16 ENVIRONMENTAL TRAFFIC DATA

16.1 Purpose

Federal regulation requires, in some cases, that an air and noise study be completed to determine what impact, if any, will result from a proposed highway improvement and what measures will be taken to lessen these impacts. Certain projects may also require that greenhouse gas emissions (GHG) be quantified. This chapter presents the general outline for the needs and creation of common traffic data inputs requested for the Air Quality and Noise Analysis sections of the Environmental Impact Statement (EIS) or Environmental Assessment (EA) and for Categorical Exclusion (Class 2) projects as applicable. Traffic data needs for statewide GHG scoping, planning, and project-level analyses are also covered.

> *The noise, air quality, and GHG methodologies in this chapter are only for the production of environmental* ***traffic data*** *needed to support calculation tool inputs. Other ODOT and consultant staff are responsible for using this environmental traffic data in noise, air quality and greenhouse gas tools and models. The actual noise, air quality and GHG analyses are outside the scope of this chapter and the APM.*

16.2 Induced & Latent Demand Project Considerations

An important consideration for projects that address capacity/congestion issues (e.g. adding travel lanes) is that assumptions regarding induced and latent demand need to be assessed (see Chapter 6). As part of the National Environmental Policy Act (NEPA) federal/state/local agency review process and the public hearing and comment periods, comments relating to the analysis and impacts of induced and latent demand are common.

Latent demand may cause the build alternative traffic to be higher than the no-build. In addition, if the project is on an edge of an urban/urbanizing area, travel demand model area, or is in an area with building land use and economic pressures (e.g. lack of affordable housing or available employment) the project alternative(s) need to be assessed for the potential of induced demand. Concerns such as these may facilitate development of bedroom communities that might add more demand to the system over time. Ideally, these kinds of expansions would also be accompanied with additional bike and transit networks and infrastructure to maximize mode share, but in cases where they are not increases the potential for latent and induced demand.

The results of the latent and induced demand assessment need to be clearly stated as part of the volume development for the alternatives. Depending on the roadway network and the extent of congestion, there may need to be separate forecasts created for the no-build and build. These separate project forecast assumptions need to be incorporated into the environmental traffic data creation process whether for noise, air quality or greenhouse gases.

Generally, a project should identify the number of new lane miles added including all auxiliary lane types (i.e. weaving, turning, etc.). Use Appendix 10A to isolate any sections of auxiliary lanes that are actually operating as through lanes. The analyst should also discuss with TPAU, ODOT Environmental Section, and their NEPA coordinator/staff any scoping needs or changes to the overall modeling approach to address potential risk from latent and induced demand.

16.3 Noise Analysis Traffic Data

ODOT is responsible for ensuring that state transportation projects are developed within the Federal Highway Administration's noise policies and procedures. To conduct the noise analysis necessary for measuring compliance, the ODOT Environmental and Hydraulic Engineering Section, or noise consultant, requires specific data from the project traffic analyst. This request is typically made through the Noise Traffic Data Request form in Appendix 16A which is filled out by the noise consultant or Environmental Section staff and delivered to the project traffic analyst. A traffic data request may be for a full or a screening-level noise study. Typically, the full study is requested, and its data requirements are discussed in the following sections. The screening level study uses a subset of the full data, so the same procedures apply. A calculation template workbook meant to streamline the noise traffic data production process in conjunction with the information in this section is available under the Volume Development section on the Technical Tools web page.

This traffic volume development process should typically only be done on the existing conditions, future no-build and final preferred alternative because of the time required to complete the work. Most times there is only one preferred alternative, but there have been cases of more than one final alternative requiring noise analysis. Any final alternatives need to be "frozen" and not be subject to changing designs, as that will incur excessive rework. Generally, it will take about three weeks for the existing conditions, two weeks for the future no-build, and two weeks for each build alternative for a medium to large-sized project.

The noise analysis needs to identify the times that have the highest impact, which would be the noisiest hour. This could be either the peak hour of all vehicles or the peak truck hour (total volumes could be much less but trucks typically make much more noise than other vehicles). This highest hour is also when the LOS C volumes occur, which is the maximum volume that can pass a point at the maximum (posted or 85th percentile) speed. Higher volumes will have slower speeds and faster speeds require low volumes and both cases will not have the highest noise levels. For example, at low volumes or densities, (LOS A or B) vehicles are independent and are not affected by others. Speeds will be higher, but volumes will be low thus the noise level will be relatively low. At high volumes or densities (LOS E – F), vehicles directly affect each other and resulting speeds are low which dampens the noise level. At LOS C (at the C/D threshold), vehicles may have to do some space adjusting but can still travel at the posted/85th percentile speed.

