CAPCOG FY14-15
PGA FY14-1
Deliverable 2.1.7
Amendment 1

ERG Project No: 3948.00.001.001

Use of MOVES and SEE for On-road Inventory Generation in the Austin Area

FINAL REPORT

Prepared for:

Capital Area Council of Governments

Prepared by:

Scott Fincher
Allison DenBleyker
Doug Jackson

Eastern Research Group, Inc.

L.D. White

Texas Transportation Institute

December 10, 2015
Revised December 28, 2015

PREPARED UNDER A GRANT FROM THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

The preparation of this report was financed through grants from the State of Texas through the Texas Commission on Environmental Quality. The content, findings, opinions, and conclusions are the work of the author(s) and do not necessarily represent findings, opinions, or conclusions of the TCEQ.

EXECUTIVE SUMMARY

Under a contract with the Capital Area Council of Governments (CAPCOG), Eastern Research Group, Inc. (ERG) produced summer and school-year, ozone-season day, link-based on-road mobile 2012 and 2018 emissions inventory estimates for the Austin-Round Rock Metropolitan Statistical Area (MSA), which consists of Bastrop, Caldwell, Hays, Travis, and Williamson Counties, using its Spatial Emissions Estimator (SEE) tool. Inventory data was developed for four day types: Monday-Thursday (M-Th), Friday (F), Saturday (Sat.), and Sunday (Sun.). SEE evaluates both link-level roadway activity (for running emissions at the MOVES project level) and zone-level activity (for start, idle, and evaporative emissions at the MOVES county level) from travel demand models (TDMs), and executes MOVES runs to estimate total on-road emissions for individual counties. This document details the inputs used to create the inventories, discusses the design and usage of the SEE and MOVES models in the process, and provides examples of model outputs for references. Full model outputs are provided as an electronic appendix to this document. The table below summarizes the total vehicle miles traveled (VMT), kilowatt-hours (kWh) of energy consumption, and tons per day (tpd) of carbon monoxide (CO), carbon dioxide (CO_2), ammonia (NH_3), nitrogen oxides (NO_X), coarse particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), and volatile organic compounds (VOC) emissions for each of the sixteen runs performed for the five-county region.

Table ES- 1 Summary of Activity and Emissions Estimates for Austin-Round Rock MSA

Year	Period	Day	VMT	Energy Consumption (kWh)	CO (tpd)	CO_2 (tpd)	NH_3 (tpd)	NO_X (tpd)	PM_{10} (tpd)	$PM_{2.5}$ (tpd)	SO_2 (tpd)	VOC (tpd)
2012	Summer	M-Th	46,396,076	81,315,396	300.83	24,498.63	1.55	51.64	3.45	1.74	0.56	24.13
2012	Summer	F	50,760,290	88,804,212	323.92	26,683.91	1.70	54.19	3.79	1.86	0.61	24.84
2012	Summer	Sat.	43,500,492	71,869,473	272.19	21,620.34	1.46	42.27	2.70	1.28	0.52	21.68
2012	Summer	Sun.	37,758,073	61,416,383	245.38	18,527.95	1.27	36.29	2.22	1.02	0.45	20.63
2012	School	M-Th	46,209,069	80,970,360	299.89	24,397.16	1.55	51.46	3.43	1.73	0.55	24.10
2012	School	F	50,543,392	88,396,144	322.81	26,563.98	1.69	54.00	3.77	1.85	0.61	24.79
2012	School	Sat.	44,448,185	73,555,052	277.41	22,116.64	1.50	43.06	2.77	1.31	0.53	21.84
2012	School	Sun.	38,236,904	62,281,702	248.24	18,782.95	1.29	36.68	2.26	1.04	0.46	20.71
2018	Summer	M-Th	54,380,341	86,482,695	231.44	26,076.03	1.34	27.52	3.07	1.15	0.17	16.38
2018	Summer	F	59,495,539	94,236,785	248.90	28,340.30	1.47	28.49	3.41	1.24	0.19	16.68
2018	Summer	Sat.	50,986,321	76,248,951	210.08	22,955.31	1.26	22.03	2.53	0.90	0.15	14.93
2018	Summer	Sun.	44,255,856	65,071,411	189.80	19,647.79	1.09	18.89	2.11	0.73	0.13	14.38
2018	School	M-Th	54,160,917	86,118,391	230.74	25,968.78	1.34	27.43	3.06	1.15	0.17	16.36
2018	School	F	59,241,354	93,810,270	248.08	28,214.87	1.46	28.40	3.39	1.24	0.18	16.66
2018	School	Sat.	52,097,023	78,024,924	214.04	23,478.48	1.28	22.40	2.60	0.92	0.15	15.01
2018	School	Sun.	44,846,781	66,023,777	192.08	19,928.27	1.11	19.09	2.15	0.75	0.13	14.42

Table of Contents

List of Tables

List of Figures

1.0 Introduction

Under previous contracts with the Houston-Galveston Area Council (H-GAC), ERG and its subcontractor Cambridge Systematics, Inc. developed a modeling framework for estimating regional on-road emission inventories for each hour of a day with highly detailed spatial resolution, including emission "hot-spots" not on the traditional travel network such as truck stops and port terminals. This framework, named the Spatial Emissions Estimator (SEE), employs MOVES2014 at both the project and county scale to cover all needed emission processes in accordance with EPA modeling guidance.[1] Among the novel features of the first SEE implementation are: a) the application of MOVES project scale to develop a regional emissions inventory, which introduces the possibility of including road grade impacts at an area-wide level; b) allocation of off-network emissions to transportation analysis zones based on travel demand model origin/destination matrices and spatial analysis of truck extended idle locations. For future implementation, the framework can be extended to include heavy-duty emission "hot spots" not already accounted for in the travel model network such as port terminals and distribution centers.

The SEE framework provides a comprehensive system for estimating regional emissions consistent with EPA guidance on preparing inventories for SIP and transportation conformity, and a platform for further customization to account for emissions hot-spots. The high degree of spatial detail is an improvement over more aggregate methods of preparing emission inventories because the location of emissions is important to photochemical air quality model frameworks, which require gridded, hourly emission estimates. For example, SEE estimates start exhaust emissions by transportation analysis zone within counties, using the relative number of trip starts in each zone, and this spatial pattern of trips varies by time of day. This feature in SEE represents an improvement over the reliance on default spatial surrogates such as local roadways or human population because SEE is using local data. Finally, the ability to account for road grade in regional emissions analysis adds a new dimension previously focused only on project level hot spot analysis for MOVES. Portions of this document are based on the original report prepared for H-GAC documenting SEE development using MOVES2010b.[2] ERG did not use the road grade capability of MOVES for the Austin area emission inventory development.

[1] U.S. EPA, MOVES2014 Technical Guidance: Using MOVES to Prepare Emission Inventories in State Implementation Plans and Transportation Conformity, Report No. EPA-420-B-015-007, January 2015

[2] ERG, "Spatial Emissions Estimator (SEE): Overview and User Documentation for Houston-Galveston- Brazoria Implementation – Final Report", October 30, 2014.

This report presents an overview of the broader SEE design, detailed discussion of inputs used to develop the Austin-area on-road emissions inventory for CAPCOG, and example summaries of outputs produced by the model. A complete archive of all electronic files generated by the model, including link-level and county-level emissions, along with files formatted for use with EPS3, are being provided to CAPCOG separately.

2.0 Model Design

2.1 Overview

The Austin-Round Rock MSA includes five counties in Central Texas, with a population of over 1.9 million people. Travel demand model (TDM) data for the region obtained from the Capital Area Metro Planning Organization (CAMPO) characterizes this area with tens of thousands of unique roadway links and thousands of travel analysis zones (TAZs). The current TDM used by CAMPO includes all five counties in the Austin-Round Rock MSA, as well as Burnet County. For this project, though, Burnet County is excluded from the analysis since it is not part of the MSA. The motivation for use of SEE in this case was to estimate emissions for each link and zone in the Austin area. An additional motivation was to have a framework that in the future could account for emissions from heavy-duty trucks that occur at specific locations not accounted for on the travel network, including distribution centers and warehouses with a high concentration of trucks.

As part of the tool development, not only were link-level emissions desired for “running” emission processes, but also emissions at the TAZ level for the “off-network” emission processes of vehicle start, evaporative and heavy-duty truck extended idle. This requires full integration of link travel and zone-based trip activity from the travel model. For truck “hoteling” activity and emissions, ERG used data provided by CAPCOG on the locations and parking capacities of truck idling locations within the region. For use of the emissions in SIP and conformity analysis, a primary requirement was that SEE produce an inventory consistent with that estimated with MOVES run in county scale inventory mode and developed based on EPA’s modeling guidance.

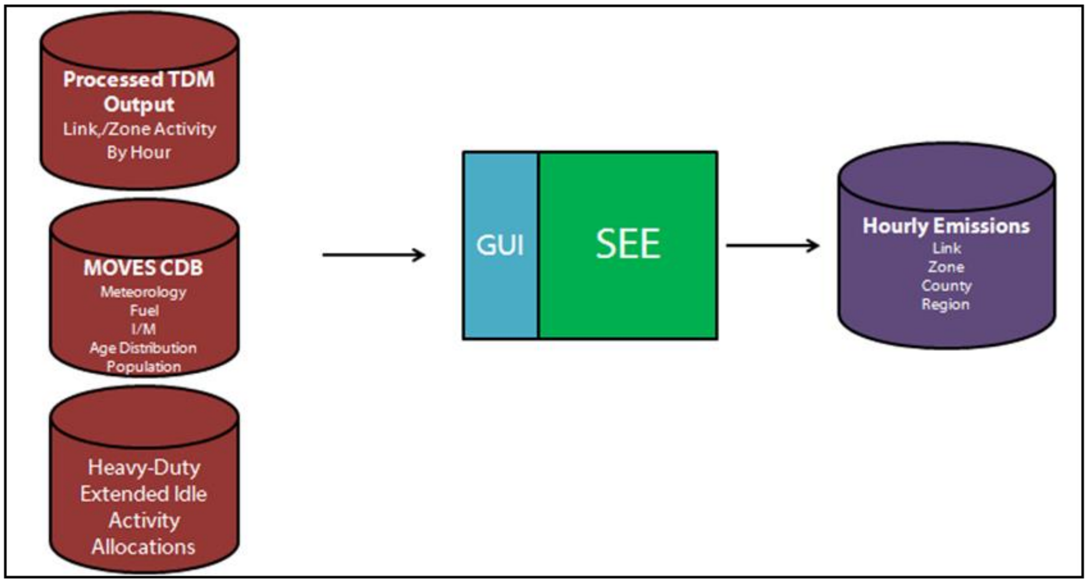
SEE provides a simple GUI-driven system, the ability to model base and projection years per conformity requirements, flexibility in output aggregation (e.g. link, zone, county, region), and the ability to use MOVES database tables directly to supply needed data not provided by travel model activity data. The latter requirement allows the user to employ the MOVES county data manager (CDM) framework to populate tables containing necessary input data such as vehicle population, fuels, inspection/maintenance program parameters, meteorology and age distribution. In this way, execution of SEE parallels that of MOVES in terms of input preparation, a key difference being the use of travel demand model output directly to provide major activity inputs such as VMT, average speed and road type distribution. The modeling suite makes use of a pre-processing utility that prepares raw travel demand model output for use in SEE, known as TRANSVMT. TRANSVMT was first developed by TTI to produce link-level activity for emissions modeling from raw travel model output by post-processing link speeds, and creating links to represent bidirectional travel and trips within a travel zone (i.e. intrazonal links).

In addition, SEE was designed to use direct MOVES runs as much as possible, while relying on supplemental scripting for calculations that are universal to different MOVES versions. The conceptual design of SEE realizes this goal to a high degree, in that it is possible for the SEE approach to rely almost exclusively on direct MOVES runs and output. The need for improved runtime performance did require reducing the number of MOVES runs by adopting a "unique links" approach whereby SEE runs MOVES only for a subset of links having unique emissions-determining properties (i.e., same road type and speed) and then calculates the emissions on other links outside of MOVES using PERL scripts.

Figure 2-1 shows an overall flow of SEE. The data canisters in red denote input data preparation before running SEE. Beginning with raw travel demand model output (traffic volume and average speed by link; trip origins and destination by TAZ), pre-processing for SEE includes running the updated TRANSVMT script to produced hourly link-level volume and speeds. SEE also requires data in MOVES input table format for non-travel related inputs. For allocation of extended idle emissions, a table of idle activity allocation factors by TAZ is also required. Pre-processing of travel demand data is required for each unique travel model run or to invoke the alternate speed post-processing routine.

Once the inputs have been prepared, to execute SEE the user makes basic input/output selections in a simple GUI. Within SEE, the on-network and off-network approaches are different but integrated into one system, with common input/output databases. PERL scripts set up and execute a separate set of MOVES runs for on-network and off-network emission processes and then post-processes the MOVES results into link-level and zone-level emissions, or sum to a coarser level of aggregation as specified by the user. The post-process scripts also implement the Texas Low Emission Diesel (TxLED) program reductions. The details of the on- and off-network processes are discussed in the following sections.

Figure 2-1. Overview of SEE Flow



2.2 On-Network Approach

Within SEE, on-network and off-network emissions are generated through a separate set of MOVES runs which share basic inputs for fuels, meteorology, age distribution, I/M and vehicle population. On-network emissions (except ramps and running loss evaporative emissions, as described below) are generated using MOVES project scale runs for unique links combined with PERL scripts that calculate emissions on other links with the same properties as the unique links, for each hour of the day. This approach allows bottom-up calculation of a regional emission inventory from individual links, while retaining the spatial distribution of travel network emissions.

Within SEE, PERL scripts are used to prepare MOVES inputs by converting TRANSVMT output to MOVES project database link inputs. It is possible to set up MOVES project scale to run all links in the Austin area directly, for each hour of the day. This approach was initially attempted to address the desire for more reliance on direct MOVES runs over external scripting, but abandoned when it became clear that runtime would be prohibitive. This led to the development of a streamlined approach, where the links defined for the MOVES project runs were only those with unique combinations of road type and average speed, known as "unique links". With emissions from these links, the remainder of links can be estimated simply by scaling emissions from the unique links according to source hours operating (SHO) of each link, defined in MOVES as VMT divided by the average speed for each link. This process replicates internal MOVES logic for calculating total emissions in inventory mode. Typically, using the unique link approach with the binned travel model speeds reduced the number of links to process through MOVES by two orders of magnitude. This became the default approach for SEE, for best replication of county-scale results.

Note that MOVES project scale doesn't include evaporative emissions, so these emissions were also added to the "off-network" county scale runs within SEE, as described below.

