4. VEHICLE ACTIVITY ESTIMATION

4.1 OVERVIEW OF THE TRAVEL MODEL

The NCTCOG Travel Demand Model (TDM) serves as the source for forecasting vehicle miles of travel (VMT) and other travel characteristics for Collin, Dallas, Denton, Ellis, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant, and Wise counties. The TDM is executed in the TransCAD environment. The model base year is 2019 and the forecasted years are 2023, 2026, 2035, 2040, and 2050. The trip characteristics forecasted include the number of trips, trip origin-destination (OD) pairs, and travel mode. The model assigns all vehicle trips to the roadway network and produces traffic volume and speed at the link level for peak and off-peak periods. The assigned roadway network with forecasted VMT and speed is then processed by the emissions model for mobile emission analysis.

4.2 TRANSPORTATION MODELING PROCESS

The forecasting technique is based on a four-step sequential process designed to model travel behavior and predict the level of travel demand at regional, sub-area, and/or small-area levels. These four steps are trip generation, trip distribution, mode choice, and roadway assignment.

4.2.1 Trip Generation Model

Traffic basic geographic unit for the travel demand models is the traffic analysis zone (TAZ). The travel model covers 10,480 square miles and 13 counties. The included counties are Collin, Dallas, Denton, Ellis, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant, Wise, and Hill; Hill County is included for modeling purposes only and will not be reported. The modeled area includes all nonattainment counties and contains 5352 TAZs, of which 5303 are internal zones and 49 are external zones or stations.

For this conformity analysis, the defined base year for the forecast is 2019. The demographic estimates and forecasts were developed by NCTCOG and reviewed by local governments. The demographic forecast process included U.S. government national data for residents and employment for 2015 and 2020, along with locally developed data sources for land use and zoning.

The function of the trip generation model is to convert demographic data into person trip productions and attractions for different purposes.

4.2.2 Trip Distribution Model

The trip distribution model determines the interaction between all zone pairs within the study area. The model connects trip ends estimated in the trip generation model, creating OD TAZ pairs and resulting in OD trip tables.

Trips production and attractions are distributed among zone pairs based on gravity models for each trip purpose. Then, a reasonableness check was performed to ensure that the modeled trip information was consistent with observed trip length distribution from the household travel survey.

4.2.3 Mode Choice Model

Mode choice model subsequently determines the mode of travel selected by travelers. These decisions are based on the characteristics of:

- The trip maker (income and auto sufficiency).
- The trip (purpose, length, and orientation).
- The availability and utility of the competing transportation modes.

Table 4-1 shows the estimated coefficients for multinomial logit model for Home-Based Work trips for different market segments.

Table 4-1. Example of Mode Choices Modeled Table for Home-Based Work (HBW)

	Veh0, Inc1	Veh0, Inc>1	Veh < Worker, Inc 1	Veh< Worker, Inc 2	Veh< Worker, Inc 3	Veh< Worker, Inc 4	Veh≥ Worker, Inc 1	Veh≥ Worker, Inc 2	Veh≥ Worker, Inc 3	Veh≥ Worker, Inc 4
Drive Alone (ASC*)	-	-	-1	-1.3	-1.5	-0.8	2.9	2.6	2.6	2.6
SR2 (ASC)	-3.3	-2	-2.2	-2.3	-2	-3	-0.5	-0.5	-0.5	-0.3
SR3+ (ASC)	-3.3	-2	-3.2	-3.1	-3.1	-3.1	-0.7	-0.7	-1.5	-1
Walk Bus (ASC)	1	0.8	1.6	0.7	-0.4	-2	0.4	0.4	0.1	-1.4
Drive Bus (ASC)	-1.1	-1.9	0	-1.6	-1.9	-3.4	-0.1	0.1	0.1	-1.1
Walk Premium (ASC)	1	0.8	1.6	0.7	0.1	-1.4	1	1	0.7	-0.8
Drive Premium (ASC)	-1.1	-1.8	0	-1.6	-1.9	-3.4	-0.1	0.1	0.5	-0.9
Walk BP (ASC)	1	0.9	1.6	0.7	-0.4	-2	1	0.9	0.7	-0.9
Drive BP (ASC)	-1.1	-1.4	0	-1.6	-1.9	-3.4	-0.1	0.1	0.1	-1.1
IVTT	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
OVTT	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.045	-0.06	-0.06	-0.06
Parking_cost	-0.2	-0.1	-0.6	-0.5	-0.34	-0.2	-0.9	-0.34	-0.24	-0.16
Cost_Coeff	-0.1	-0.05	-0.3	-0.25	-0.17	-0.1	-0.45	-0.17	-0.12	-0.08
DallasCBD_DABP	1	1	1	1	1	1	1	1	1	1
DallasCBD_DAB	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
DallasCBD_DAP	1.2	1.2	1.2	1.2	1.2	1.2	1	1.2	1.2	1.2
DallasCBD_WABP	1	1	1	1	1	1	0.9	1	1	1
DallasCBD_WAB	0.9	0.9	0.9	0.9	0.9	0.9	1.2	0.9	0.9	0.9