The noise analyst will obtain noise measurements in the field to establish the existing conditions. The traffic data supplied by the transportation analyst will be used by the noise analyst to calibrate the traffic levels to the existing noise levels. The noise measurements should be done under similar seasonal conditions (e.g. the PM peak hour used in a MPO area representing the 30th highest hour condition or use of a summer average weekday in a coastal community, etc.) as the traffic to minimize any seasonal pattern impacts that cannot be adjusted for (see Chapter 5). The difference in traffic volumes between the existing conditions and the future no-build will help establish the noise levels for the future no-build. The same goes for translating the future no-build to the future build. In a sense, this is analogous to post-processing with a travel demand model. The noise analysis will be summarized in a report which serves as the basis for recommending any noise mitigations such as soundwalls.

16.3.1 Input Data Needs

The traffic data requested will be the existing and the future design years for the no-build and the design year for the build alternative(s). The data will be provided in a directional segment or link basis. For each of the separate years, the following is required per link:

- Unique link identifier
- Link name
- Link length (mi.)
- Link type
- Posted speed (mph)
- 85th percentile speed (mph); if known
- LOS C volume (vph); Needed if any link volume for any analyzed year has a segment LOS D or higher, so it is highly advisable to include regardless to save time
- Peak hour and peak truck hour volume (vph)
- Percentages (decimal form) of vehicle groups:
  - Automobiles (FHWA Classes 1-3)
  - Medium Trucks (FHWA Classes 4-5)
  - Heavy Trucks (FHWA Classes 6-13)
  - Optional- Motorcycles (FHWA Class 1) and buses (FHWA Class 4)

Other information:

- Percentage of vehicles expected to stop on traffic signal approaches
- Existing and future zoning (or predicted/planned changes in land use from existing)
- Intersection turning movement diagrams (generally just for screening-level requests)

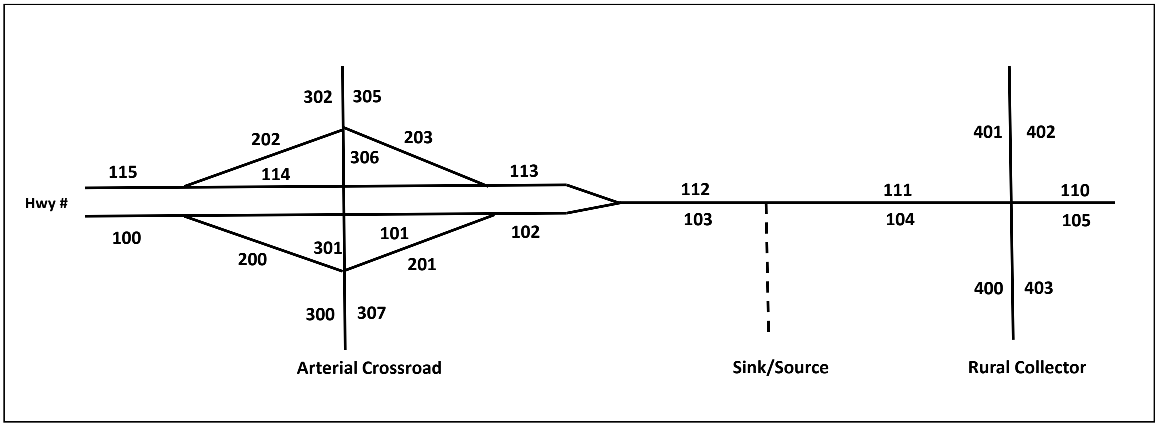
Links & Identifiers

The noise data process requires that the project area roadway network be broken into individual segments as everything will be recorded at the link level. This will be in the form of link diagrams depicting the study area roadway segments that will be included in the analysis for all considered no-build and build scenarios. These diagrams are not only useful for graphically relating the data provided to its location, but help in identifying links created, modified, or removed with each alternative and will facilitate the review and error-checking process. These can either be on paper or in an electronic format (i.e. Excel).

Each link must be given a unique number for identification purposes. Link numbers must be directional. Only roadways with collector and higher functional classifications should be included in a 500’ range from the subject facilities in the project area. Local streets and private driveways will have too low of speed and/or volume to make a significant noise impact and can be ignored. All count locations need to be represented as a node. Intersections with local streets and driveways should be noted as a sink/source location and should be a node (link break) if there was a count performed at that location. Creating a break at these locations will make the overall volume balancing process easier. Links representing the local street or driveway at this location should not be added, so the only intersection legs that would be represented would be on the mainline.