2.3 Off-Network Approach

Off-network emissions include start (exhaust and crankcase), evaporative (permeation, vapor venting, liquid leaks and refueling) and extended idle emission processes. With the exception of refueling, these are estimated in SEE with a MOVES county scale run for a weekday, producing emission results by hour. Refueling is not estimated in SEE intentionally, following the precedent set by the TTI's suite of modeling tools for on-road emissions. The county scale MOVES run shares input tables with the on-network project scale runs for vehicle population, fuels, fuel technology, inspection/maintenance, meteorology, age distribution. For the remaining input tables unique to county scale activity (total VMT, hourly VMT distribution, road type VMT distribution, and average speed distribution), input tables are produced by PERL scripts that aggregate link-level activity estimated by the travel model and pre-processed using TRANSVMT, according to EPA's modeling guidance. This is needed because in MOVES, off-network activity is related to on-network activity (e.g., hours parked depends on hours operating); using aggregated TRANSVMT activity ensures the off-network activity is consistent with travel model network results.

The results of the county-scale MOVES runs are then allocated to TAZs in the Austin area with PERL scripts and allocation factors by TAZ and time of day. Since the same meteorology is used for an entire county, the level of detail in the internal MOVES allocation approach is unnecessary, and allocation of emissions to zones can be done through post-processing. This approach was taken in SEE because runtime performance proved to be much better.

Allocation factors for start and evaporative emissions are calculated within SEE using PERL scripts, based on travel demand model origin/destinations by zone. Start allocations are based on number of trip origins by zone, and evaporative (park) allocations are based on number of trip ends by zone. These are estimated by the Austin-Round Rock MSA travel demand model for four time periods - AM peak (6:00 AM - 8:59 AM), Midday (9:00 AM - 2:59 PM), PM peak

(3:00 PM - 5:59 PM) and Overnight (6:00 PM - 5:59 AM) – and allocations are estimated for each time period and applied to the appropriate hourly MOVES results.

ERG developed spatial allocation factors to distribute hotelling emissions from county total to the TAZs where truck stops are located according to a recent CAPCOG study[3] on extended idling. ERG calculated the magnitude of hotelling hours based on observed occupancy rates of parking spaces multiplied by the parking capacity of truck stops and added in the hotelling that occurs along frontage roads throughout the 5-county MSA. ERG provided the hotelling hours as a user input to MOVES2014 to override EPA default calculations of extended idling, and then SEE allocated the resulting county hotelling emissions to the subset of TAZs where the activity actually occurs. ERG also developed splits of the hotelling activity from small diesel auxiliary power units (APU) engines versus larger main engines using truck driver survey results from the same CAPCOG study. The proportions of diesel APU and main engine hotelling were also provided to MOVES2014 in order to override the EPA default national average assumption of 30% APUs on model year 2010+ combination long-haul trucks.

2.4 Overview of Model Options and Scenarios

During this project, the following model options and outputs were specified:

- Use of the latest available version of the EPA mobile emissions factor model, which is currently MOVES2014 (October 2014 release) and is available at http://www.epa.gov/otaq/models/moves.
- Use of the latest version of SEE, developed by ERG for H-GAC.
- Modeling of the following pollutants:
    - Volatile Organic Compounds (VOC),
    - Carbon Monoxide (CO),
    - Nitrogen Oxide (NO),
    - Nitrogen Dioxide (NO_2),
    - Nitrous Acid (HONO),
    - Nitrate (NO_3),
    - Nitrogen Oxides ($NO_X = NO + NO_2 + HONO$),
    - Sulfur Dioxide (SO_2),
    - Carbon Dioxide (CO_2),
    - Ammonia (NH_3),
    - Ammonium (NH_4),
    - Water Vapor (H_2O),

[3] Hoekzema, A., *Modeling Truck Emissions in Central Texas*. Paper presented at the 21st EPA Emission Inventory Conference, San Diego, California. April 2015.

    - Particulate Matter (both $PM_{2.5}$ and PM_{10}, including organic carbon (OC), elemental carbon (EC), sulfate (SO_4), brake wear, tire wear, non-EC PM, and non-EC non-SO_4 PM),
    - Total Energy Consumption.
- Modeling of MOVES pollutant processes that include running exhaust, crankcase running exhaust, start exhaust, crankcase start exhaust, extended idle exhaust, auxiliary power exhaust (APU), crankcase extended idle exhaust, evaporative permeation, evaporative fuel vapor venting, and evaporative fuel leaks.
- Temporal variability by season (school and summer season) and by four day types: Monday-Thursday, Friday, Saturday, and Sunday, consistent with TCEQ protocols for modeling on-road emissions for photochemical modeling applications.
- Use of the latest available TDM output for the Austin-Round Rock MSA from the Capital Area Metropolitan Planning Organization (CAMPO) to estimate hourly vehicle miles traveled (VMT) for each roadway segment or "link" in the transportation network.
- Input of source use type (SUT) mixes, age distributions, VMT adjustment factors, fuel formulations and market share, and meteorology specific to the Austin-Round Rock MSA.
- Input of vehicle inspection and maintenance (I/M) parameters for Travis and Williamson Counties reflecting the current programmatic configuration and the MOVES default compliance factors for passenger cars (93.12% compliance factor, assuming 100% regulatory class coverage, 96% compliance rate, and 3% waiver rate), passenger trucks (91.26% compliance factor, assuming 98% regulatory class coverage, 96% compliance rate, and 3% waiver rate), and light commercial trucks (86.6% compliance factor, assuming 93% regulatory class coverage, 96% compliance rate, and 3% waiver rate).
- Post-processing of diesel emissions to account for the effects of the TxLED program, using factors developed by the TCEQ using MOVES2014 available at ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/Statewide/mvs/txled/ in the "mvs14-statewide-txled-analysis-06-12-18.zip" package of files.

3.0 MOVES and SEE Inputs

The two tables below describe where the various MOVES2014 input files fit into the SEE model's processing stream. Details on the origin of data and analysis to prepare the inputs are discussed separately by file type, following this overview.

SEE runs the MOVES2014 model at two different scales. MOVES2014 Project Scale runs prepare link-level estimates of the emissions occurring over-the-road (except evaporative emissions and ramps), and County Scale runs primarily prepare the off-network emissions such as starts, evaporative, and extended idle emissions. Because the Project Scale in MOVES2014 does not allow modeling of evaporative hydrocarbons nor a direct option to model highway links as ramps, SEE adds these onto the MOVES2014 County Scale runs. SEE seamlessly coordinates the different scale MOVES2014 and the post-processing steps so that in the end, all on-the-road emissions by link are reported in a single table, and all off-network emissions are reported together in another table by county and travel zone.

As shown below, the two scales of MOVES2014 require a number of input tables, some of which are calculated by SEE based on travel demand model data, and some must be provided by the user.

Table 3-1. Project Scale MOVES2014 Inputs (On-network Emissions)

Database table name	Description	Calculated by SEE	Provided by User
AVFT	Gasoline/diesel splits by source use type and model year		X
Fuel Formulation	Description of fuel properties		X
Fuel Supply	Assignment of fuels to counties		X
IM Coverage	Inspection and maintenance program description and coverage		X
Link	Each link, road type, length, vehicle volume, average speed, and road grade (road grade not used by SEE).	X	
Link Source Type Hour	Link level fleet mix that lists the fraction of VMT for each source type and fuel type.	X	
Source Type Age Distribution	Relative distribution of vehicle population by model year		X
Zone Month Hour	Hourly temperature and humidity		X

Table 3-2. County Scale MOVES2014 Inputs (Off-network, Evaporative, and Ramp Emissions)

Database table name	Description	Calculated by SEE	Provided by User
AVFT	Gasoline/diesel splits by source use type and model year		X
Average Speed Distribution	Distribution of VMT by speed bins by hour, source type, day type, and road type.	X	
Day VMT Fraction[1]	Distribution of VMT to day types (weekday, weekend). SEE is set up to run one day at a time, so this file always has a fraction of 1.	*N/A*	
Fuel Formulation	Description of fuel properties		X
Fuel Supply	Assignment of fuels to counties		X
Hour VMT Fraction	Distribution of VMT from day to hours.	X	
Hotelling Activity Distribution	Fraction of hotelling hours main engines vs. APUs by model year.		X
Hotelling Hours	Total hotelling hours by hour of day and model year.		X
HPMS Vtype Year	Annual VMT by HPMS vehicle type	X	
IM Coverage	Inspection and maintenance program description and coverage		X
Month VMT Fraction[2]	Distribution of VMT from annual to month of year. SEE is set up to run one day in a particular month at a time, so this file always has a fraction of 1.	*N/A*	
Road Type	Contains fraction of ramp travel relative to travel on all restricted access roads, separately by urban and rural.	X	
Road Type Distribution	Distribution of VMT across the MOVES road types.	X	
Source Type Age Distribution	Relative distribution of vehicle population by model year		X
Source Type Year	Vehicle population by source type		X
Zone Month Hour	Hourly temperature and humidity		X

[1, 2] These are required by MOVES but should not be modified by the User; they are automatically looked up by SEE.

In addition to the MOVES2014 inputs listed above, there are a number of input files that SEE requires, such as travel demand model hourly data and several cross-references files, listed below.

Table 3-3. Other SEE Inputs

Input File Name	Description
TRANSVMT Files *CAPCOG1218_TRANSVMT_YYYY_SSS_DDD.HH*	Flat files containing hourly TRANSVMT output of link descriptions, VMT, and speeds. There were 384 files in all – corresponding to two years, two seasons, four day types, and 24 hours. • YYYY = 2012, 2018 • SSS = Sch, Sum • DDD = Wkd, Fri, Sat, Sun • HH = hours 01 through 24
Trips Files *AUS_YYYY_PERIOD_TripMatrix.asc*	Flat files containing the number of origin and destination trips by time period. There were 8 files in total. SEE uses these to calculate spatial allocations at the sub-county level for start emissions and parked-vehicle evaporative emissions. • YYYY = 2010, 2020 • PERIOD = AMPK, MDAY, OVN, PMPK
County Lookup	Maps the travel network's county codes 1-6 to the 5-digit FIPS code
Ext Idle Zone and Capacity	Relative fractions that sum to 1 by county, used to spatially allocate county hotelling emissions to travel zones
Link Definitions	List of the travel network link IDs by unique Anode and Bnode combination that can occur in any hour in the travel network
Road Type Lookup	Maps the travel network's road type codes to the appropriate MOVES road type code
Source Type Age Lookup	A copy of the default MOVES2014 SourceTypeAge table that contains relative annual mileage accumulation by model year. SEE uses this to prepare travel fractions for the Project Scale MOVES runs.
Sub Day Type XX	Where XX is the two-digit code to represent day type WK, FR, SA, or SU. The day type file is used to help with organization of inputs that vary by day type.
Time Period Designation	Defines time periods of the travel demand model and trips files: AM peak, Midday, PM peak, and Overnight. The spatial allocation of starts and parked-vehicle evaporative emissions depends partly on this file
TTI District 4 ST/FT/RT Fleet Mix	TxDOT district level daily average fleet mix. Fractions of VMT across Source Use Type (ST) and Fuel Type (FT) sum to 1 for each MOVES road type (RT).
TxLED Adjustment	Adjustment factors to reduce NOx emissions from diesel-fueled vehicles due to the use of Texas Low Emission Diesel (TxLED)

3.1 TRANSVMT Files

TTI prepared all TRANSVMT files and supplied them to ERG for use in SEE to create the emission inventories for this work. This section describes Austin area 2012 and 2018 link-based VMT and speeds, and was also written by TTI for inclusion in this report.

A critical component of link-based emissions inventories are VMT and speed estimates by hour and direction for each link in the travel demand model (TDM). TTI developed link-based VMT and speed estimates in support of the Capital Area Council of Government's (CAPCOG) emissions inventory work under the auspices of the Texas Department of Transportation's (TxDOT) Inter-Agency Contract with TTI. This work consisted of developing VMT and speeds by year (2012 and 2018), season (school season defined as September 15 through October 15 and April 15 through May 15 and summer season defined as June 10 through August 10, excluding July 4), and day type (Weekday defined as Monday through Thursday, Friday, Saturday, and Sunday). For the purpose of this analysis, each unique combination of season and day type was considered an analysis scenario, producing a total of eight unique sets of hourly VMT and speeds by direction for each year. This analysis also required that VMT be adjusted for Highway Performance Monitoring System (HPMS) consistency and to reflect estimated levels characteristic of each analysis scenario. The TRANSVMT utility (see Appendix A for a description of the utility), the latest available data sets from the Austin area 2010 and 2020 TDMs, and post-processing factors developed from several other data sources, were used to produce this hourly VMT by direction.

Data Sources

TTI used the latest available Austin area 2010 and 2020 TDMs (both dated February 9, 2015), to estimate the directional link VMT and speeds by hour. Because TDMs do not account for intrazonal VMT, TTI estimated the intrazonal VMT using the TDM's trip matrix and calculated zonal radii data sets. Since the TDMs are by time period (i.e., four assignments and trip matrices for each TDM), TTI applied the TDM time period data to each hour as Table 3-4 shows.

Table 3-4. Time-of-Day Travel Periods.

Period	Hours
AM Peak	6 a.m. - 9 a.m.
Mid-Day	9 a.m. – 3 p.m.
PM Peak	3 p.m. – 6 p.m.
Overnight	6 p.m. - 6 a.m.

TTI used several other data sources to adjust the VMT for HPMS consistency and to estimate each analysis scenario VMT. The first data source is HPMS VMT estimates, which are based on traffic count data collected according to a statistical sampling procedure specified by the Federal Highway Administration (FHWA) designed to estimate VMT. TTI used the county total HPMS Annual Average Daily Traffic (AADT) VMT to ensure the travel model VMT was consistent with the HPMS VMT estimates. (The U.S. Environmental Protection Agency [EPA] and FHWA have endorsed HPMS as the appropriate source of VMT and require that VMT used to construct on-road mobile source emissions estimates be consistent with that reported through HPMS.)

The second data source is automatic traffic recorder (ATR) vehicle counts, which are collected by TxDOT at selected locations throughout Texas on a continuous basis. These vehicle counts are available by season, month, and weekday, as well as on an annual average daily basis (AADT). The counts are very well suited for making seasonal, day-of-week, and time-of-day comparisons (e.g., seasonal adjustment and hourly allocation factors), even though there may be relatively few ATR data collection locations in any given area. TTI grouped multiple years (2004 through 2013) of Austin TxDOT District data from the ATR stations to develop these factors.

3.2 VMT Adjustments

Since TDMs do not exist for either 2012 or 2018, TTI used intermediate year adjustment factors (i.e., growth factors) to develop the analysis scenario VMT from an existing TDM (2012 from the 2010 TDM and 2018 from the 2020 TDM). For each analysis year, TTI adjusted the TDM VMT for HPMS consistency and for seasonality (i.e., summer weekday). For 2012, which by definition is a historical year (i.e., HPMS VMT exists for 2012), TTI used county-level VMT control totals to develop VMT adjustment factors, which TTI applied to the 2010 TDM. For 2018, which by definition is considered a future year (i.e., HPMS VMT data does not exist), TTI used a regional HPMS factor (based on the 2010 validation year TDM) and seasonal day-type-specific factors (based on ATR data from within the Austin TxDOT District). Since the TDM VMT is annual non-summer weekday traffic (ANSWT), TTI used weekend day profile factors for the Saturday and Sunday day types to adjust the VMT to represent the weekend day type proportions, or profiles.