4.2.4 Roadway Assignment Model

The Roadway Traffic Assignment Model loads the travel demand (trips) to the roadway network, calculates delay for congested links, and reassigns as necessary to achieve network equilibrium. This step is performed using a User Equilibrium traffic assignment model.

4.3 Speed Estimation Procedure

As part of the TDM calibration process, speeds for each roadway facility type are estimated and further categorized by area type. These input speeds reflect the average hourly travel speeds.

The roadway traffic assignment model produces speed as well as traffic volume for each roadway link for each time period: AM peak, PM peak, and off-peak. These periods are defined based on congestion level in the roadway network for each forecast year. Period traffic volume is broken into hourly volume for 24 hours. The final output is VMT and speed by each hour for each link.

4.4 Local Street VMT

The roadway network of the regional TDM does not contain details of local (residential) streets. However, a VMT estimate is possible based on data provided by the travel model. Local street VMT is calculated for each county by multiplying the number of intrazonal trips by the intrazonal trip length and then adding the VMT from the zone's centroid connectors. The temporal distribution is assumed to be the same as for non-local streets.

4.5 Model VMT Adjustments

An adjustment factor based on the Texas Department of Transportation's (TxDOT's) Highway Performance Monitoring System (HPMS) was applied to the TDM's VMT to ensure consistent reporting across the state. The HPMS adjustment factor is applied to the model estimated time-of-day VMT before the estimation of time-of-day speed. In this way, the time-of-day speeds used in the estimation of emissions are based on HPMS-adjusted VMT. This methodology is consistent with the procedures used by the Texas A&M Transportation Institute (TTI) in developing model adjustment factors for the rest of Texas.

4.5.1 HPMS Adjustments

The HPMS adjustment factor is applied to the model estimated time-of-day VMT prior to the estimation of time-of-day speed. In this way, the time-of-day speeds used in the estimation of emissions are based on the HPMS-adjusted VMT. The factor used to reconcile model-estimated regional VMT to HPMS-estimated regional VMT is calculated by dividing the HPMS-estimated average non-summer weekday VMT:

$$HPMS\ ANSWT = HPMS\ AADT\ \times AADT\_to\_ANSWT\ factor$$

$$HPMS\ factor = HPMS\ ANSWT / Model\_estimated\_ANSWT$$

Where:

HPMS ANSWT = HPMS-based average non-summer weekday travel.

As Table 4-2 shows, the HPMS adjustment factor was calculated based on these calculations.

Table 4-2. 2019 HPMS Factor

HPMS AADT VMT[1]	AADT-to-ASWT Factor	HPMS-Based ASWT VMT	TDM VMT[1]	HPMS Factor[2]
188,941,395	1.042	196,876,934	208,590,323	0.9438

[1] Non-Local Roads (Including Toll Roads). Total of the counties included. Counties included were Collin, Dallas, Denton, Ellis, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant, and Wise counties
[2] Applied to all analysis years and areas in the TDM.

4.5.2 Seasonal and Daily Adjustments

Seasonal adjustment factors were applied to the TDM VMT to convert it to summer weekday VMT. These factors were derived from the 2022-2023 average data collected by TxDOT Permanent Automatic Traffic Recorder (ATR) stations. The core counties include Collin, Dallas, Denton, Rockwall, and Tarrant. For these counties, the applicable adjustment factor(s) are determined based on the area type of each TAZ (Traffic Analysis Zone), specifically, whether it is classified as Urban or Rural. For all remaining counties, a single set of perimeter factor(s) is applied.