As much as possible, keep consistent numbering between the existing, no-build, and build link diagrams. This will mean adding extra links that have zero data into the existing and no-build future network that will accommodate the build alternative(s). It is best not to be completely sequential in the numbering by leaving gaps to accommodate extra links. This will avoid having out-of-order numbering if a new link is needed to be added later. For example, if the eastbound links were numbered 1 to 22, it would be better to start the westbound numbering at 30 instead of 23. The series numbers can also be changed to represent a different facility type for better clarity. For example, the mainline freeway could have the range of numbers being 1-50, the intersecting arterial could be in the 100’s and the ramps connecting the two could be in the 200’s. So in this case, Link 101 would be on the crossroad and Link 204 would be a ramp. The more consistent the diagrams are between all the scenarios, the easier it will be for the traffic analyst to create and troubleshoot and the noise analyst to follow. There is nothing wrong with having links with no data in the scenarios if they are labeled as not existing yet (i.e. “Future Link”) or not existing anymore (i.e. “Removed”). Exhibit 16-1 shows a sample project area with a wider highway that has access-control and medians transitioning to a two-lane highway section with at-grade intersections. Different numbering was used for the highway, ramp, arterial, and collector links. The link numbering was also non-consecutive to allow for the future alternative to keep numbering between scenarios consistent as possible.

Exhibit 16-1 Sample Link Diagram



Link Characteristics

Each directional link has a series of specific characteristics. This includes link name, length, type, and speed. Link names need to be descriptive with the street name, from-to, and direction. For example, this would be NB Main St (Elm St – Oak St) for a two-way roadway or like SB I5 to WB I105 Off-ramp for a one-way roadway. There should be no ambiguity on location between the description and the numerical identifier.

Link length is defined as the center-to-center intersection spacing. For state highway facilities (mainline, connections, or frontage roads), use of official roadway inventory data is preferred for existing and the future no-build conditions. Build alternative segment lengths should be determined from available single-line or detailed design drawings. Links on the edge of the network should have a default length of 0.25 mile.

Link type is a general identifier of the roadway environment. This is defined as either rural, urban street, or freeway. Study areas outside of an urban growth boundary should use the "rural" classification unless the facility is a freeway, then the "freeway" classification will override. Freeway ramps and related free-flow interchange connections should also use the "freeway" classification. Urban street interchange crossroads or other urban at-grade facilities should use the "urban street" classification.

Link speeds, at a minimum, are the posted speeds. Dual-posted highways with truck speed limits should weight-average the regular and the truck speed limit together using the heavy truck percentage. If the speed is weight-averaged, it should be rounded to the nearest whole number. If available for existing conditions, the 85th percentile operating speed should be included in addition to the posted speed limit. The 85th percentile operating speed is the highest overall speed at which a driver can travel on a given highway under favorable weather conditions, prevailing traffic conditions, and without at any time exceeding the safe speed as determined by the design speed. This can be estimated by using an analysis of average speeds or could be directly generated from probe speed data packages such as RITIS.

LOS C Volumes

In noise analysis, the LOS C volume is assumed to represent the maximum volume that can be sustained at free-flow speed resulting in the maximum noise condition. This is defined at the LOS C/D threshold as the maximum LOS C value. Because vehicle speeds typically affect noise levels more than vehicle volumes, this condition is often the most critical. In areas where peak period congestion is minimal or only occurs for a short time, allowing for continuously high speeds, the peak hour or peak truck hour may be critical. However, in areas where congestion is present for extended periods, lowering vehicle speeds, the LOS C volume may have a greater impact. It should be noted, however, that many links in a study area will not reach the LOS C level and some may exceed it.

LOS C volumes need to be determined on a link basis to establish a maximum volume threshold. If the peak hour or the peak truck hour volume exceeds the LOS C volume on a link, then the link volume is capped at the LOS C value. This way, the link volumes shown (and related vehicle percentages) will not exceed LOS C and will represent the maximum noise condition.

Capped link volumes will no longer balance across adjacent links. Links with capped volumes will need to reduce the number of vehicles such that the vehicle group (e.g. buses) percentages remain constant.

LOS C volumes need to be obtained from the latest version of the Highway Capacity manual for the respective facility type (e.g. freeway, multi-lane, two-lane highway, or urban street). Use the appropriate segment characteristics (number of lanes, widths, and other adjustment factors) to determine an initial value. This should have been done already as part of the project analysis so copies of the same software files can be used to start with. The LOS C volume is calculated using the HCM density-based methodologies, via an iterative process based on the project volumes (i.e. 2x, 1.5x, 0.75x, etc.), to identify the volume where the LOS C threshold occurs (at the top end of LOS C, adjacent to LOS D).