3.3 Intermediate Year Adjustment Factors

TTI used intermediate year adjustment factors (i.e., growth factors) to estimate the analysis year VMT from an existing TDM, essentially creating 2012 and 2018 TDM VMT (including the estimated intrazonal VMT). TTI developed these adjustment factors using the bounding year TDMs (2010 and 2020 TDMs) and applied them to the analysis year's respective TDM (2010 for the 2012 analysis year and 2020 for the 2018 analysis year). TTI based the intermediate year adjustment factors on the annually compounded growth rates between the bounding year TDMs. TTI then converted the annual growth rates into the intermediate year adjustment factors using the following equation:

$$\text{Intermediate Year Adj. Factor} = \text{Growth Rate}^{\text{Target Year - Base Year}}$$

Where:

Target Year	=	the desired intermediate year;
Base Year	=	the year of the TDM used for estimating the VMT; and
Growth Rate	=	the annual growth rate from the range of TDM years encompassing the target year.

To maintain consistency between counties and the four time periods in the TDM, TTI developed these adjustment factors separately for each time period and county. Appendix B shows the annually compounded growth rates and intermediate year adjustment factors for each analysis year without a TDM by county and time period.

3.4 Weekend Day Profile Factors

Since the TDM VMT is ANSWT, TTI adjusted the VMT proportions (including the estimated intrazonal VMT) by assignment period to represent the weekend day type (Saturday and Sunday only) proportions, or profiles. TTI only applied these factors for the Saturday and Sunday day types. TTI developed the weekend day profile factors by county and individually for each year, season, and weekend day type for each TDM assignment period.

The weekend day profile factors by TDM assignment period are the product of two main components, one that essentially expands TDM assignment time-period VMT to the 24-hour total, and one that reallocates the expanded TDM VMT for the time period to the weekend day type proportion for that time period. TTI developed these weekend day profile factors using: 1) county-level time period assignment (AM Peak, Mid-Day, PM Peak, and Overnight) ANSWT and intrazonal VMT (to develop the TDM time period VMT expansion component); and 2) regional ATR-based weekend day type hourly travel fractions (to develop the TDM assignment period reallocation component).

TTI calculated the expansion components (one per assignment period for each day type) of the weekend day profile factors for each county as county 24-hour TDM VMT (assignment and intrazonal) divided by county assignment time period TDM VMT. TTI developed the re-allocation components by summing the weekend day hourly travel fractions within each TDM assignment period to produce one four-factor set of assignment-period-specific regional weekend day travel fractions for each day type. TTI multiplied the two components, one corresponding to each assignment period, which produced the weekend day profile factors. TTI performed these calculations by county for each year, season, and weekend day type. Appendix C shows the weekend profile factors.

3.5 2012 Historical Year Analyses – VMT Control Totals and VMT Adjustment Factors

To estimate the 2012 analysis scenario VMT (i.e., season and day-type specific), TTI used county-level VMT control totals to develop county-level VMT adjustment factors. The VMT control totals are comprised of two key components: 2012 county-level HPMS AADT VMT and AADT-to-analysis scenario adjustment factors.

TTI developed the AADT-to-analysis scenario adjustments factors using aggregated ATR data for the years 2004 through 2013 for ATR stations within the Austin TxDOT District. TTI calculated these regional factors by dividing the seasonal average day-of-week count by the AADT traffic count. Table 3-5 shows the AADT-to-analysis scenario adjustment factors.

Table 3-5. AADT-to-Summer Analysis Scenario Adjustment Factors for Control Total Development

Season	Weekday	Friday	Saturday	Sunday
School	1.03158	1.12834	0.99227	0.85417
Summer	1.03575	1.13318	0.97111	0.84292

TTI then developed the VMT control totals by multiplying the 2012 HPMS AADT VMT for each county by the appropriate summer weekday adjustment factor to produce 48 VMT control totals (one for each county and analysis scenario). To develop the county-level VMT adjustment factors, TTI divided each county's respective control total by the total TDM VMT (2010 TDM assignment VMT plus intrazonal VMT estimate with the applied intermediate year factors). For each link in the 2010 TDM, TTI multiplied the volume by the corresponding intermediate year factor, VMT adjustment factor (based on the county where the link is located), and weekend profile factors (Saturday and Sunday day types only). TTI then multiplied the adjusted link volumes by the associated link lengths to produce the 2012 link-level, HPMS-consistent analysis scenario VMT. Table 3-6, Table 3-7, Table 3-8, and Table 3-9 show the VMT control totals and VMT adjustment factors.

Table 3-6. Weekday VMT Control Totals and VMT Adjustment Factors.

County	TDM VMT[1]	School		Summer	
		Control	VMT[2]	Control	VMT[2]
Travis	27,323,640.908	27,372,448	1.001786259	27,483,224	1.005840477
Williamson	10,784,587.409	10,084,179	0.935054687	10,124,989	0.938838791
Hays	5,997,238.531	4,957,779	0.826676974	4,977,843	0.830022514
Bastrop	2,114,546.264	2,330,275	1.102021289	2,339,705	1.106480875
Caldwell	1,339,170.608	1,464,388	1.093503689	1,470,315	1.097929562

[1] 2010 TDM (including intrazonal VMT) with applied intermediate year factors.
[2] Applied to 2010 TDM VMT (including intrazonal VMT), along with other VMT adjustment factors.

Table 3-7. Friday VMT Control Totals and VMT Adjustment Factors.

County	TDM VMT[1]	School		Summer	
		Control	VMT[2]	Control	VMT[2]
Travis	27,323,640.908	29,939,932	1.095751921	30,068,414	1.100454149
Williamson	10,784,587.409	11,030,056	1.022761055	11,077,389	1.027150004
Hays	5,997,238.531	5,422,809	0.904217661	5,446,080	0.908097947
Bastrop	2,114,546.264	2,548,850	1.205388619	2,559,788	1.210561360
Caldwell	1,339,170.608	1,601,745	1.196072397	1,608,619	1.201205425

[1] 2010 TDM (including intrazonal VMT) with applied intermediate year factors.
[2] Applied to 2010 TDM VMT (including intrazonal VMT), along with other VMT adjustment factors.

Table 3-8. Saturday VMT Control Totals and VMT Adjustment Factors.

County	TDM VMT[1]	School		Summer	
		Control	VMT[2]	Control	VMT[2]
Travis	27,323,640.908	26,329,370	0.963611332	25,767,993	0.943065863
Williamson	10,784,587.409	9,699,902	0.899422633	9,493,088	0.880245821
Hays	5,997,238.531	4,768,853	0.795174808	4,667,175	0.778220672
Bastrop	2,114,546.264	2,241,475	1.060026465	2,193,684	1.037425398
Caldwell	1,339,170.608	1,408,585	1.051833867	1,378,552	1.029407300

[1] 2010 TDM (including intrazonal VMT) with applied intermediate year factors.
[2] Applied to 2010 TDM VMT (including intrazonal VMT), along with other VMT adjustment factors.

Table 3-9. Sunday VMT Control Totals and VMT Adjustment Factors.

County	TDM VMT[1]	School		Summer	
		Control	VMT[2]	Control	VMT[2]
Travis	27,323,640.908	22,665,063	0.829503765	22,366,408	0.818573486
Williamson	10,784,587.409	8,349,949	0.774248349	8,239,923	0.764046197
Hays	5,997,238.531	4,105,163	0.684508875	4,051,070	0.675489224
Bastrop	2,114,546.264	1,929,525	0.912500726	1,904,100	0.900476870
Caldwell	1,339,170.608	1,212,550	0.905448486	1,196,572	0.893517221

[1] 2010 TDM (including intrazonal VMT) with applied intermediate year factors.
[2] Applied to 2010 TDM VMT (including intrazonal VMT), along with other VMT adjustment factors.

3.6 2018 Future Year Analyses – HPMS Adjustment Factor

For future year analyses, TTI used an HPMS adjustment factor to adjust the total VMT (TDM assignment VMT plus intrazonal VMT estimate) from each TDM for HPMS consistency. TTI developed this factor using the county-level total VMT from the validation year (2010) TDM, the 2010 county-level HPMS VMT reported by TxDOT, and multiple years (2004 through 2013) of ATR data from ATR stations within the Austin TxDOT District (to produce the ANSWT adjustment factors for the following first equation). The formula for the HPMS factor calculation, as applied for each county, is:

County HPMS VMT (AADT) × ANSWT Adjustment Factor = County HPMS VMT (ANSWT)

Region HPMS VMT (ANSWT) / Region Model VMT (ANSWT) = HPMS Factor

Applying the ANSWT adjustment to the HPMS AADT VMT (i.e., conversion from AADT to ANSWT) produces seasonal, day-of-week consistency between the TDM VMT and HPMS VMT components of the HPMS factor. The actual values for the county HPMS factors are:

- Travis: 25,684,800.32 × 1.0344726 = 26,570,222.17 (HPMS ANSWT VMT);
- Williamson: 9,494,672.50 × 1.0344726 = 9,821,978.55 (HPMS ANSWT VMT);
- Hays: 4,774,728.59 × 1.0344726 = 4,939,325.90 (HPMS ANSWT VMT);
- Bastrop: 2,114,636.71 × 1.0344726 = 2,187,533.74 (HPMS ANSWT VMT); and
- Caldwell: 1,022,308.61 × 1.0344726 = 1,057,550.25 (HPMS ANSWT VMT); and
- TDM Region: 46,070,731.29 / 47,116,126.32 = 0.977812373 (HPMS Factor).

3.7 2018 Future Year Analyses – Seasonal Adjustment Factor

For any future year analysis, TTI applies seasonal adjustment factors to adjust the TDM and estimated intrazonal VMT to reflect each activity scenario (i.e., season and day type). TTI developed the seasonal adjustment factors for the Austin area using aggregated ATR data from stations within the Austin TxDOT District for the years 2004 through 2013. TTI calculated these factors by dividing the average seasonal day-of-week count by the ANSWT traffic count.

Table 3-10 shows the seasonal adjustment factors used in these analyses.

Table 3-10. Seasonal Adjustment Factors for Future Year Analyses.

Season	Weekday	Friday	Saturday	Sunday

Season	Weekday	Friday	Saturday	Sunday
School	0.99720	1.09074	0.95920	0.82571
Summer	1.00124	1.09542	0.93875	0.81483

3.8 2018 Future Year Analyses – VMT Summary

For each 2018 analysis scenario, the final HPMS-consistent, day-type-specific VMT is comprised of two parts: the link-level VMT and the estimated intrazonal VMT. Using the 2020 TDM, TTI multiplied the volume for each link by the appropriate intermediate year factor, the HPMS factor, the seasonal adjustment factor, the appropriate weekend day profile factor (Saturday and Sunday day types only), and the link's respective length to estimate the link-level VMT (hourly factors distributed the resulting VMT over each hour of the day, discussed in a later section). TTI also applied the intermediate year, HPMS, seasonal adjustment factor, and weekend day profile factors (as well as the hourly factors mentioned previously) to the intrazonal VMT. Table 3-11 and Table 3-12 show the TDM and 2018 VMT summaries.

Table 3-11. Austin Area 2018 School VMT Summary.

County	2020	Weekday	Friday	Saturday	Sunday
Travis	31,799,406	29,852,879	32,653,158	28,715,284	24,719,034
Williamson	14,625,720	13,215,257	14,454,883	12,711,667	10,942,609
Hays	7,660,692	7,026,264	7,685,346	6,758,516	5,817,946
Bastrop	2,618,518	2,420,380	2,647,418	2,328,147	2,004,143
Caldwell	1,823,744	1,646,138	1,800,550	1,583,409	1,363,049
Total	**58,528,080**	**54,160,918**	**59,241,355**	**52,097,023**	**44,846,781**

[1] Includes intrazonal VMT.

Table 3-12. Austin Area 2018 Summer VMT Summary.

County	2020 TDM[1]	Weekday	Friday	Saturday	Sunday
Travis	31,799,406	29,973,823	32,793,261	28,103,078	24,393,322
Williamson	14,625,720	13,268,796	14,516,904	12,440,656	10,798,423
Hays	7,660,692	7,054,729	7,718,321	6,614,425	5,741,286
Bastrop	2,618,518	2,430,186	2,658,777	2,278,511	1,977,736
Caldwell	1,823,744	1,652,807	1,808,276	1,549,651	1,345,089
Total	**58,528,080**	**54,380,341**	**59,495,539**	**50,986,321**	**44,255,856**

[1] Includes intrazonal VMT.

3.9 Hourly Travel Factors

TTI used hourly travel factors to distribute the TDM and intrazonal VMT to each hour of the day. TTI developed these seasonal, day-type-specific hourly travel factors using multi-year (2004 through 2013) aggregated ATR station data from the Austin TxDOT District. To maintain VMT proportions within each of the four assignment time periods, TTI normalized the hourly fractions within each time period to produce the time period hourly travel factors. TTI then multiplied each factor (i.e., 24, or one for each hour of the day) by the link volume (in addition to the other VMT adjustment factors). TTI then multiplied these adjusted link volumes by their respective link lengths to estimate the link level VMT estimates for each analysis scenario. TTI also multiplied these factors by the estimated intrazonal VMT to produce the final hourly-adjusted VMT. Table 3-13,

Table 3-14,

Table 3-15, and

Table 3-16 show the time period hourly travel factors.

Table 3-13. Weekday Time Period Hourly Travel Factors.

Assignment	Hour	School		Summer	
		Base Factor	Time Period Factor[1]	Base Factor	Time Period Factor[1]
AM Peak	6:00 a.m.	0.055149	0.295542	0.052152	0.290009
	7:00 a.m.	0.068536	0.367282	0.066125	0.367710
	8:00 a.m.	0.062918	0.337176	0.061552	0.342281
Mid-Day	9:00 a.m.	0.056165	0.167195	0.056401	0.165350
	10:00 a.m.	0.051565	0.153501	0.052155	0.152902
	11:00 a.m.	0.054345	0.161777	0.055667	0.163198
	12:00 p.m.	0.056403	0.167903	0.058165	0.170522
	1:00 p.m.	0.057558	0.171341	0.058923	0.172744
	2:00 p.m.	0.059890	0.178283	0.059789	0.175284
PM Peak	3:00 p.m.	0.064378	0.332782	0.063503	0.332837
	4:00 p.m.	0.064824	0.335087	0.064054	0.335725
	5:00 p.m.	0.064252	0.332131	0.063236	0.331438
Overnight	6:00 p.m.	0.060756	0.213916	0.060132	0.208591
	7:00 p.m.	0.048912	0.172215	0.048457	0.168091
	8:00 p.m.	0.038667	0.136143	0.038362	0.133073
	9:00 p.m.	0.033431	0.117708	0.034761	0.120582
	10:00 p.m.	0.024926	0.087762	0.026649	0.092442
	11:00 p.m.	0.016714	0.058849	0.018035	0.062561
	12:00 a.m.	0.010626	0.037413	0.011522	0.039968
	1:00 a.m.	0.007227	0.025446	0.007719	0.026776
	2:00 a.m.	0.006670	0.023485	0.006962	0.024150
	3:00 a.m.	0.005694	0.020048	0.005796	0.020106
	4:00 a.m.	0.008225	0.028960	0.008237	0.028573
	5:00 a.m.	0.022169	0.078055	0.021646	0.075087

[1] Used in the VMT calculation process.

