to distribute the hourly SUT starts to each age category. The SUT hourly starts by age are written to the starts table output file, along with the user-supplied monthID, yearID, dayID (used to form the output hourDayID), and zoneID (set using the user-supplied county FIPS code.

For the hoteling hours table output (optional), the utility uses travel fractions specific to SUT 62 to distribute the hourly hoteling hours input (output from the OffNetActCalc utility) to each age category. These travel fractions are calculated by multiplying the SUT 62 age distribution by the calculated relative mileage accumulation rates (MOVES defaults adjusted to reflect the emissions inventory 24-hour VMT mix) for each age category and dividing by the sum of the product for all the age categories. These travel fractions are multiplied by the hourly hoteling hours input and written to the hoteling hours table output, along with the user-supplied dayID (used to form the output hourDayID), monthID, yearID, and zoneID (set using the user-supplied county FIPS code.

Post Processing Utilities

The post-processing utilities process the intermediate results from the EI Main Utility to produce the post-processed emission estimate results in a tab-delimited file (including all of the SUT/fuel type combinations listed in the VMT mix on a single line, separated by a tab character) for the specified county by pollutant, link roadway type, and SUT/fuel type combination for each of the specified episode periods. A 24-hour (or total if all 24 hours are not specified) output is also included in the tab-delimited file. Only those pollutant/process combinations in the pollutants input file with tab-delimited output units other than "NONE" will appear in the tab-delimited output file. Prior to output, any unit conversions between mass units (i.e., pounds to grams or pound-mole to gram-mole) are performed by the utility. Unit conversions between unit types (i.e., gram-moles to grams or TEQ to grams) are not performed internally by the utility (these types of unit conversions must be done using the RatesAdj utility). This tab-delimited file also includes hourly and 24-hour summaries of the off-network activity and VMT, VHT, and speed by link road type. Link emissions may also be output by county, pollutant, process, and each SUT/fuel type combination. If specified, the tab-delimited activity and emissions by SCC output file is also created, which lists the activity and emissions for each SCC pollutant by SCC.