Roadway segments (e.g. merge section, freeway mainline) are relatively straightforward to iterate the initial LOS volume to reach the C/D threshold. Similarly, for signalized intersections, iterate until the overall intersection reaches the LOS C/D threshold. Roundabout and unsignalized intersection approach links for, the LOS C volumes will also need to be iterated using a "best approach" practice using the limiting leg (e.g. the leg with the lowest approach capacity) as it is a balancing activity between the mainline and side-street leg LOS. If mainline volumes were adjusted to LOS C/D, then the side street volumes would likely be LOS F and too high. Likewise, iterating side street volumes to LOS C/D probably will result in mainline volumes being too low. Trying to get the mainline and the side-street to LOS C/D at the same time results in a situation that would not occur unless large changes were made in the overall volume patterns which would result in inconsistences with other links not to mention with the volumes used in the rest of the project analysis. Iterate up or down based on the project volumes (i.e. 1.5x, 1.25x, 0.75x etc.) until the limiting leg reaches the LOS C/D threshold.

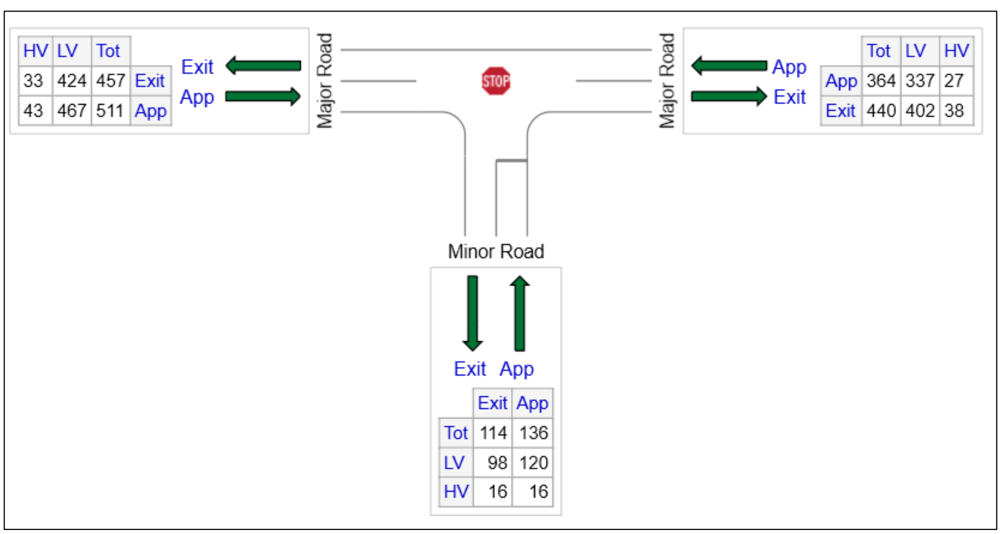
Report out all approach links at that point as LOS C volumes. Report out the departing link LOS C volumes if they end up being approach volumes for adjacent intersections. This will require that the LOS C volume from the departing link and the approach link to be averaged to create one LOS C volume per link. For documentation purposes, only the final software output with the final LOS C volumes is needed.

Use the following LOS C defaults only for links at the end of the network or for departing intersection links that are not also a calculable approach link at the next downstream intersection.

- For freeway free-flow ramp roadways and on-ramps, assume 1300 pcphpl. The analyst should consider effects of ramp metering on freeway ramp LOS C volumes, where applicable.
- For urban arterials, assume 600 pcphpl.
- For suburban arterials, assume 1000 pcphpl.
- For rural two-lane highways, assume 800 pcphpl.
- For rural multilane highways, assume 1200 pcphpl

Example 16-2 LOS C Calculations

As part of the noise analysis for a simple urban intersection upgrade project, LOS C volumes are needed for each exiting and entering leg of this two-way stop-controlled “T” intersection. Peak hour light and heavy vehicle volumes and other geometric/control details were entered into a SIDRA analysis (note that any intersection software could be used).



These inputs resulted in the below output. A review of the lane approach capacities indicates that the minor road approach is the limiting leg, so that is the controlling leg on the volume iteration to find the LOS C/D threshold. The starting LOS results show this approach to be LOS C, so initial volumes will need to be raised to have the LOS reach the C/D threshold.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	136	12.0	335	0.405	100	22.9	LOS C
Approach	136	12.0		0.405		22.9	LOS C
East: Major Road							
Lane 1	364	7.5	1679	0.217	100	2.2	LOS A
Approach	364	7.5		0.217		2.2	NA
West: Major Road							
Lane 1	511	8.5	1691	0.302	100	0.1	LOS A
Approach	511	8.5		0.302		0.1	NA
Intersection	1011	8.6		0.405		3.9	NA

The volume iteration is started by assuming a volume multiplier (1.1x since the likely needed change is small) to apply to all entering and exiting volumes. After entering the new volumes the analysis reports that the minor leg is now at LOS D, so the 10% volume increase is a bit too high.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	150	12.3	300	0.501	100	28.5	LOS D
Approach	150	12.3		0.501		28.5	LOS D