Table 3-14. Friday Time Period Hourly Travel Factors.

Assignment	Hour	School		Summer	
		Base Factor	Time Period Factor[1]	Base Factor	Time Period Factor[1]
AM Peak	6:00 a.m.	0.048017	0.288993	0.045677	0.284624
	7:00 a.m.	0.061447	0.369821	0.058980	0.367518
	8:00 a.m.	0.056689	0.341186	0.055825	0.347858
Mid-Day	9:00 a.m.	0.051794	0.154780	0.052931	0.155670
	10:00 a.m.	0.050781	0.151753	0.052266	0.153714
	11:00 a.m.	0.055166	0.164857	0.056554	0.166325
	12:00 p.m.	0.057589	0.172098	0.058672	0.172554
	1:00 p.m.	0.058694	0.175400	0.059495	0.174974
	2:00 p.m.	0.060605	0.181112	0.060103	0.176763
PM Peak	3:00 p.m.	0.061721	0.338577	0.061115	0.337849
	4:00 p.m.	0.060449	0.331600	0.060126	0.332383
	5:00 p.m.	0.060125	0.329823	0.059653	0.329768
Overnight	6:00 p.m.	0.059159	0.186667	0.057857	0.181594
	7:00 p.m.	0.052493	0.165633	0.052126	0.163608
	8:00 p.m.	0.043147	0.136143	0.043385	0.136173
	9:00 p.m.	0.038981	0.122998	0.040297	0.126480
	10:00 p.m.	0.034085	0.107550	0.034196	0.107331
	11:00 p.m.	0.025697	0.081083	0.026062	0.081801
	12:00 a.m.	0.011976	0.037788	0.012759	0.040047
	1:00 a.m.	0.008432	0.026606	0.008922	0.028004
	2:00 a.m.	0.008725	0.027530	0.008983	0.028195
	3:00 a.m.	0.006623	0.020898	0.006747	0.021177
	4:00 a.m.	0.008134	0.025666	0.008144	0.025562
	5:00 a.m.	0.019471	0.061438	0.019125	0.060028

[1] Used in the VMT calculation process.

Table 3-15. Saturday Time Period Hourly Travel Factors.

Assignment	Hour	School		Summer	
		Base Factor	Time Period Factor[1]	Base Factor	Time Period Factor[1]
AM Peak	6:00 a.m.	0.021823	0.226810	0.022452	0.232740
	7:00 a.m.	0.031944	0.332000	0.032069	0.332431
	8:00 a.m.	0.042450	0.441190	0.041947	0.434829
Mid-Day	9:00 a.m.	0.051276	0.138531	0.051388	0.139517
	10:00 a.m.	0.057952	0.156567	0.057944	0.157317
	11:00 a.m.	0.063286	0.170978	0.063228	0.171663
	12:00 p.m.	0.065923	0.178102	0.065435	0.177655
	1:00 p.m.	0.066195	0.178838	0.065656	0.178254
	2:00 p.m.	0.065509	0.176984	0.064676	0.175594
PM Peak	3:00 p.m.	0.065186	0.342614	0.064059	0.342505
	4:00 p.m.	0.063626	0.334414	0.062447	0.333886
	5:00 p.m.	0.061449	0.322972	0.060525	0.323609
Overnight	6:00 p.m.	0.058508	0.170387	0.057958	0.166464
	7:00 p.m.	0.051224	0.149175	0.051037	0.146585
	8:00 p.m.	0.044679	0.130115	0.044414	0.127563
	9:00 p.m.	0.042403	0.123487	0.043924	0.126155
	10:00 p.m.	0.038258	0.111416	0.039044	0.112139
	11:00 p.m.	0.030368	0.088438	0.031039	0.089148
	12:00 a.m.	0.020618	0.060044	0.021120	0.060659
	1:00 a.m.	0.014435	0.042038	0.015038	0.043191
	2:00 a.m.	0.014272	0.041563	0.014808	0.042530
	3:00 a.m.	0.009344	0.027212	0.009616	0.027618
	4:00 a.m.	0.007694	0.022407	0.008021	0.023037
	5:00 a.m.	0.011578	0.033718	0.012155	0.034911

[1] Used in the VMT calculation process.

Table 3-16. Sunday Time Period Hourly Travel Factors.

Assignment	Hour	School		Summer	
		Base Factor	Time Period Factor[1]	Base Factor	Time Period Factor[1]
AM Peak	6:00 a.m.	0.013090	0.217532	0.013498	0.217041
	7:00 a.m.	0.019390	0.322227	0.020164	0.324227
	8:00 a.m.	0.027695	0.460241	0.028529	0.458732
Mid-Day	9:00 a.m.	0.042245	0.111419	0.042487	0.112171
	10:00 a.m.	0.054912	0.144827	0.055132	0.145556
	11:00 a.m.	0.063237	0.166784	0.063708	0.168198
	12:00 p.m.	0.071674	0.189036	0.071682	0.189250
	1:00 p.m.	0.073882	0.194858	0.073438	0.193885
	2:00 p.m.	0.073206	0.193076	0.072322	0.190940
PM Peak	3:00 p.m.	0.072641	0.340603	0.070843	0.340316
	4:00 p.m.	0.071273	0.334188	0.069291	0.332861
	5:00 p.m.	0.069358	0.325209	0.068034	0.326823
Overnight	6:00 p.m.	0.065501	0.188549	0.064603	0.184123
	7:00 p.m.	0.057016	0.164123	0.054928	0.156547
	8:00 p.m.	0.047788	0.137560	0.046864	0.133564
	9:00 p.m.	0.039505	0.113717	0.041562	0.118453
	10:00 p.m.	0.030800	0.088659	0.033034	0.094148
	11:00 p.m.	0.020870	0.060075	0.022800	0.064981
	12:00 a.m.	0.025155	0.072410	0.025290	0.072078
	1:00 a.m.	0.017352	0.049949	0.017709	0.050471
	2:00 a.m.	0.017410	0.050116	0.017590	0.050132
	3:00 a.m.	0.010709	0.030826	0.010729	0.030578
	4:00 a.m.	0.007114	0.020478	0.007275	0.020734
	5:00 a.m.	0.008177	0.023538	0.008488	0.024191

[1] Used in the VMT calculation process.

3.10 Time-of-Day Directional Split Factors

The TDMs for the Austin area are also non-directional (i.e., speed and volume are only listed for the link, not in both directions). TTI used directional split factors to produce the VMT and speeds by direction. TTI multiplied these factors by the link volume to estimate the volume of travel in each direction, one record containing the estimated volume in the peak (or dominant) direction, and the second record containing the estimated volume in the opposite direction. TTI used these directional volume estimates not only to estimate the VMT in each direction, but also to estimate the directional speeds (discussed in the next section).

TTI developed the directional split factors for application by time-of-day period at the functional classification (Table 3-17), and area type level (
Table 3-18).

Table 3-17. Austin Area TDM Functional Classifications.

Functional Class Code	Functional Class Description
0	Centroid Connector
1	Interstate
2	Freeway
3	Expressway
4	Principal Arterial Divided
5	Principal Arterial Controlled Left Turn (CLT)
6	Principal Arterial Undivided
7	Minor Arterial Divided
8	Minor Arterial CLT
9	Minor Arterial Undivided
10	Collector Divided
11	Collector CLT
12	Collector Undivided
13	Local Divided
14	Local CLT
15	Local Undivided
16	Director Connector
17	Ramp
18	Frontage
19	HOV Mainlane
20	HOV Ramp
21	Toll Facility 1
22	Toll Facility 2 - Faster Speed
23	Toll Ramp
24	Toll Direct Connector

Table 3-18. Austin Area TDM Area Types.

Area Type Code	Area Type Description
1	Central Business District
2	Urban Intense Residential
3	Urban Residential
4	Suburban Residential
5	Rural
6	Externals

These time-of-day directional split factors were taken from the Austin area's Early Action Compact (EAC) State Implementation Plan (SIP) on-road mobile source emissions inventory technical note, *Austin/San Marcos Metropolitan Statistical Area On-Road Mobile Source Emissions Inventories: 1995, 1999, 2002, 2005, 2007, and 2012*, TTI, August 22, 2003. These data are the newest available. Appendix D of that report contains the directional splits.

3.11 Estimation of Link Speeds

To estimate link operational (congested) speeds, TTI used a speed model involving both the link estimated free-flow speed and estimated directional delay (as a function of volume and capacity). TTI used this model to estimate the hourly, directional, congested speed for each link, except for the TDM centroid connectors and added intrazonal links. TTI calculated the congested speed using the following formula:

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

Typically, free-flow speed factors are used to convert TDM speeds (which are by definition level of service [LOS] C) to LOS A speeds (free flow). However, the coded speeds in the TDMs were designated as free-flow speeds (per the 2010 Travel Model Validation document); thus eliminating the application of speed factors for the Austin area TDMs.

The second component of the speed model used to calculate the congested speed is the estimated directional delay. TTI calculated the directional delay (in minutes per mile) due to congestion using the following volume/delay equation:

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

Where:

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

The delay model parameters (A, B, and M) were developed for the Dallas/Fort Worth area and verified by application in other Texas urban areas. Table 3-19 shows these parameters, followed by Table 3-20, which lists the functional classes used in the TDMs and their capacity category (except for centroid connector and intrazonal, which do not use capacity data).

Table 3-19. Volume/Delay Equation Parameters.

Facility Category	A	B	M
High-Capacity Facilities	0.015	3.5	5
Low-Capacity Facilities	0.050	3.0	10

Table 3-20. Functional Class Categories for Applying Delay Parameters.

Category	TDM Functional Class Code	TDM Functional Class Description
High-Capacity	1	Interstate
	2	Freeway
	19	HOV Mainlane
	21	Toll Facility 1
	22	Toll Facility 2 - Faster Speed
Low-Capacity	3	Expressway
	4	Principal Arterial Divided
	5	Principal Arterial CLT
	6	Principal Arterial Undivided
	7	Minor Arterial Divided
	8	Minor Arterial CLT
	9	Minor Arterial Undivided
	10	Collector Divided
	11	Collector CLT
	12	Collector Undivided
	13	Local Divided
	14	Local CLT
	15	Local Undivided
	16	Director Connector
	17	Ramp
	18	Frontage
	20	HOV Ramp
	23	Toll Ramp
	24	Toll Direct Connector

3.12 Trips Files

The TDM uses origin/destination trips matrices to load the network and estimate VMT. SEE uses these trip matrices on a relative basis to determine where start emissions and evaporative emissions from parked vehicles occur at a sub-county level. The trips matrices are four time period-specific files that contain origin and destination TAZs and a count of the vehicle trips between TAZs, or within the same TAZ (referred to as an intrazonal trip).

CAMPO's TDM has approximately 2,300 TAZs underlying the link network. The spatial pattern of those trips across the Austin area changes by time period of the day and only represents weekday. The weekday time periods are AM peak, PM peak, Midday and Overnight represent travel that reflects commuting. However, Saturday and Sunday trips should not reflect weekday AM and PM peaks, and therefore for modeling these weekend day types, SEE applied the midday trip spatial pattern during all hours of the day. For modeling the Weekday and Friday day types, SEE used the appropriate time period's trip distribution according to hour of the day, listed previously in Table 3-4. Table 3-20 summarizes the patterns by day type for the CAPCOG emission inventory modeling. The 2010 trip matrices were used for all 2012 simulations, and the 2020 trip matrices were used to model 2018. The same distributions were used for school and summer season types.

Table 3-21. Assignment of Weekday Trip Patterns to CAPCOG Modeling Day Types

CAPCOG Emission Inventory Day Type	CAMPO Trip Pattern
Weekday (Monday – Thursday)	Hourly assignments in Table 3-4
Friday	Hourly assignments in Table 3-4
Saturday	Midday trip pattern applied in all hours
Sunday	Midday trip pattern applied in all hours

3.13 County Lookup and Road Type Lookup

The County Lookup SEE input file, shown below in Table 3-22, cross-references the single-digit county code used in the TDM and reported in TRANSVMT hourly files to the standard 5-digit FIPS code needed in emission inventory modeling. The Road Type Lookup SEE input file maps the combination of TDM functional class and area type to MOVES road type ID. There are 109 combinations of functional class (26 unique types) and area types (6 unique types). The combination of TDM functional class (Table 3-23) and area type (Table 3-24) determines the MOVES road type. Although the Road Type Lookup input file for SEE performs the mapping in a single file on the basis of combination functional class and area type, this report documents them separately in two tables for simplicity.

Table 3-22. County Lookup Cross-Reference

TDM County Code	County Name	FIPS Code
1	Travis	48453
2	Williamson	48491
3	Hays	48209
4	Bastrop	48021
5	Caldwell	48055

Table 3-23. Functional Class Road Type Lookup Cross-Reference

Functional Class	Functional Class	MOVES Road Type
0	Centroid Connector	Unrestricted Access Road
1	Interstate	Restricted Access Road
2	Freeway	Restricted Access Road
3	Expressway	Restricted Access Road
4	Principal Arterial Divided	Unrestricted Access Road
5	Principal Arterial Controlled Left Turn	Unrestricted Access Road
6	Principal Arterial Undivided	Unrestricted Access Road
7	Minor Arterial Divided	Unrestricted Access Road
8	Minor Arterial CLT	Unrestricted Access Road
9	Minor Arterial Undivided	Unrestricted Access Road
10	Collector Divided	Unrestricted Access Road
11	Collector CLT	Unrestricted Access Road
12	Collector Undivided	Unrestricted Access Road
13	Local Divided	Unrestricted Access Road
14	Local CLT	Unrestricted Access Road
15	Local Undivided	Unrestricted Access Road
16	Director Connector	Unrestricted Access Road
17	Ramp	Restricted Access Road – only Ramps
18	Frontage	Unrestricted Access Road
19	HOV Mainlane	Restricted Access Road
20	HOV Ramp	Restricted Access Road – only Ramps
21	Toll Facility 1	Restricted Access Road
22	Toll Facility 2 - Faster Speed	Restricted Access Road
23	Toll Ramp	Restricted Access Road – only Ramps
24	Toll Direct Connector	Restricted Access Road
40	Intrazonal Links	Unrestricted Access Road

Table 3-24. Area Type in the Road Type Lookup Cross-Reference

TDM Area Type	MOVES Road Type (Area Type
Rural	Rural
Externals	Rural
Central Business District	Urban
Urban Intense Residential	Urban
Urban Residential	Urban
Suburban Residential	Urban

3.14 Extended Idle Zone and Capacity

This input file is used by SEE to spatially allocate county total hotelling emissions (from both main engines and APUs) to individual TAZs in which truck stops and rest areas are located. The location of truck stops was determined using a combination of the CAPCOG Idling Study[4] and the Truck Stops Plus Database[5]. ERG performed a GIS intersection analysis to determine which TAZ contained each extended idling location, and then summed the parking capacity in each TAZ. Table 3-25 shows the content of the input file – county, TAZ, and capacity. SEE reads this file and normalizes the parking capacities and normalizes the distribution over TAZs so that they sum to one (1) for each county. SEE later allocates the county total extended idling and APU emissions to TAZs using the relative distribution that comes from this input file.