Table 4-3. Seasonal Factors

County Type	Summer Weekday
Core Urban	1.10
Core Rural	1.01
Perimeter	1.01

4.5.3 Hourly Adjustments

The hourly factors in Table 4-4 are used to convert the TDM output into hourly VMT. Since the NCTCOG's TDM has the Peak Periods defined into half-hour intervals, these adjustments are initially applied at the half-hour level and the VMT is then aggregated to the hourly level. Additionally, for each County Type category, the fractional allocations for each period sum to 1;

as a result, the fractional allocations across the three time periods – AM Peak, PM Peak, and Off-Peak – sum to 3.

Table 4-4. Hourly Distribution Factors

Time Period	County Type		
	Core Urban	Core Rural	Perimeter
0:00	0.02	0.01	0.02
1:00	0.01	0.01	0.01
2:00	0.01	0.01	0.01
3:00	0.01	0.01	0.02
4:00	0.02	0.01	0.03
5:00	0.06	0.02	0.05
6:00	0.05	0.02	0.04
6:30	0.18	0.13	0.17
7:00	0.42	0.41	0.43
8:00	0.39	0.46	0.40
9:00	0.09	0.08	0.09
10:00	0.08	0.09	0.09
11:00	0.08	0.10	0.09
12:00	0.09	0.11	0.10
13:00	0.09	0.11	0.10
14:00	0.10	0.11	0.10
15:00	0.29	0.26	0.28
16:00	0.29	0.29	0.30
17:00	0.29	0.31	0.30
18:00	0.13	0.14	0.12
18:30	0.05	0.06	0.05
19:00	0.08	0.09	0.07
20:00	0.06	0.07	0.05
21:00	0.05	0.05	0.04
22:00	0.04	0.03	0.03
23:00	0.02	0.01	0.01

4.5.4 Non-Recurring Congestion

The delay caused by nonrecurring congestion is added to the freeway travel times and congestion delay due to bottlenecks to obtain an increased freeway travel time, which translates into reduced speed on freeway facilities. Arterial street emissions are not significantly affected by incidents because alternate routes on the arterial system are generally available; therefore, this factor is not applied to non-freeway type facilities.

4.6 ESTIMATION OF ON-NETWORK ACTIVITY

4.6.1 Roadway VMT

Roadway VMT is provided by hour, county, road type and area type. Appendix D.5 VMT, Speed, and Emissions Summaries contains all the network years with the final VMT estimates.

4.6.2 Average Loaded Speeds

Average loaded speeds are provided by hour, county, road type, and area type. The final average loaded speeds are listed in Appendix D.5 VMT, Speed, and Emissions Summaries.

4.6.3 Centerline and Lane Miles.

Centerline miles and lane miles are provided by functional class and area type for each analysis year and are listed in Appendix C.2 Links, Miles, Centerline, and Lane Miles Summaries.

4.6.4 Transit Systems

The transit trips are excluded from the highway assignment and are not considered in the calculation of roadway VMT.

4.7 ESTIMATION OF OFF-NETWORK ACTIVITY

County-level, hourly estimates of the Source Hour Parked (SHP) and starts activity were required for each vehicle type to estimate the off-network (or parked vehicle) emissions. Source Hours Extended Idling (SHEI) and Auxiliary Power Unit (APU) hours estimates were needed for combination long-haul trucks. For the estimation of the SHP and vehicle starts vehicle population estimates were also needed.

The vehicle population and hourly SHP, starts, SHI, and APU hours are available in Appendix D.3 – Activities.

4.7.1 Vehicle Populations

Vehicle population data were used to estimate SHP and vehicle starts off-network activity. The vehicle population estimates were derived from end of year 2021, county specific vehicle registration data provided by the TxDMV, TxDOT district level VMT mix data, and HPMS-reported county-level VMT totals.

The following steps were used to disaggregate the TxDMV vehicle registration data to vehicle population data by vehicle type.

1. VMT mix data was used to calculate the proportional representation of each MOVES vehicle type within each TxDMV aggregation class (first column of Table 4-6).