For the second iteration the volume multiplier was set at 1.05x which splits the difference between the starting volume and the first iteration. The analysis results still show LOS D, so again the volume multiplier would be cut in half to 1.025x for the third iteration.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	142	11.5	318	0.448	100	25.2	LOS D
Approach	142	11.5		0.448		25.2	LOS D

The third iteration resulted in LOS C, so the 1.025x factor is a bit low, so the volume factor was raised to be halfway at 1.037x for the fourth iteration.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	138	11.8	326	0.423	100	23.9	LOS C
Approach	138	11.8		0.423		23.9	LOS C

The fourth iteration also resulted in LOS C, so it is a bit closer, but a fifth iteration was done with the factor again splitting the difference at 1.043x.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	140	11.6	323	0.434	100	24.4	LOS C
Approach	140	11.6		0.434		24.4	LOS C

The fifth iteration also resulted in LOS C with slightly lower capacities. One last iteration was performed with a volume factor of 1.047x.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	141	11.5	321	0.440	100	24.7	LOS C
Approach	141	11.5		0.440		24.7	LOS C

The sixth and final iteration resulted in LOS C which was judged to be close enough to the threshold at 141 vph versus 142 vph from the 3rd iteration which resulted in LOS D. Typically five to seven iterations will be necessary to close in on a final value.

Lane Use and Performance							
	DEMAND FLOWS [Total veh/h	HV] %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Aver. Delay sec	Level of Service
South: Minor Road							
Lane 1	141	11.5	320	0.441	100	24.8	LOS C
Approach	141	11.5		0.441		24.8	LOS C

Once the LOS C/D threshold is determined to be reached then the approach volumes for the limiting and other legs are reported out as the LOS C maximum volumes. Departing leg volumes can also be used if they are also approach leg volumes for adjacent intersections.
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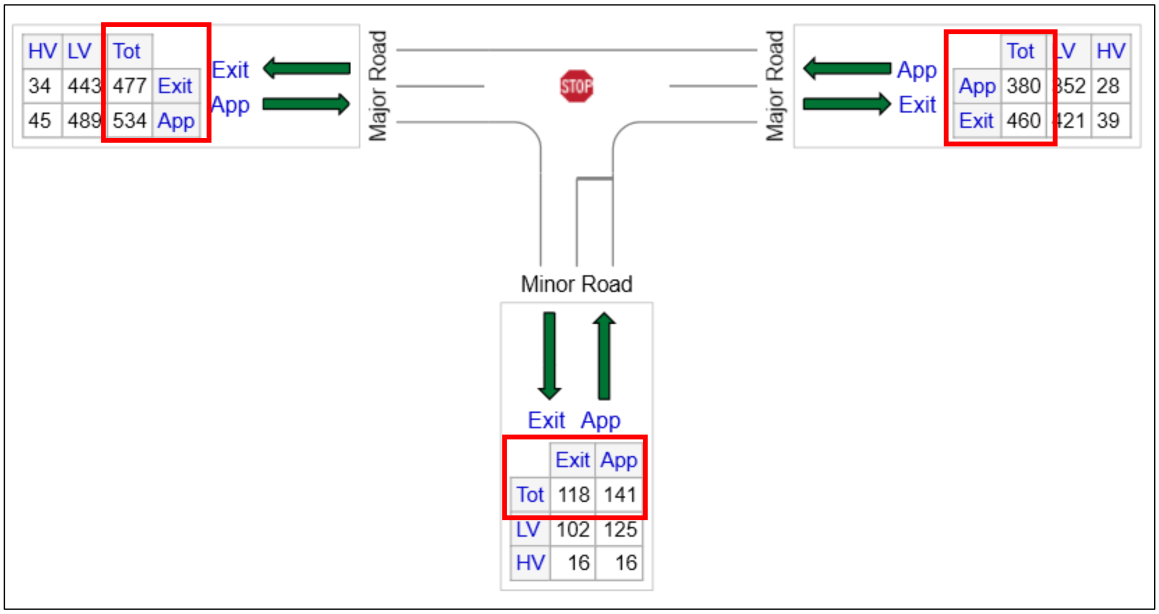


Peak Hour and Peak Truck Hour Volumes

Each link in the defined project area will need an assigned directional peak hour and peak truck hour volume. This will need to be done for the existing conditions, future no-build, and the future build (design) year scenarios.

Peak hour volumes should be based on the same counts, system peak hour, and factoring assumptions used to develop the project volumes following Chapter 5 and 6 methodologies. Any previously calculated peak hour project volumes for each of the three scenarios (existing, future no-build and future build) need to be converted from a turn movement basis to a link approach basis.