Table 3-25. Extended Idle Zone and Capacity Input File

FIPS Code	County	TAZ ID	Capacity (# of Parking Spaces)
48021	Bastrop	1173	20
		1286	20
48055	Caldwell	1313	20
48209	Hays	723	29
		818	20
		900	20
48453	Travis	80	40
		176	20
		179	65
		612	20
		1348	10
		1354	20
		1593	20
48491	Williamson	30	20
		653	20
		937	20
		1012	20
		1025	20
		1045	20
		1586	45
		1587	20
		1701	20

4 Hoekzema, A., *Modeling Truck Emissions in Central Texas*. Paper presented at the 21st EPA Emission Inventory Conference, San Diego, California. April 2015.
5 Truck Stops Plus Database, available online at truckstopsplus.com.

3.15 Link Definitions

The Link Definitions input file is a list of all possible links that can occur in any hourly TRANSVMT file, sequentially numbered according to unique combinations of Anode and Bnode. There are 38,105 links in the 2012 network and 39,741 links in 2018 corresponding to the 5-county MSA.

3.16 Source Type Age Lookup

SEE uses a copy of the MOVES2014 table *SourceTypeAge* for its contents of relative annual mileage accumulation by model year for each source type. SEE embeds the relative annual mileage accumulation rates into the Source Type Age Distribution input file that is provided to MOVES Project Scale runs to estimate the link-level emissions.

3.17 TxDOT District Level Fleet Mix

The fleet mix input file lists the fraction of VMT on each MOVES road type that is from each source type and fuel type. The fleet mix sums to one (1) for each MOVES road type, and the distributions are unique for Weekday, Friday, Saturday, and Sunday, and different for 2012 and 2018. The fleet mix files were developed by TTI for the calendar years 2010 and 2020. TTI develops fleet mix in 5-year increments of TxDOT traffic classification data. The 2010 fleet mix file was the best available for year 2012 modeling, and the 2020 fleet mix files were applied for the CAPCOG year 2018 modeling.

3.18 TxLED Adjustments

The Texas Low Emission Diesel (TxLED) Adjustments input file for SEE lists the calendar year, source type, and an adjustment factor to reduce NO_X emissions outside of MOVES. SEE reduces the NO_X emissions (as well as NO, NO_2, and HONO) from all diesel-fueled vehicles using the factors in Table 3-26. The adjustment factors were developed by TCEQ using MOVES2014[6].

Table 3-26. TxLED Adjustment Factors in the CAPCOG Modeling

Source Type ID	2012 Adjustment Factor	2018 Adjustment Factor
21	0.941332	0.950120
31	0.946595	0.949572
32	0.943393	0.946780
41	0.941609	0.943453

[6] ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/Statewide/mvs/txled/ filename: mvs14-statewide-txled-analysis-06-12-17-18.zip

Source Type ID	2012 Adjustment Factor	2018 Adjustment Factor
42	0.941875	0.943765
43	0.942015	0.943686
51	0.943829	0.946987
52	0.949274	0.951108
53	0.949968	0.951248
54	0.944264	0.946353
61	0.945242	0.948200
62	0.944500	0.947908

3.19 MOVES Input Files

Source Type Age Distribution

The age distribution file is read into MOVES County Scale for the off-network runs. For the MOVES Project Scale runs, SEE first embeds the relative mileage accumulation rates by model year – effectively providing an updated version of the age distribution to the Project Scale implementation that already accounts for newer vehicles traveling more miles annually than older vehicles. The data source for the 2012 modeling was mid-year 2012 vehicle registration data. For the future year 2018 modeling, the base data was mid-year July 2014 registration data projected to 2018 using EPA's age distribution projection tool[7]. The main advantage of using EPA's age distribution projection tool rather than using the most recent mid-year age distribution is that the projection tool preserves the impact of the drop-off in new car purchases during the "Great Recession" from December 2007 to June 2009 in the appropriate year. Using the July 2014 age distribution to represent the 2018 age distribution would have shifted this dip in the distribution of 2008 and 2009 model years three years ahead to 2011 and 2012.

Table 3-27. Source Type Age Distribution Geographic Averaging and Data Sources

Source Use Type	Geographic Average of Data	Basis for 2012 Age Distribution	Basis for 2018 Age Distribution
Motorcycle	MSA-wide	Mid-year 2012	Mid-year 2014 Projected to 2018
Passenger Car	MSA-wide	Mid-year 2012	Mid-year 2014 Projected to 2018
Passenger Truck	MSA-wide	Mid-year 2012	Mid-year 2014 Projected to 2018
Light Commercial	MSA-wide	Mid-year 2012	Mid-year 2014 Projected to 2018
Intercity Bus	MOVES default	Mid-year 2012	Mid-year 2014 Projected to 2018
Transit Bus	MOVES default	Mid-year 2012	Mid-year 2014 Projected to 2018
School Bus	MOVES default	Mid-year 2012	Mid-year 2014 Projected to 2018
Refuse Truck	MOVES default	Mid-year 2012	Mid-year 2014 Projected to 2018
Single Unit Short-haul Truck	MSA-wide	Mid-year 2012	Mid-year 2014 Projected to 2018
Single Unit Long-haul Truck	Texas statewide	Mid-year 2012	Mid-year 2014 Projected to 2018
Motorhome	MOVES default	Mid-year 2012	Mid-year 2014 Projected to 2018
Combination Unit	MSA-wide	Mid-year 2012	Mid-year 2014 Projected to 2018
Combination Unit	Texas statewide	Mid-year 2012	Mid-year 2014 Projected to 2018

[7] http://www.epa.gov/otaq/models/moves/documents/age-distribution-projection-tool-moves2014.xlsm

Fuel Supply and Fuel Formulation

The data source for the 2012 input was the TCEQ 2012 non-link statewide runs, in which the fuels were based on ERG's 2011 summer fuel study report for the TCEQ.[8] The 2018 input data source was the TCEQ 2017 non-link statewide runs[9], in which TTI developed regional average parameters for all Texas counties. In that study report, Austin area was in Region 2, and Table 3-28 shows the 2017 gasoline and diesel parameters, which ERG directly for 2018 in this emission inventory. There were fuels available under a 2018 non-link statewide inventory, but the 2017 fuels dataset was selected for this study because it represents the latest fuel information available to date.

Table 3-28. Fuel Formulation Inputs

Fuel Parameter	2012 Gasoline	2012 Diesel	2018 Gasoline	2018 Diesel
fuelFormulationID	10702	30011	10702	30011
fuelSubtypeID	13	20	12	20
RVP	7.54	n/a	7.8	n/a
sulfurLevel (ppm)	42.6	5.48	10	11
ETOHVolume (% vol)	9.904	n/a	9.76	n/a
MTBEVolume (% vol)	0	n/a	0	n/a
ETBEVolume (% vol)	0	n/a	0	n/a
TAMEVolume (% vol)	0	n/a	0	n/a
aromaticContent (%wt)	23.823	n/a	22.63	n/a
olefinContent (% wt)	13.800	n/a	12.58	n/a
benzeneContent (% wt)	0.511	n/a	0.61	n/a
e200	51.193	n/a	50.17	n/a
e300	80.365	n/a	83.87	n/a
volToWtPercentOxy	0.3653	n/a	0.3653	n/a
T50 (deg. F)	200.86	n/a	202.50	n/a
T90 (deg. F)	328.357	n/a	321.76	n/a

I/M Coverage

Since September 2005, all gasoline-powered vehicles registered in Travis and Williamson Counties that are 2 to 24 years old are required to pass an annual emissions test. The data source for I/M inputs was the TCEQ 2012 and 2018 non-link statewide runs, with an update

[8] http://tceq.state.tx.us/assets/public/implementation/air/am/contracts/reports/mob/5821199776FY1103-20110831-ergi-summer_2011_fuels.pdf

[9] TTI, 2015. *Production of Statewide On-Road Mobile Source Emission Inventories for 2017, Technical Report*. Prepared for the Texas Commission on Environmental Quality, Air Quality Planning and Implementation Division. August.

to the compliance factor to match the default MOVES2014 compliance factors. The MOVES2014 compliance factors differ from the MOVES2010b default compliance factors due to updated regulatory class adjustment factors, one of three components in the compliance factor calculation to reflect the percentage of vehicles within a source use type that are subject to the program. The other two factors are the compliance rate and the waiver rate. The formula for the compliance factor is as follows:

Compliance Factor = (Compliance Rate) x (1 – Waiver Rate) x (Regulatory Class Adjustment)

The MOVES2014 default compliance factors used in this work assume a 96% compliance rate, a 3% waiver rate, and a regulatory class adjustment factor of 100%, 98%, and 93% for passenger car, passenger truck, and light commercial truck respectively. Compliance factor inputs for this study were therefore 93.12%, 91.26%, and 86.60% for passenger car, passenger truck, and light commercial trucks. The default regulatory class adjustments reflect EPA's assumption that I/M programs only apply to vehicles with gross vehicle weight ratings of 8,500 pounds or less, and represent the percentage of gasoline-powered passenger cars, passenger trucks, and light commercial trucks that meet that criteria. In the Austin area, however, all gasoline-powered vehicles between 2 and 24 years old are subject to testing other than motorcycles. Since MOVES2014 does not include data that would enable direct modeling of emission reduction benefits for heavy-duty gasoline vehicles, these use of these regulatory class adjustment factors isolates the modeled emission reduction benefits to only light-duty vehicles. Although there may be emission reduction benefits from heavy-duty gasoline vehicles, these estimated benefits were not incorporated into this study because they were based only on MOVES light-duty vehicles.

The use of default compliance factors for 2018 can be justified based on the significant programmatic change to the I/M program that occurred in March 2015, when vehicles began to be required to pass a vehicle inspection as a condition for receiving their annual registration. This programmatic change is expected to improve compliance with the state's vehicle inspection requirements.

The program parameters aside from compliance factors are Exhaust OBD and Evaporative OBD with Gas Cap checks on all 1996+ model year vehicles with a 2-year grace period. The pre-1996 vehicles are subject to a two-speed idle (TSI) test and a gas cap only evaporative check, and vehicles older than 24 years are exempt from testing.

Source Type Year and AVFT

The data source for vehicle population was the TCEQ 2012 and 2018 non-link statewide runs. The starting point for AVFT was also this same data source, however ERG noted that the geographic basis for this data was statewide. Upon closer examination of initial SEE results of population splits between gas and diesel compared to the non-link runs, ERG saw large discrepancies in the fraction of diesels population for some source types. Therefore, ERG modified the statewide AVFT file by incorporating county-level splits of gasoline and diesel for the Austin area that were present in the statewide runs as a post-processing step. After making this change to AVFT, the diesel fractions by source type from SEE matched the statewide runs much more closely.

Hotelling Activity Distribution

The Hotelling Activity Distribution inputs include fractions of hotelling hours from main engines vs. hotelling with use of a smaller diesel auxiliary power units (APUs), battery-powered APUs, or "engine off" time, which is assumed to represent time spent using shoreside power. Of these four types of hotelling activity, emissions are only generated from idling the main engine or using diesel APUs. During hotelling, diesel-powered APUs consume far less fuel than the main engines primarily used for truck propulsion. The MOVES2014 assumptions for the nation are that there will be no APUs on pre-2010 model year combination unit long haul trucks, but that APUs will begin to penetrate the fleet beginning in year 2010 at a rate of 30% on all 2010+ model years. In this way, EPA expects that their use will grow into the future (up to 30%) in order to meet the Heavy Duty GHG Rule targets.

CAPCOG recently conducted a survey of truck drivers[10] at multiple truck stops throughout the Austin area. Table 24 in CAPCOG's idling study reported that during idling periods exceeding one hour, 5 drivers using a diesel APU out of the total 183 drivers (178 + 5) who idled with an engine on. The 5 of 183 total is 2.73% APU on average, but as expected, the APU presence was found have a higher relative presence on newer model year trucks. CAPCOG study Table 23 showed that 17.6% of 2008+ model year trucks were equipped with diesel APU, which was a factor of 2.4 times higher than the APU presence on the pre-2008 trucks (7.3% diesel APU). Melding this information with the overall 2.73% APU and the fraction of activity by pre-2008 and 2008+ model year trucks in Texas, ERG estimated that 1.6% of pre-2008 trucks in the Austin area use APUs during extended idle, and 3.9% of 2008+ trucks do this. Table 3-29

[10] Hoekzema, A., *Modeling Truck Emissions in Central Texas*. Paper presented at the 21st EPA Emission Inventory Conference, San Diego, California. April 2015.

summarizes the input file for MOVES that reflects the CAPCOG study data. Beginning in 2010, the MOVES2014 assumption of 30% APU is substantially higher than the CAPCOG value of 3.9%. Future studies would be helpful in checking on whether the presence of APUs on trucks that hotel in the Austin area varies with sampling, in light of the previous observed APU penetration being so much lower than EPA's prediction for a national average.

Table 3-29. Hotelling Activity Distribution Inputs

Begin Model Year	End Model Year	Operating Mode ID	Operating Mode Name	Operating Mode Fraction
1960	2007	200	Extended Idling	0.983818
2008	2050	200		0.961245
1960	2007	201	Hotelling Diesel Aux	0.016182
2008	2050	201		0.038755

Hotelling Hours

The Hotelling Hours input file for MOVES2014 lists total hotelling hours by county, hour of the day, and vehicle age 0 to 30 years old. The calculation of hotelling hours for 2012 was calculated based on the overnight truck parking capacity by county multiplied by the CAPCOG study occupancy rates by time of day plus the miles of frontage road by county reported in the CAPCOG study multiplied by the idling hours per miles of frontage road.

Table 3-30. 2012 Summary of Hotelling Hours (Idle Hours per Day)

County	Weekday	Friday	Saturday	Sunday
Bastrop	339.2	253.7	85.9	65.4
Caldwell	622.9	466.0	153.5	113.3
Hays	907.3	679.3	205.8	137.1
Travis	1,187.6	889.0	274.4	187.4
Williamson	2,683.7	2,007.7	653.4	475.7
Total	5,740.70	4,295.70	1,373.00	978.90

The estimates for 2018 were generated by scaling the 2012 hotelling hours using the ratio of 2018 to 2012 Austin area VMT from combination unit long-haul trucks.

Table 3-31. 2018 Summary of Hotelling Hours (Idle Hours per Day)

County	Weekday	Friday	Saturday	Sunday
Bastrop	389.3	291.1	98.6	75.0
Caldwell	714.8	534.7	176.1	130.0
Hays	1,041.2	779.5	236.2	157.4
Travis	1,362.9	1,020.2	314.9	215.0
Williamson	3,079.7	2,304.0	749.9	545.9
Total	6,587.90	4,929.50	1,575.70	1,123.30

Zone Month Hour

MOVES requires monthly average temperature and relative humidity values for each hour of the day to perform its calculations. To prepare MOVES inputs for the Austin area, calendar year 2012 Local Climatological Data (LCD) were obtained from the National Climatic Data Center (NCDC) web site (available at http://www.ncdc.noaa.gov/IPS/lcd/lcd.html).