Table 4-5. Vehicle Registration Aggregations and Vehicle Types

Vehicle Registration[1] Aggregation	Associated Vehicle Type[2]
Motorcycles	MC_Gas
Passenger Cars (PC)	PC_Gas; PC_Diesel;
Trucks ≤ 8.5 K GVWR (pounds)	PT_Gas; PT_Diesel; LCT_Gas; LCT_Diesel;
Trucks > 8.5 and ≤ 19.5 K GVWR	RT_Gas; RT_Diesel; SUShT_Gas; SUShT_Diesel; MH_Gas; MH_Diesel; Obus_Gas; Obus_Diesel; TBus_Gas; TBus_Diesel; SBus_Gas; SBus_Diesel;
Trucks > 19.5 K GVWR	CShT_Gas; CShT_Diesel; CShT;
NA[1]	SULhT_Gas; SULhT_Diesel; CLhT_Gas; CLhT_Diesel;

[1] The four long-haul SUT/fuel type populations are estimated using a long-haul-to-short-haul weekday SUT VMT mix ratio applied to the short-haul SUT population estimate.
[2] The year-end TxDMV county registrations data extracts were used (i.e., the three-file data set consisting of: 1—light-duty cars, trucks, and motorcycles; 2—heavy-duty diesel trucks; and 3—heavy-duty gasoline trucks) for estimating the vehicle populations.

2. The proportional fractions calculated in Step 1 were multiplied by the total number of vehicles reported in each TxDMV vehicle registration category to obtain the estimated number of vehicles (populations) for each modeled MOVES vehicle type.

Analysis year vehicle type populations were then calculated by applying a vehicle types of population growth factor (VPGF). The VPGF was calculated using county-level HPMS reported total VMT for the registration data year 2021 and each analysis year.

4.7.2 Off-network Idling Hours

Off-network idling (ONI) is idling activity that occurs while a vehicle is idling in a parking lot, drive-through, driveway while waiting to pick up passengers or loading/unloading cargo. ONI applies to all MOVES source types.

TTI estimates ONI hours activity (i.e., source hours idling [SHI] off-network) for each hour of the day using the following formula.

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

Where:

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

$SHI_{network}$ is the total source hours idling that occurs on the network (idling that occurs as a component of drive cycles) and is calculated by multiplying SHOnetwork by a road idle fraction (RIF). RIF is the proportion of idling (in units of time) that occurs within a drive-cycle at a specified operational speed. Default values for RIF were used as defined in the MOVES data table “roadidlefraction”.

TIF is the total idle fraction or total idling time on and off-network divided by total SHO on and off-network: TIF = (SHInetwork + ONI) / (SHOnetwork+ ONI). Default values for TIF were used as defined in the MOVES data table “totalidlefraction”.

4.7.3 Source Hours Parked

The first activity measure needed to estimate the off-network emissions is county-level estimates of SHP by hour and vehicle type. The SHP was estimated as a function of total hours (hours a vehicle exists) minus its hours of operation on roads (Source Hours Operating [SHO] is the same as Vehicle Hours Travel [VHT]).

The vehicle type SHP estimates were calculated for each hour of the day based on the link VMT and speeds, the VMT mix used in the link-based emissions analysis, and the vehicle population estimates.

The VMT mix was applied to the link VMT to produce VMT estimates by vehicle type. Link VMT was divided by the link speed to produce SHO estimates. SHO was aggregated across links and then subtracted from source hours (equal to vehicle population since source hours equal the number of hours in the period) resulting in SHP estimates by vehicle type. This was performed for each analysis year, county, and hour of day.

4.7.4 Starts

Vehicle starts were estimated using county-level vehicle type populations and data from MOVES representing the average number of vehicles starts per vehicle type per hour. The starts per vehicle were calculated using MOVES with data on the age distribution and fuel fractions of the local fleet.

The starts per vehicle were calculated using MOVES with data on the age distribution and fuel fractions of the local fleet. Texas A&M Transportation Institute (TTI) used local age distributions and fuel fractions inputs to MOVES combined with MOVES default parameters (startsageadjustment, startsmonthadjust [June through August average], and startspervehicle) to produce hourly starts per vehicle output representative of the June through August summer period. The output was then post-processed to produce the scenario-specific starts per vehicle for the summer (or non-school) period defined by the study scope.

MOVES was used to calculate starts per vehicle (i.e., the average number of starts per vehicle type per hour) for weekday day type for the June through August summer period. To produce the scenario-specific non-school period (10 June through 10 August), the MOVES output summer period starts per vehicle were multiplied by conversion factors based on period weighted average

MOVES default startsmonthadjust data. Using the startsmonthadjust default data, the non-school conversion factor is the ratio of non-school-period-to-average June through August summer period.

The local vehicle start activity estimates were calculated as the product of national default starts/vehicle and the local vehicle type population estimates. The weekday vehicle start estimates for each vehicle type were calculated by county, analysis year, and hour of day.