If it is known in the project scoping process that a noise and/or an air quality analysis will be eventually needed, then at least 16 or preferably 24-hour (FHWA 13 vehicle class) classification turn movement counts need to be ordered at all signalized intersections in addition to all intersections with substantial traffic volumes and/or heavy vehicle movements. These counts would also be used for the project volumes and analysis to maintain consistency with the later environmental analyses. Shorter duration counts (i.e. four hours) can still be used for peak hour volumes and be factored to daily volumes using factors from nearby long duration counts but will prove difficult for the calculation of the peak truck hour if they are not in the right period (typically morning). It is generally more efficient and less costly to have a single long duration count than multiple short duration counts.

A separate system peak hour is determined for the peak truck hour similarly as done for the peak hour (see Chapter 5) by noting when the highest amounts of trucks and buses occur (FHWA Classes 4- 13). The easiest way to do this is to add columns to a classification count export summing up the auto (FHWA Classes 1-3), medium truck (FHWA Classes 4 & 5) and heavy trucks (FHWA Classes 6-13) and the total trucks (medium + heavy). Identify the peak hour when the highest total trucks occur.

Exhibit 16-2 shows part of a 24-hour classification count with additional summary columns for the auto, medium truck, heavy truck, and total truck summaries. The total truck summary column allows for a quick identification of the truck peak hour when the highest total of medium and heavy trucks occurs. The highlighted hourly volume in the exhibit just happens to be the highest number of medium trucks in this count but that cannot be counted on to identify the truck peak hour by itself. In addition, while the identified truck peak hour in this count was from 12-1 PM, the actual truck peak hour could start on any 15-minute interval. This calculation is repeated for each count and then the resulting system peak truck hour is chosen from the count peak truck hours following the same process used in Chapter 5.

Exhibit 16-2 Peak Truck Hour Identification

	Multi Trailer Trucks (5 or less axles)	Multi Trailer Trucks (6 axles)	Multi Trailer Trucks (7 or more axles)	Auto	Med Trks	Hvy Trks		Class 4-13	
11:00	0	3	2	929	63	103		166	
11:15	0	0	0					0	
11:30	0	0	0					0	
11:45	0	0	0					0	
12:00	0	2	8	1055	83	101		184	
12:15	0	0	0					0	
12:30	0	0	0					0	
12:45	0	0	0					0	
13:00	0	1	4	1128	52	99		151	
13:15	0	0	0					0	
13:30	0	0	0					0	
13:45	0	0	0					0	
14:00	0	0	0	1110	60	102		162	

Truck peak hours typically occur in the mid-morning hours as this is when drivers are trying to minimize delays when going through an urban area or trying to time arrivals into or through a larger adjacent metropolitan area or are making deliveries within an urban area. The number of trucks and buses in the truck peak hour need to exceed the values in the peak hour. However, there likely will be links that will not exceed in the system peak truck hour versus the individual count truck peak hours because of the overall volume patterns in the study area. These exceptions are addressed in the calculation process. The peak truck hour volumes are created as part of the overall calculation process described later rather than independently/directly from the raw count values as done with the peak hour volumes. Note that the truck peak hour volumes are also “all vehicle” volumes which would be the sum of the auto, medium truck, and heavy truck columns in Exhibit 16-2 above. This should not be confused with the vehicle breakouts such as the “peak truck hour medium trucks” which would be the number of medium trucks in the truck peak hour.

Vehicle Classifications and Groups

The noise traffic data process will require percentages and related volumes for certain vehicle groups. All the 13 FHWA vehicle classes will need to be reallocated into these summary groups. This only needs to be done for the system peak hour and peak truck hours on each count to minimize the time and effort needed. Noise sources associated with transportation projects can include passenger vehicles, medium trucks, heavy trucks, and buses. Each of these vehicles produces noise, however, the source and magnitude of the noise can vary greatly depending on vehicle type. For example, while the noise from passenger vehicles occurs mainly from the tire-roadway interface and is, therefore, located at ground level, the noise from heavy trucks is produced by a combination of noise from tires, engine and exhaust resulting in a noise source that is approximately eight feet above the ground.

The 13 FHWA vehicle classes are shown below:

- ***Class 1: Motorcycles:*** All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than steering wheels. This category includes motorcycles, , mopeds, and three-wheel motorcycles. This category is not intended to include micro-mobility devices such as e-scooters and e-bikes.
- ***Class 2: Passenger Cars***: All sedans, coupes and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.
- ***Class 3: Other Two-Axle, Four-Tire Single Unit Vehicles***: All two-axle, four-tire vehicles, other than passenger cars. Included in this classification are pickups, sport utility vehicles, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carry-alls and minibuses. Other two-axle, four-tire single-unit vehicles pulling recreational or other light trailers are included in this classification.
- ***Class 4: Buses***: All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered a truck and should be appropriately classified.
- ***Class 5: Two-Axle, Six-Tire, Single-Unit Trucks***: All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.
- ***Class 6: Three-Axle Single-Unit Trucks***: All vehicles on a single frame including trucks camping and recreational vehicles, motor homes, etc., with three axles.
- ***Class 7: Four or More Axle Single-Unit Trucks***: All trucks on a single frame with four or more axles.
- ***Class 8: Four or Fewer Axle Single-Trailer Trucks***: All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.
- ***Class 9; Five-Axle Single-Trailer Trucks***: All five-axle vehicles consisting of