One LCD text file was downloaded for each month in 2012 for Austin-Bergstrom International Airport. Since the LCD summaries contain much more information than MOVES requires, the appropriate monthly averages were extracted and converted to MOVES inputs. To process the downloaded LCD files, ERG used an internally developed tool (LCD_to_MOVES) to parse the text and extract average monthly temperature and relative humidity by hour, in a format that could be directly imported to MOVES using the CDB.

4.0 Challenges, Opportunities, Recommendations

One of the challenges of this project was updating SEE to be compatible with MOVES2014 in the timeframe dictated by CAPCOG's inventory needs. The newest version of MOVES contains new table structures, a new emission process (for APUs), additional pollutants, and a new methodology for handling ramp emissions (along with new source use types to support them). Many of the changes were to be implemented under a separate contract with H-GAC, but the start of that contract was delayed. As a result, updates to SEE necessary for generation of CAPCOG inventories were also delayed.

Further delays resulted from underestimates of model computing time. ERG originally estimated that running SEE for all scenarios and counties would take 2-3 days per scenario; in some cases, the runs took more than twice that long. Even with additional computing resources applied to the modeling, runtime was a problem. Future updates to SEE will be focused on reducing runtime as much as possible.

With respect to efficiency, a further challenge was that SEE was originally developed as a conformity tool intended for modeling one day type of one season. To improve SEE efficiency for inventory generation in the future, ERG may consider modifying the tool to import additional temporal factors such that SEE could model additional day types and seasons while using fewer sets of MOVES runs, and just a single import of TRANSVMT data. Another possibility here is the inclusion of growth factors to model future years for which TDM data is not directly available.

During the modeling process, ERG was able to expand the capability of the SEE tool to run in a Linux environment (in addition to its existing Windows platform). ERG updated the Perl scripts included with the tool for use with Linux, and brought MOVES2014 over to a Linux server as well, for use in a few of the modeled scenarios. In the future, ERG will look to combine its experience with modeling MOVES in the Amazon cloud environment with the development Linux features of SEE and MOVES. Together, running both tools in the cloud has the potential to decrease runtime by orders of magnitude at a slight incremental cost.

5.0 Model Outputs and Summaries

Apart from this report, the primary deliverable for this project consists of emissions inventory data files. ERG is providing, under separate cover, electronic deliverables consisting of on-road inventories organized by day type (Mon-Thu, Fri, Sat, Sun) and calendar year (2012 and 2018) for the summer and school year seasons. ERG is providing SEE outputs containing inventory data with details of emissions by pollutant, process, and roadway type, and is additionally providing EPS3 format output files consistent with those formats developed by TTI for TCEQ. ERG is also providing summary files, including a file showing the aggregate weekday emissions and activity by model year and source use type for summer 2012, school year 2012, summer 2018, and school year 2018.

5.1 List of Electronic Deliverables Submitted to CAPCOG

ERG provided the following electronic deliverables to CAPCOG:

- TRANSVMT TDM data provided by TTI (trip matrices and link files)
- Various inputs required for SEE/MOVES derived from TCEQ data (source type distributions, meteorology, AVFT, etc.)
- County-level MOVES import XML, runspecs, input databases, and output databases created by SEE
- Project-level MOVES import XML, runspecs, input databases, and output databases SEE
- SEE output databases and crosstab summaries
- Link-level emissions data in a format similar to that provided to TCEQ by TTI in the past as described in Appendix A of the TTI Report *2006 and 2008 On-Road Mobile Source Emissions Inventories for Photochemical Model Inputs: Austin MSA*.

5.2 Summary of Weekday Activity and Emissions Estimates

The following tables summarize the key activity inputs and model outputs for the weekday day types aggregated to the county level for summer and school year periods in 2012 and 2018.

Table 5-1. Weekday Vehicle Miles Traveled Summary by County

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	2,330,275	2,339,705	2,420,380	2,430,186
Caldwell	1,464,388	1,470,315	1,646,138	1,652,807
Hays	4,957,779	4,977,843	7,026,264	7,054,729
Travis	27,372,448	27,483,224	29,852,878	29,973,823
Williamson	10,084,179	10,124,989	13,215,257	13,268,796
TOTAL	46,209,069	46,396,076	54,160,917	54,380,341

Table 5-2. Weekday Vehicle Starts Summary by County

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	301,735	301,735	350,651	350,651
Caldwell	142,784	142,784	162,603	162,603
Hays	616,634	616,634	739,913	739,913
Travis	4,025,441	4,025,441	4,518,407	4,518,407
Williamson	1,625,074	1,625,074	1,903,649	1,903,649
TOTAL	6,711,668	6,711,668	7,675,223	7,675,223

Table 5-3. Weekday Vehicle Hours Summary by County

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	50,521	50,757	51,987	52,225
Caldwell	32,012	32,147	33,507	33,650
Hays	98,426	98,851	151,530	152,243
Travis	700,185	703,641	757,967	761,600
Williamson	223,613	224,615	303,693	305,039
TOTAL	1,104,757	1,110,011	1,298,684	1,304,757

Table 5-4. Weekday Average Speed Summary by County

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	46.1	46.1	46.6	46.5
Caldwell	45.7	45.7	49.1	49.1
Hays	50.4	50.4	46.4	46.3
Travis	39.1	39.1	39.4	39.4
Williamson	45.1	45.1	43.5	43.5
TOTAL	41.8	41.8	41.7	41.7

Table 5-5. Weekday Source Hours Parked Summary by County

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	1,301,571	1,301,334	1,519,079	1,518,841
Caldwell	602,119	601,984	688,554	688,410
Hays	2,671,190	2,670,765	3,171,463	3,170,751
Travis	17,421,801	17,418,344	19,581,916	19,578,282
Williamson	7,112,840	7,111,836	8,289,705	8,288,363
TOTAL	29,109,521	29,104,263	33,250,717	33,244,647

Table 5-6. Weekday Hotelling Hours Summary by County

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	339	339	388	388
Caldwell	622	622	714	714
Hays	906	906	1,040	1,040
Travis	1,187	1,187	1,362	1,362
Williamson	2,683	2,683	3,079	3,079
TOTAL	5,737	5,737	6,583	6,583

Table 5-7. Weekday Energy Consumption Summary by County (kWh)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	4,336,184	4,354,451	4,064,155	4,081,301
Caldwell	2,735,592	2,746,652	2,786,872	2,798,210
Hays	8,663,029	8,698,835	11,231,332	11,279,292
Travis	47,839,522	48,047,765	47,332,953	47,536,495
Williamson	17,396,034	17,467,693	20,703,079	20,787,396
TOTAL	80,970,360	81,315,396	86,118,391	86,482,695

Table 5-8. Weekday CO Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	16.48	16.53	11.27	11.30
Caldwell	9.73	9.76	7.25	7.28
Hays	32.87	32.97	29.59	29.69
Travis	175.12	175.68	127.45	127.84
Williamson	65.69	65.88	55.19	55.35
TOTAL	299.89	300.83	230.74	231.44

Table 5-9. Weekday CO_2 Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	1,284.19	1,289.50	1,207.84	1,212.81
Caldwell	808.35	811.55	822.78	826.05
Hays	2,584.85	2,595.31	3,331.18	3,345.14
Travis	14,448.71	14,510.11	14,340.29	14,400.44
Williamson	5,271.06	5,292.17	6,266.70	6,291.58
TOTAL	24,397.16	24,498.63	25,968.78	26,076.03

Table 5-10. Weekday NH_3 Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	0.08	0.08	0.06	0.06
Caldwell	0.05	0.05	0.04	0.04
Hays	0.17	0.17	0.18	0.18
Travis	0.91	0.91	0.73	0.74
Williamson	0.34	0.34	0.33	0.33
TOTAL	1.55	1.55	1.34	1.34

Table 5-11. Weekday NO_X Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	3.19	3.20	1.56	1.56
Caldwell	2.00	2.01	1.08	1.09
Hays	6.25	6.27	3.81	3.82
Travis	28.49	28.59	14.17	14.21
Williamson	11.53	11.57	6.81	6.83
TOTAL	51.46	51.64	27.43	27.52

Table 5-12. Weekday PM_{10} Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	0.19	0.19	0.14	0.14
Caldwell	0.12	0.12	0.09	0.09
Hays	0.32	0.32	0.36	0.36
Travis	2.11	2.12	1.78	1.79
Williamson	0.69	0.69	0.70	0.70
TOTAL	3.43	3.45	3.06	3.07

Table 5-13. Weekday $PM_{2.5}$ Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	0.11	0.11	0.06	0.06
Caldwell	0.07	0.07	0.04	0.04
Hays	0.19	0.19	0.15	0.15
Travis	1.00	1.01	0.64	0.64
Williamson	0.36	0.37	0.27	0.27
TOTAL	1.73	1.74	1.15	1.15

Table 5-14. Weekday SO_2 Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	0.03	0.03	0.01	0.01
Caldwell	0.02	0.02	0.01	0.01
Hays	0.06	0.06	0.02	0.02
Travis	0.33	0.34	0.09	0.09
Williamson	0.12	0.12	0.04	0.04
TOTAL	0.55	0.56	0.17	0.17

Table 5-15. Weekday VOC Emissions by County (tpd)

County	School Year 2012 Weekday	Summer 2012 Weekday	School Year 2018 Weekday	Summer 2018 Weekday
Bastrop	1.35	1.35	0.89	0.89
Caldwell	0.73	0.73	0.47	0.47
Hays	2.62	2.62	1.95	1.95
Travis	13.86	13.88	9.06	9.07
Williamson	5.54	5.55	3.99	4.00
TOTAL	24.10	24.13	16.36	16.38

6.0 Quality Assurance and Quality Control

This section describes updates to SEE required for incorporation of the MOVES2014 model, as well as other QA/QC steps taken during the modeling process.

6.1 SEE Updates

As part of a project for H-GAC, the SEE tool was updated to include features of latest version of MOVES2014. During this process, ERG updated code that performed ramp calculations based on new MOVES2014 road types designated for ramps. This approach used a MOVES County Scale runs with ramp fractions in the *RoadType* table based on TDM data. After updating the code, ERG did QA to verify that total ramp VMT output by MOVES using this approach exactly matched the TDM ramp VMT.

ERG also added a new VMT-based spatial allocation feature to apply unique link emissions back onto all links, a method that could not be previously applied at the MOVES Project Level. In this update, running evaporative emissions were allocated across all links, and ramp emissions were mapped specifically onto the ramp links (instead of onto proxy highway links).

Further, ERG enabled new user inputs for MOVES2014 in SEE, a required functionality for importing CAPCOG’s idling study data. This included updates for both hotelling hours (total hours per county) and hotelling activity distribution (APU vs. Main Engine). ERG also applied a change which allowed the new MOVES APU emission process to be carried throughout SEE.

Finally, ERG updates SEE to enable fuel types to be carried through SEE’s calculations so that the fuel type detail would be present in the output emissions, updated various references to the MOVES2014 database, and updated tables and associated queries whose structures changed between MOVES versions (e.g., monthVMTFraction). At CAPCOG’s request, ERG also developed new output features that allow for TTI-style crosstab activity and output summaries, and an additional script to create ASCII files in a format suitable for use with Environ’s EPS3 model.

6.2 General QA Procedures

ERG conducted a review to make sure that the TDM data and MOVES inputs provided were complete for both the time periods of interest (calendar year and month). The output data compiled under this work was quality assured by independently checking the results of each of the ten Perl scripts that perform calculations within SEE, along with the MOVES inputs and outputs SEE prepares, to ensure accuracy regarding of activity assignments by roadway and source type, VMT and emissions magnitudes, and spatial distribution of emissions. Databases were also checked for integrity to make sure no records are dropped or duplicated during calculations.

Data review occurred as soon as possible in order to quickly identify and correct any procedural errors that could affect data integrity. During the QA process, ERG prepared draft charts and graphs of emissions and activity produced in both SEE and MOVES to verify that outputs are within acceptable ranges and are internally consistent.

6.3 Comparison to Other Inventories

Under a previous project for H-GAC[11], ERG performed extensive QA of SEE in which model runs were performed to directly compare SEE results to MOVES county scale inventory mode results using inputs developed for the 2018 HGB SIP, and updated travel demand modeling produced by HGAC. All inputs were aligned between SEE and MOVES, with MOVES inputs for meteorology, fuels, inspection/maintenance, vehicle population, age distribution and fuel technology mix taken directly from SIP inputs posted publicly by the Texas Commission on Environmental Quality (TCEQ). SEE's processing of the TRANSVMT output for 2018 produced the link-level inputs for the project scale SEE runs, and the county-scale inputs of VMT, hourly VMT distribution, average speed distribution, and road type distribution. This ensured that the SEE vs. MOVES county scale runs were directly comparable. Results of Houston-area benchmark runs indicated that the county level and overall totals for SEE and MOVES county scale are within one-half percent for each pollutant. Thus, ERG has good reason to believe that the SEE model is able to produce results that closely match VMT-based emissions inventories at the county scale.

For this work, ERG performed three types of QA checks. The first QA check was to perform emissions benchmarking of SEE results compared to emission results from a standalone MOVES County Scale Inventory run with consistent model inputs. The emissions benchmark was important because of several code changes made to SEE just prior to use for the Austin area emissions inventories. The code changes are discussed in the following paragraph. The second of three QA checks was comparison of SEE results for one county in Austin to another inventory, the TCEQ 2012 non-link statewide emissions[12]. Third and finally, all scenarios from SEE were

[11] ERG, "Spatial Emissions Estimator (SEE): Overview and User Documentation for Houston-Galveston- Brazoria Implementation – Final Report", October 30, 2014.
[12] ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/Statewide/mvs/2012/

compared to each other ensure that the trends were realistic – by year (2012 and 2018), season (summer and school year), and day type of the week (Monday-Thursday, Friday, Saturday, Sunday).

6.4 Emissions benchmarking to check SEE code changes

Several code changes were necessary in order for SEE to be ready to produce emission inventories for the Austin area suitable for EPS3 processing prior to input to an air quality model. The specific code updates to SEE are listed below.

1. ERG adapted SEE to use MOVES2014. Previously, it ran with an earlier version, MOVES2010b.
2. ERG updated SEE to model highway ramp links as MOVES road types for ramps, which have a unique drive cycle that is more aggressive than typical highway driving, and higher emission rates as a result. Previously, SEE followed the TTI approach to ramps in place at the time of original SEE development in 2014, which was to model ramps as the *Unrestricted Access* MOVES road type. Incidentally, TTI has since updated their approach to ramps as well.
3. ERG enabled SEE to carry the detail of *fuel type ID* through the emission inventory calculation to the output stage. Previously, SEE aggregated over fuel type ID in an early step. Adding this detail to the outputs was necessary for the EPS3 emissions processing that occurs downstream of the raw emission inventories.