4.7.5 Hotelling: Source Hours Extended Idling and Auxiliary Power Unit Hours

Hotelling hours were calculated for heavy-duty, long-haul trucks only (i.e., SUT 62) in several steps. First total hotelling hours were calculated using information from a TCEQ extended idling study[5]. Scaling factors were then used to convert these base hotelling hours to those relevant to each analysis year, which were then allocated to each hour of the day. Estimations were then made of the proportions of hotelling hours that occur in each of the four hotelling categories: idling using the main engine (SHEI), diesel APU operation, electric APU operation, or main engine off and no auxiliary power[6].

4.7.5.1 Estimating 24-Hour Hotelling

County-level hotelling scaling factors were developed to transform base 2017 winter weekday total daily hotelling hours to daily hotelling hours for each conformity analysis year scenario. Scaling factors were calculated using the ratio of heavy-duty long haul VMT for each scenario relative to heavy-duty long haul VMT for a 2017 winter weekday (scenario SUT 62 VMT divided by 2017 winter weekday SUT 62 VMT).

Total daily hotelling for each county and scenario was calculated by multiplying the appropriate scaling factor by the total daily hotelling hours contained in the 2017 winter weekday total daily hotelling hours study.

4.7.5.2 Hotelling by Hour Estimation

Daily hotelling hours were allocated to each hour of the day as a function of the inverse of activity scenario hourly VHT fractions for SUT 62. The hourly VHT fractions were calculated using the hourly VHT from the SHP estimation process (VHT = SHO). The inverses of these hourly VHT fractions were calculated and then normalized across all hours to produce the county-level, hotelling hours hourly distribution.

If the hourly hotelling hours were greater than SHP (for SUT 62), the final hotelling hours estimate was set to the SHP.

4.7.5.3 SHEI and APU

County, analysis year, and summer weekday hotelling hours were first estimated using 24-hour weekday hotelling hour estimates for a 2017 baseline year (from the most recent TCEQ extended

[5] Heavy-Duty Vehicle Idle Activity Study, Final Report. Texas A&M Transportation Institute, Environment and Air Quality Division, July 2019.
[6] Only SHEI and APU diesel hoteling generate emissions. The other fractions are calculated for completeness.

idling study); baseline and analysis year scenario VMT, speeds, and VMT mix; and analysis year scenario SHP estimation data.

The baseline-year county hotelling hours estimates for a 24-hour weekday from the TCEQ study were scaled to each analysis scenario using the ratio of analysis-scenario-to-baseline combination long-haul truck 24-hour VMT (as truck VMT increases, so does hotelling activity).

The 24-hour hotelling estimates were then distributed to each hour of the day using the hotelling hours hourly distribution calculated for the analysis scenario as the inverse of the hourly distribution of VHT (or SHO, from the SHP calculation process) for combination long-haul trucks. Within each hour, SHP and hotelling hours were compared, and if hotelling hours exceeded the SHP, hotelling hours were set equal to the SHP.

SHEI and APU hours components of hotelling hours were then estimated for each hour using the hourly hotelling hours estimates, combination long-haul truck travel fractions (calculated from local age distributions and MOVES default relative mileage accumulation rates), and hotelling activity distributions for each model year.

The SHEI and APU hours activity distribution fractions (see Table 4 6) were each first multiplied by the travel distribution (model-year operating mode activity fraction multiplied by the associated mode-year travel fraction). The products of the SHEI fractions and travel fractions were then summed to produce the total SHEI fraction, and the same process was performed for APU hours to produce the total APU hours fraction. (The sum of the SHEI and APU hours fractions subtracted from 1.0 results in the fraction of hotelling hours with electric power or no power in use).

Table 4-6. Hotelling Activity Distribution by Model Year

Begin Model Year	End Model Year	200 Extended Idling	201 Hotelling Diesel Aux	203 Hotelling Battery AC	204 Hotelling APU Off
1960	2009	0.80	0.00	0.00	0.20
2010	2020	0.73	0.07	0.00	0.20
2021	2023	0.48	0.24	0.08	0.20
2024	2026	0.40	0.32	0.08	0.20
2027	2060	0.36	0.32	0.12	0.20

The total SHEI and APU hours fractions were then each multiplied by the hotelling hours for each hour of the day to produce the SHEI and APU hours estimates for each hour. This was performed for each analysis scenario (analysis-year summer weekday).