two units, one of which is a tractor or straight truck power unit.
- ***Class 10: Six or More Axle Single-Trailer Trucks***: All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
- ***Class 11: Five or Fewer Axle Multi-Trailer Trucks***: All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.
- ***Class 12: Six-Axle Multi-Trailer Trucks***: All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
- ***Class 13: Seven or More Axle Multi-Trailer Trucks***: All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

In reporting information on trucks the following criteria should be used:
- *Truck tractor units traveling without a trailer will be considered single-unit trucks.*
- *A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered one single-unit truck and will be defined only by the axles on the pulling unit.*
- *Vehicles are defined by the number of axles in contact with the road. Therefore, "floating" axles are counted only when in the down position.*
- *The term "trailer" includes both semi- and full trailers.*

The summary vehicle groups are as follows:

- (Optional) Motorcycles (Class 1)
- Automobiles (Class 2 & 3): Passenger cars and other two-axle four-tire vehicles
- (Optional) Buses (Class 4)
- Medium trucks (Class 5): Two-axle six-tire trucks
- Heavy Trucks (Classes 6 – 13): Three-axle and greater single-unit trucks and all combination tractor-trailer trucks

The ODOT standard noise request combines the motorcycles into the automobile category and the buses into the medium truck categories, however all the categories may still be requested if there are substantial volumes of these vehicle classes. Separate motorcycle data is rarely needed in Oregon, but specific data related to bus volumes may be appropriate where the link could be experiencing higher than average bus traffic due to influence by a nearby school, bus barn, or tourist attraction. Noise requests from consultants may have the combined or all five categories listed. Generally, it is preferred to have a smaller number of classes to minimize the overall work, which can be very substantial for larger networks considering that the number of motorcycles and buses on a link basis tends to be small and which has limited impact on the results. Check with the project noise staff on whether all five or just the three main groups are needed before starting.

Other Information

For each approach link at a signalized intersection the percentage of vehicles expected to stop (arriving on the red phase) needs to be estimated. The proportion of vehicles arriving on red for uncoordinated/isolated signals is the inverse of the green time to cycle length (g/c ratio) calculated as:

$P_{red} = [1 - [(Total\ Split - yellow\ time - all\text{-}red\ time)/Cycle\ length)] \times 100$

If signals are coordinated or closely spaced then the proportion is based on the directional bandwidth available for the coordinated/progressed segment, which will extend across multiple links. Review the time-space diagram from (Synchro, SIDRA, etc.) and determine the arterial bandwidth for the desired direction. The total split, yellow and all-red times come from the upstream signal rather than the subject location as this overall calculation determines how much of the vehicle stream that leaves the upstream signal will stop at the subject location. Use the subject location if it is the first signal in the segment. In this case, the proportion of vehicles arriving on red is calculated for each approach link:

$P_{red} = [1 - [(Directional\ bandwidth / (Total\ split_{upstream} - yellow\ time_{upstream} - all\text{-}red\ time_{upstream})] \times 100$

Example 16-2: Proportion of Vehicles Expected to Stop Calculation

A highway signalized intersection has actuated (isolated) operation in the east-west direction and coordinated operation north-south. The cycle length is 100 seconds.

From the Synchro program file for the appropriate alternative and year containing the intersection, the timing window shows the needed total split, yellow and all-red times. The subject intersection times are used for the actuated isolated eastbound and westbound directions and the northbound coordinated time since it is first in this direction. The upstream intersection times are used for the southbound direction.

Subject Intersection

TIMING SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Total Split (s)	10.0	55.1	55.1	9.4	54.5	54.5	35.5	35.5	—	35.5	35.5	—
Yellow Time (s)	4.7	4.7	4.7	4.7	4.7	4.7	4.0	4.0	—	3.5	3.5	—
All-Red Time (s)	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	—	0.5	0.5	—