In order to verify the new code changes to SEE, ERG compared sample results from SEE for one county to a standalone MOVES County Scale Inventory run using consistent inputs. A standalone MOVES County Scale MOVES run was selected as the benchmark of comparison because it is EPA's required model scale for creating emission inventories for SIPs and transportation conformity. By comparison, SEE calculates some of the emissions from a County Scale run and emissions from unique links from a Project Scale run, and combines them with post-processing to prepare the full inventory. By showing SEE can produce the same emissions as a County Scale Inventory Mode run, we are proving that SEE results are in agreement with MOVES guidance. Table 6-1 shows the emissions results of the comparison for Travis County for a 2012 summer weekday. The emissions changes for VOC and CO are within rounding errors. The NOx emissions differ by 2.55% overall, which is caused by the TxLED adjustments that SEE applies to diesel-fueled NOx emissions. The MOVES model cannot currently account for TxLED fuel, so this difference in NOx is expected.

Table 6-1. Comparison of Emissions and VMT from SEE with a Standalone MOVES County Scale Run

Fuel Type	VOC (kg)	CO (kg)	NOx (kg)	VMT (mi)
SEE results				
Gasoline	11,615.09	153,893.00	15,557.42	25,604,836
Diesel	1,110.50	6,945.47	11,504.29	1,878,388
Total	**12,725.59**	**160,838.47**	**27,061.71**	**27,483,224**
MOVES County Scale Benchmark				
Gasoline	11,616.12	153,947.57	15,563.05	25,604,829
Diesel	1,111.47	6,953.29	12,188.50	1,878,387
Total	**12,727.59**	**160,900.86**	**27,751.55**	**27,483,216**
Percent differences (SEE-Benchmark)/Benchmark				
Gasoline	0.01%	0.04%	0.04%	0.00%
Diesel	0.09%	0.11%	5.95%	0.00%
Overall	**0.02%**	**0.04%**	**2.55%**	**0.00%**

6.5 Comparison of SEE results for Austin with the TCEQ non-link emission inventory

Table 6-2 shows VMT and emissions of VOC, CO, NO_X, $PM_{2.5}$, NH_3, SO_2, and CO_2 at the county level for the Austin area. The top set of numbers reported are from the 2012 TCEQ non-link statewide runs and below that are the same results from the SEE link-based inventory. The overall VMT was larger in the link-based network by 2.3% and most pollutants were within -4% to 6% of the non-link inventory with the exception of CO emissions, which was 13.5% larger in the link-based inventory. A major difference between the non-link inventory and link inventory is that the latter is based on the travel demand model which predicts congested speeds based on hourly volumes on specific links. By comparison, the non-link inventory uses average speeds. CO is the pollutant that is most sensitive to changes in speed, thus it is not surprising that it would differ the most in this comparison. Aside from Caldwell County (FIPS 48055), the largest differences in CO appear to occur in the counties expected to have the most traffic congestion – the link-based inventory for Travis (48453) and Williamson (48491) have the highest CO differences from the non-link inventory of 15.6% and 10.5%, respectively. Caldwell County has higher emissions across the board because the travel model had 42.3% higher VMT than the non-link inventory VMT.

Table 6-2. County Level Comparison of VMT (miles/day) and On-road Emissions (tons/day) between the TCEQ Non-Link and SEE Link Emission Inventories.

County	VMT	VOC	CO	NOx	PM2.5	NH3	SO2	CO2
TCEQ Non-Link Inventory								
48021	2,305,510	1.30	15.19	3.29	0.11	0.08	0.03	1,237.59
48055	1,033,103	0.59	6.85	1.47	0.04	0.04	0.01	543.83
48209	4,991,904	2.65	31.43	7.02	0.21	0.17	0.06	2,626.22
48453	26,911,670	13.23	151.91	29.84	0.93	0.89	0.31	13,606.23
48491	10,117,124	5.36	59.6	11.88	0.36	0.34	0.12	5,161.10
Total	**45,359,311**	**23.13**	**264.99**	**53.5**	**1.64**	**1.52**	**0.53**	**23,174.96**
SEE Link Inventory								
48021	2,339,705	1.35	16.53	3.2	0.11	0.08	0.03	1,289.50
48055	1,470,315	0.73	9.76	2.01	0.07	0.05	0.02	811.55
48209	4,977,843	2.62	32.97	6.27	0.19	0.17	0.06	2,595.31
48453	27,483,224	13.88	175.68	28.59	1.01	0.91	0.34	14,510.11
48491	10,124,989	5.55	65.88	11.57	0.37	0.34	0.12	5,292.17
Total	**46,396,076**	**24.13**	**300.83**	**51.64**	**1.74**	**1.55**	**0.56**	**24,498.63**
Percent differences (Link-NonLink)/NonLink								
48021	1.5%	3.6%	8.8%	-2.7%	1.9%	2.1%	1.7%	4.2%
48055	42.3%	23.2%	42.5%	36.3%	59.8%	41.1%	44.8%	49.2%
48209	-0.3%	-0.9%	4.9%	-10.7%	-9.0%	-1.0%	-1.6%	-1.2%
48453	2.1%	5.0%	15.6%	-4.2%	8.9%	2.3%	6.9%	6.6%
48491	0.1%	3.6%	10.5%	-2.6%	1.7%	1.0%	1.5%	2.5%
Overall	**2.3%**	**4.4%**	**13.5%**	**-3.5%**	**6.0%**	**2.5%**	**5.4%**	**5.7%**

6.6 Trends in VMT and Emissions

The last type of QA ERG performed was to ensure that all of the other scenario results make sense in relation to the 2012 summer weekday inventory from SEE reported above in Table 6-2. ERG reviewed the emissions trends to ensure they followed the expected patterns from 2012 to 2018 and by season and day type. The next eight figures show the trends for VMT, CO_2, SO_2, NH_3, NO_X, $PM_{2.5}$, VOC, and CO. In all charts, the results are similar comparing School to Summer, and there is a repeated pattern of increase in activity or emissions going from Weekday (M-Th) to Friday (F), followed by a decrease on Saturday (Sat.) and further decrease on Sunday (Sun.). The patterns by year vary by pollutant.

Figure 6-1 (VMT) and Figure 6-2 (CO_2) show increases from 2012 to 2018, due to the increase in vehicle population which increases the vehicle-miles driven and amount of fuel consumed. Fuel consumption is the basis in MOVES for the CO_2 calculation.

Figure 6-1. VMT trends by SEE Scenario

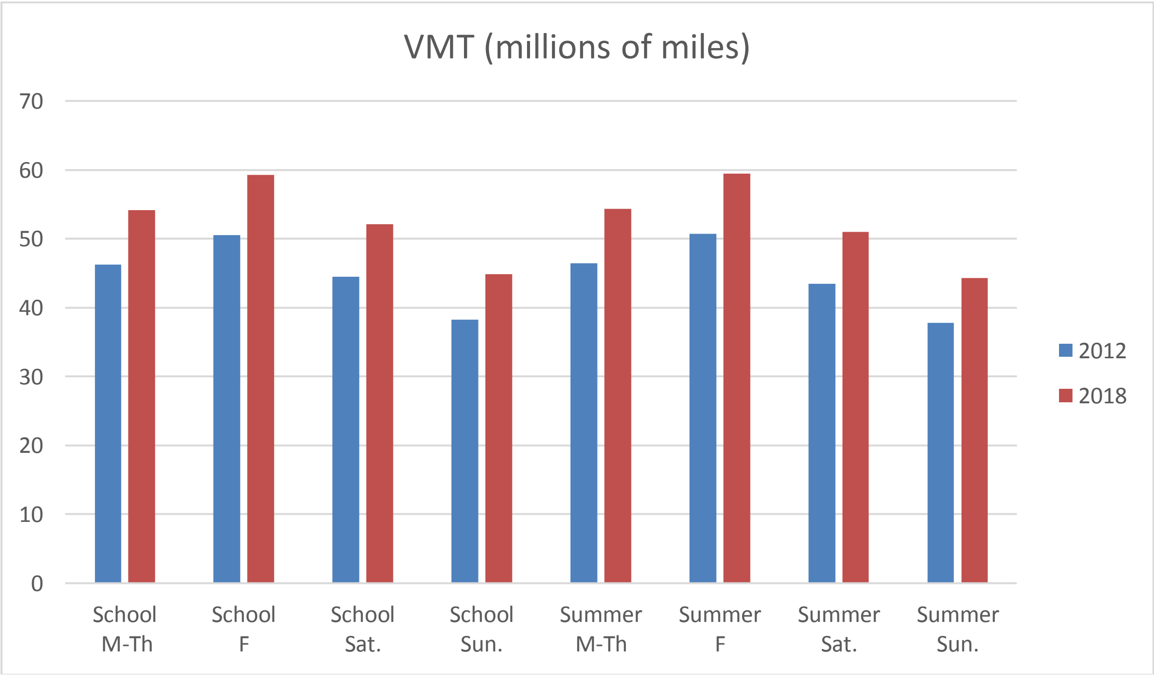
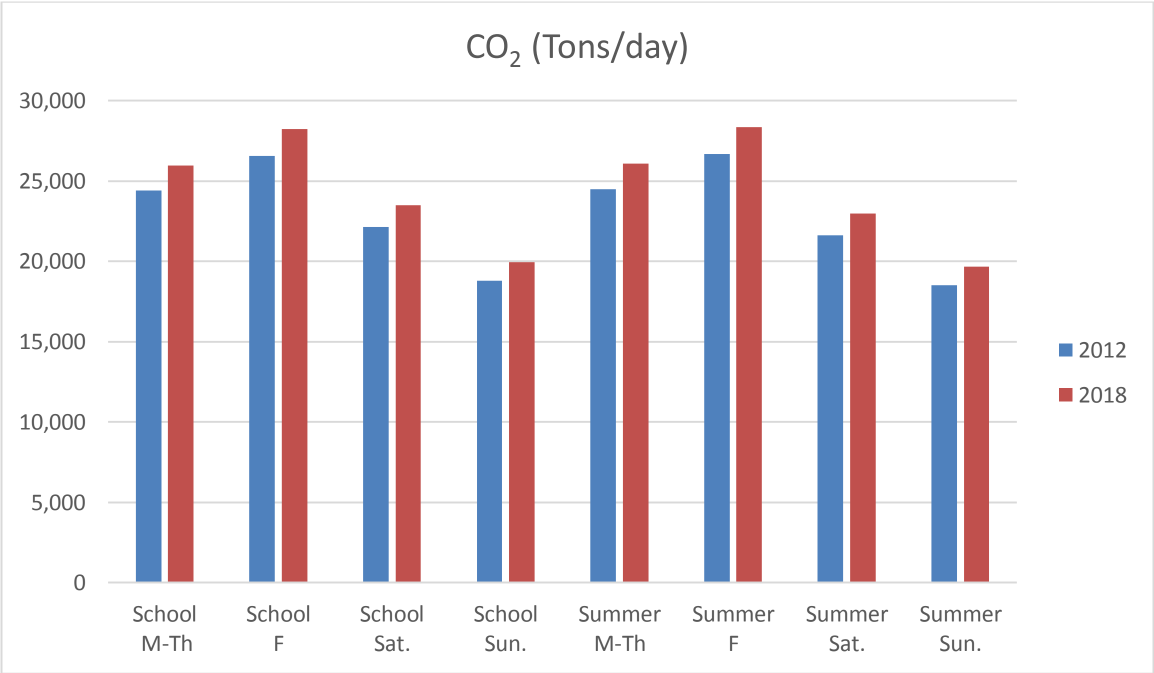
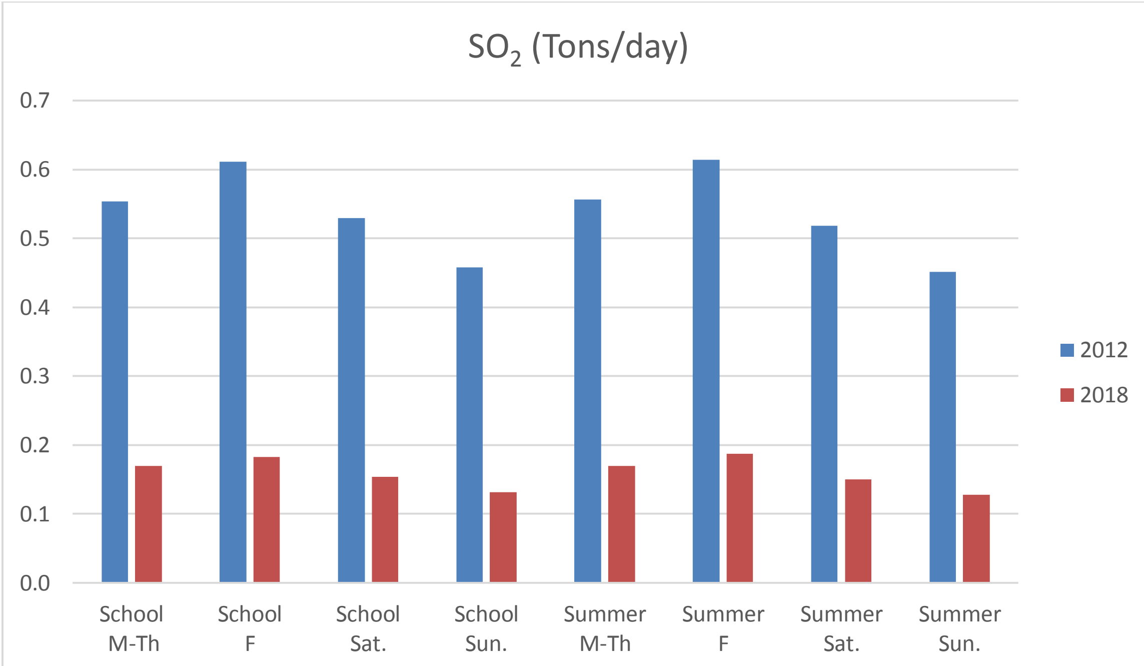


Figure 6-2. CO2 trends by SEE Scenario



Fuel consumption is also the basis for SO2 calculations, but this pollutant is influenced strongly by the drop in gasoline sulfur from 42.7 ppm in 2012 to 10 ppm in 2018 (the projected sulfur standard). Figure 6-3 shows about a 70% drop in emissions of SO_2 from 2012 to 2018.

Figure 6-3. SO_2 trends by SEE Scenario



Emissions of NH_3, NO_X, $PM_{2.5}$, VOC and CO (Figure 6-4 to Figure 6-8) all decrease from 2012 to 2018 due to the fleet turning over to more stringent emission standards.

Figure 6-4. NH_3 trends by SEE Scenario

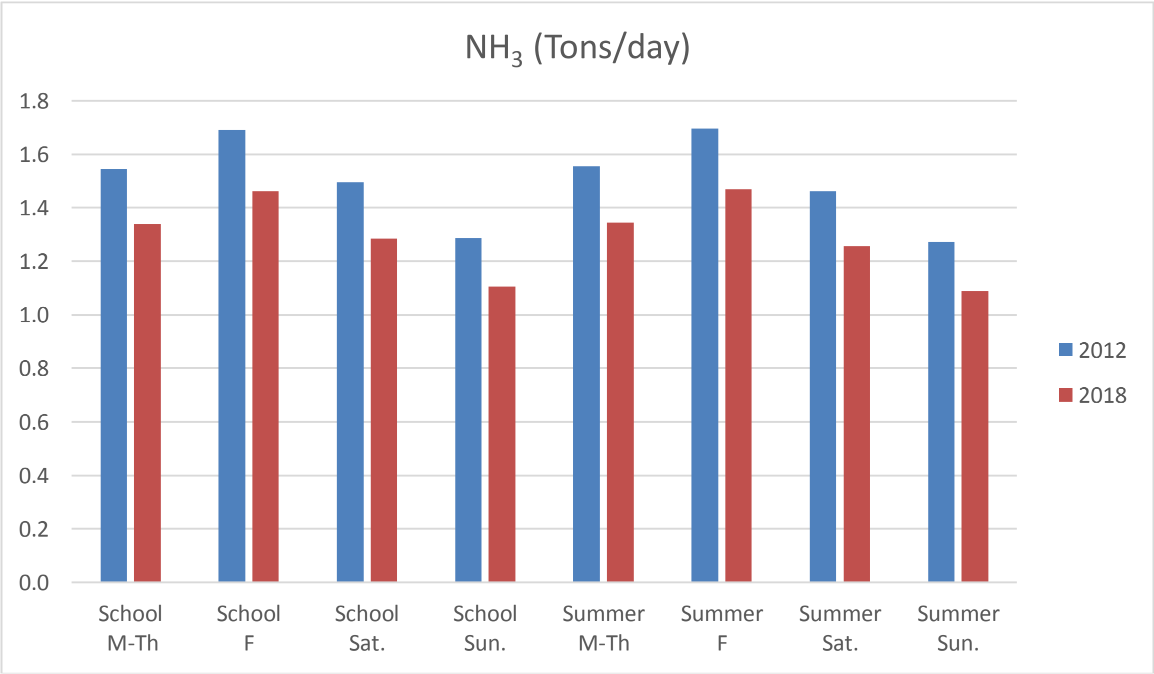


Figure 6-5. NOx trends by SEE Scenario

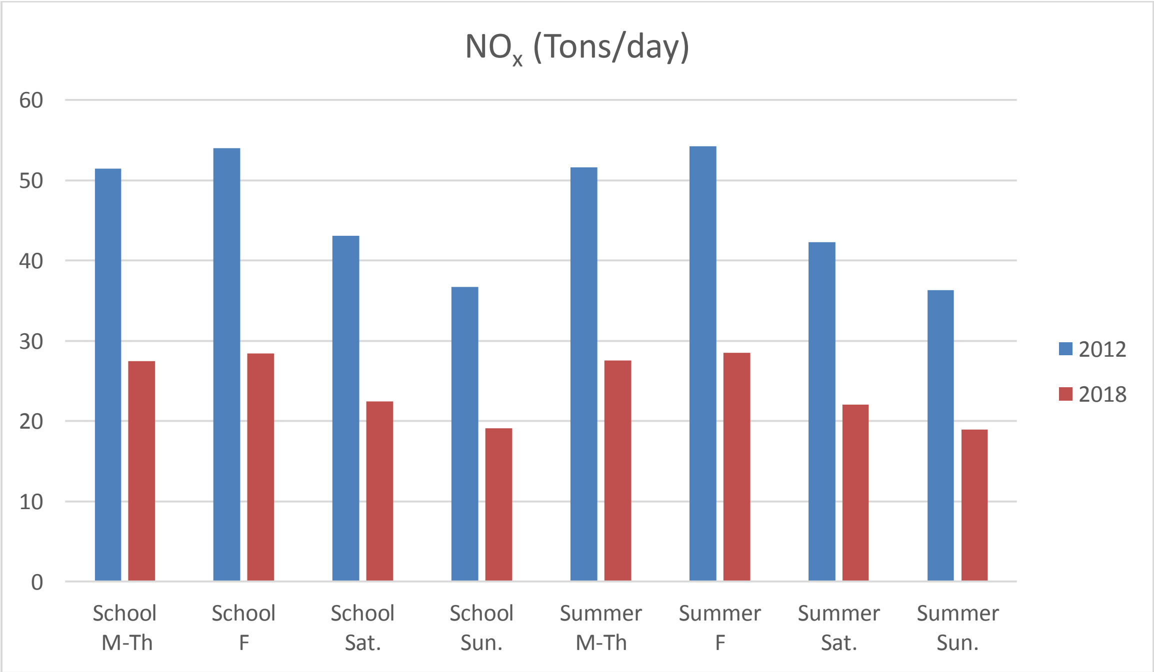


Figure 6-6. $PM_{2.5}$ trends by SEE Scenario

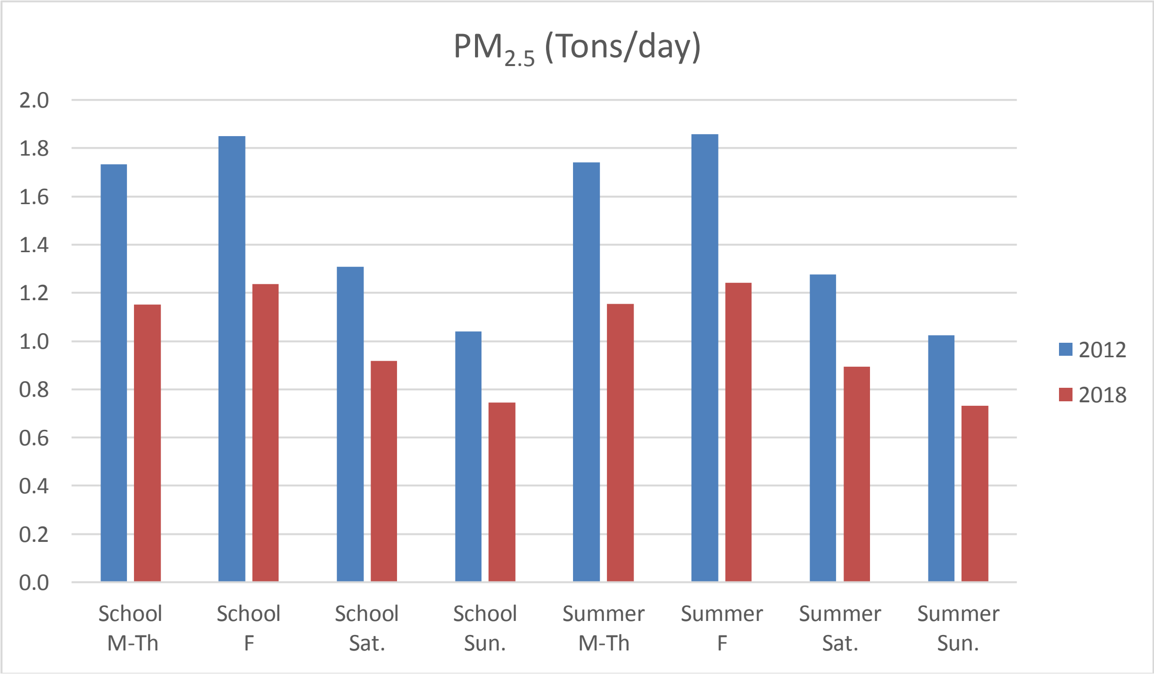


Figure 6-7. VOC trends by SEE Scenario

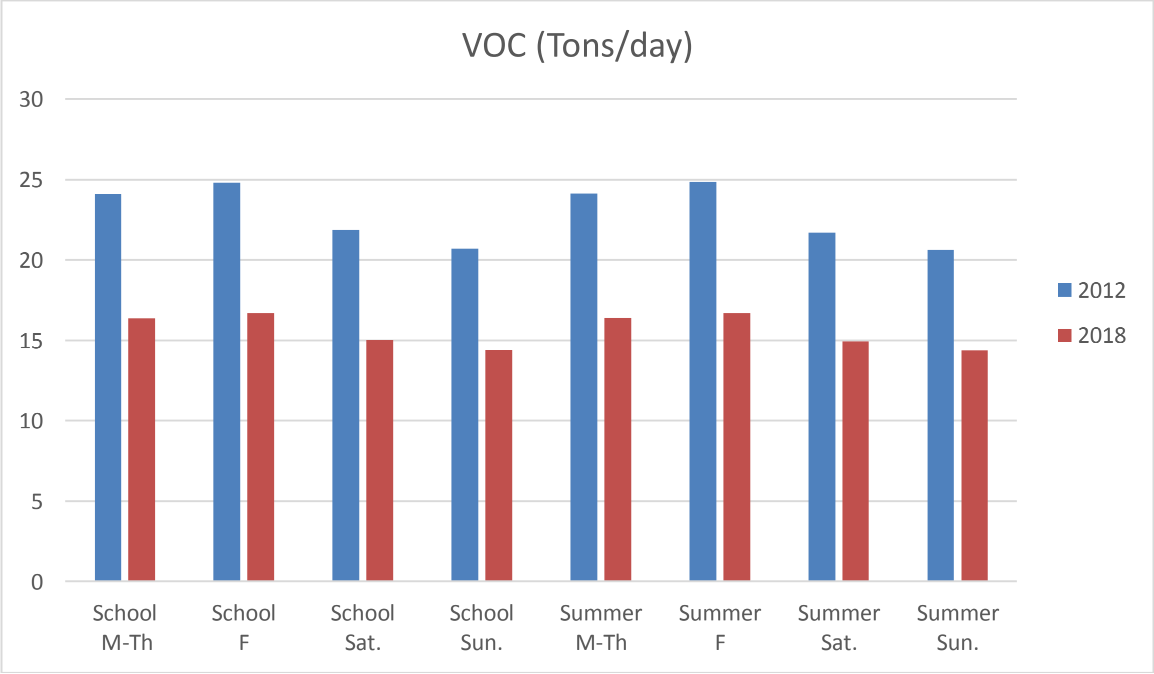
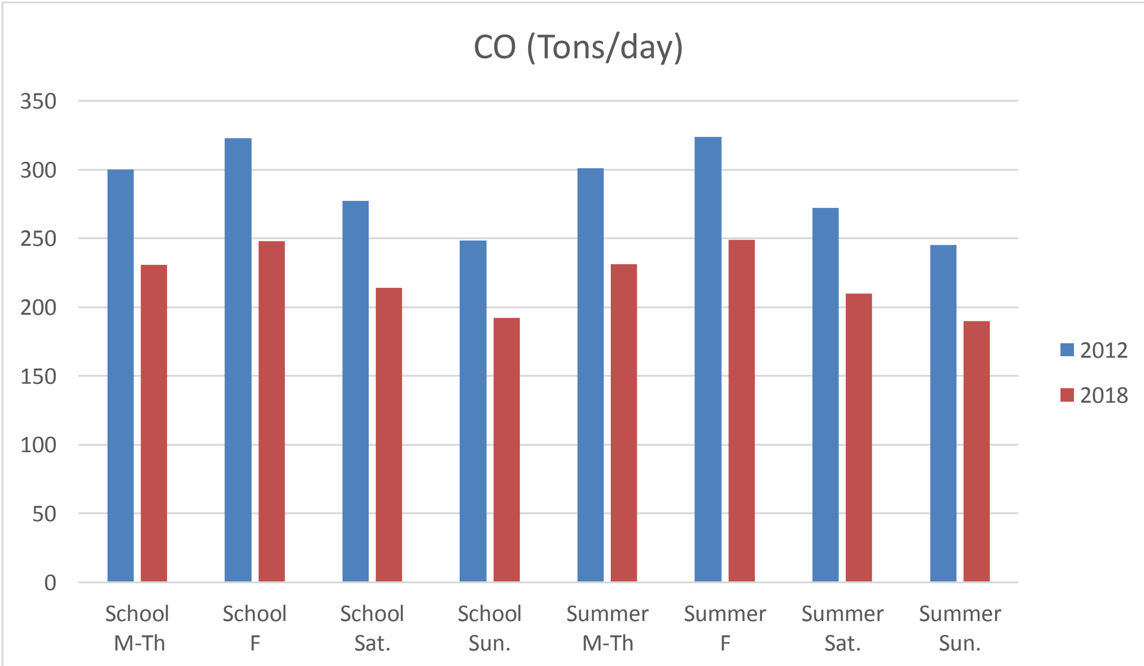


Figure 6-8. CO trends by SEE Scenario



6.7 QA Findings

ERG encountered a number of issues while processing SEE model runs during this project. These issues are described in more detail below.

First, some of the initial set of SEE runs failed because of both faulty hardware and lack of available hard drive space for output storage. To fix this, ERG replaced some of the hardware used for the modeling, and adapted SEE to run in a Linux environment to work on more powerful hardware with better processing and available storage. ERG also ordered nine additional rental machines to assist with processing, which reduced SEE runtime from 5 days to approximately 2.5 days.

In addition, ERG discovered numerous errors in the VMT reporting of SEE (caused by code updates to address changes in fuel specifications in MOVES2014), which were introduced just prior to this work. At the same time, actual VMT was being lost in the SEE runs in addition to mistakes in the summary reporting. This delayed deeper level QA from occurring at the beginning of the project. To resolve this problem, each time a loss of actual VMT was identified, ERG re-ran the scenario.

During QA of the draft report, CAPCOG noted that the fuel formulations and fuel specification inputs used in the 2012 calendar year runs were not, as specified in the QAPP, consistent with "fuels data made available by TCEQ". Rather, in the initial set of 2012 runs, ERG had used fuels input provided by TTI, which differed in fuel sulfur, RVP, and ethanol content. As a result, ERG re-ran all 2012 scenarios.

Later on in the process, CAPCOG and ERG discovered in parallel that 60% of the emissions were being lost in all scenarios. To address this: ERG scoured the SEE code, and discovered a bug in SEE in the creation of the 'link' table for the on-network Project Scale MOVES runs. ERG fixed this and reviewed all other aspects of the code at this time while the progress of the emission inventory project temporarily put on hold, and fully benchmarked the model before re-running any additional scenarios. Taking care of this bug caused an additional 2-week delay. During this thorough review, ERG also updated a couple of inputs: both the 2018 fuels (to use the latest fuels survey data in-use by TCEQ for their 2017 statewide non-link runs) and AVFT input (re-calculated so that diesel fractions of the vehicle population would match TCEQ's statewide non-link runs for 2012 and 2018 for the Austin area). Previously ERG had directly used TCEQ's posted AVFT files, which were based on statewide averages.

ERG encountered further delays in delivering EPS3-formatted files due to much longer than expected runtimes for the scripts that generated those files. In order to speed this process along, ERG ported some of the aggregation code from Perl to Python to decrease runtime, and split the process into "chunks" to take advantage of multiple processors on the rental machines.

Also, in the original set of 2018 runs performed for CAPCOG, Burnet County (FIPS 48053) was included, as TDM data for that county was provided by TTI. Burnet County emissions are not explicitly provided in this report, but are available under separate cover. At CAPCOG's request, Burnet County was not included in the subsequent 2012 runs discussed above.

7.0 Acknowledgements

The authors gratefully acknowledge Andrew Hoekzema of CAPCOG for project funding and technical direction, Graciela Lubertino, Chris Van Slyke and Chi Ping Lam of H-GAC for funding the initial SEE project and the conversion of SEE to MOVES2014; Anita White of ERG for report formatting and editing; and Dennis Perkinson and L.D. White of TTI for providing TRANSVMT outputs for the Austin region.