Upstream (Southbound) Intersection

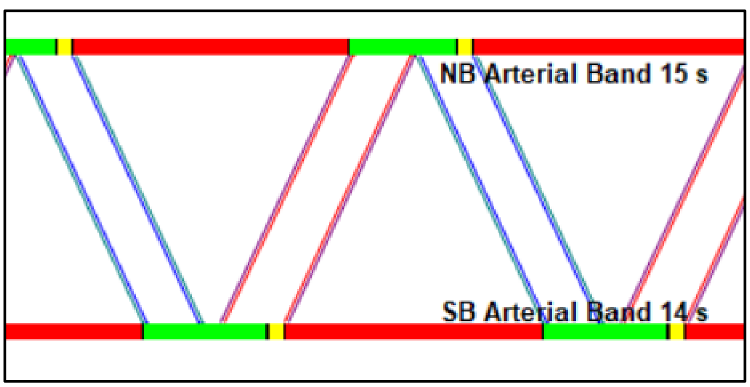
TIMING SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Total Split (s)	69.0	69.0	—	69.0	69.0	—	31.0	31.0	—	31.0	31.0	—
Yellow Time (s)	4.0	4.0	—	4.0	4.0	—	3.5	3.5	—	3.5	3.5	—
All-Red Time (s)	0.5	0.5	—	0.5	0.5	—	0.5	0.5	—	0.5	0.5	—

$P_{red} = [1 - [(\text{Total Split} - \text{yellow time} - \text{all-red time})/\text{Cycle length})] \times 100$

The total split, yellow and all-red times for the eastbound and westbound directions are entered into the equation above for isolated approaches:

$P_{red\text{-}EB} = [1 - [(55.1 - 4.7 - 0.7) / 100] \times 100 =$ **50.3%**
$P_{red\text{-}WB} = [1 - [(54.5 - 4.7 - 0.7) / 100] \times 100 =$ **50.9%**

For the northbound and southbound approaches, the coordinated equation is used:
$P_{red} = [1 - [(\text{Directional bandwidth} / (\text{Total split}_{upstream} - \text{yellow time}_{upstream} - \text{all-red time}_{upstream})] \times 100$
The time-space diagram from Synchro shows a 14 second bandwidth southbound and 15 seconds northbound. In this case there are only two signalized intersections north-south, so the link bandwidth is the same as the arterial bandwidth (normally this is not the case).



For the northbound direction, since the subject intersection is first, the timing from it is used in the equation:

$P_{red\text{-}NB} = [1 - [(15 / (35.5 - 4.0 - 0.5)] \times 100 =$ **51.6%**

The southbound direction uses the upstream intersection timing since it is first:

$P_{red\text{-}SB} = [1 - [(14 / (31.0 - 3.5 - 0.5)] \times 100 =$ **48.1%**

The overall zoning information is needed for the study area. This is not correlated with the roadway links. This is just a map showing existing zoning. A map showing future comprehensive plan zoning is needed if different from the existing.

Typically just for screening-level noise studies (check with the noise analyst to confirm if this will apply), a turning movement diagram is needed for each intersection in each of the three-year scenarios (existing year, future no-build, and future build alternative). This can be directly from an intersection analysis program, however if there are a larger number of intersections, a consolidated diagram showing multiple locations should be used to lessen the number of pages.

16.3.2 Calculations

The calculations necessary in the noise traffic data production are to generate the proportions of each of the summary vehicle groupings. These proportions will be used in the overall process to generate initial unbalanced volumes for each group, which are then balanced, and the proportions updated to create the final results. This will need to be done for the peak hour and the peak truck hour for all links.
For the peak hour, each of the vehicle groups are calculated by dividing the subject vehicle group volume by the total number of vehicles in the peak hour except for automobiles, which are simply subtracted:

$$Peak\ Hour\ Motorcycles\ Factor = \frac{Motorcycles\ in\ the\ peak\ hour}{Total\ peak\ hour\ vehicles}$$

$$Peak\ Hour\ Buses\ Factor = \frac{Buses\ in\ the\ peak\ hour}{Total\ peak\ hour\ vehicles}$$

$$Peak\ Hour\ Medium\ Trucks\ Factor = \frac{Medium\ trucks\ in\ the\ peak\ hour}{Total\ peak\ hour\ vehicles}$$

$$Peak\ Hour\ Heavy\ Trucks\ Factor = \frac{Heavy\ trucks\ in\ the\ peak\ hour}{Total\ peak\ hour\ vehicles}$$

$$Peak\ Hour\ Automobiles\ Factor = 1 - \sum Peak\ hour\ factors\ for\ all\ other\ groups$$

The peak truck hour is calculated from the relationship of the truck peak hour to the peak hour. This factor translates the peak hour volumes into peak truck hour volumes. Peak truck hour volumes are less than the peak hour volumes by definition, so the maximum value of the peak truck hour factor is 0.999. If any links have factors 1.000 or greater, they need to be capped at a maximum 0.999. Once the peak truck hour factor is created, then all the separate vehicle factors are based on it, which is different from the peak hour factors:

$$Peak\ Truck\ Hour\ Factor, \max 0.999 = \frac{Total\ truck\ peak\ hour\ vehicles}{Total\ peak\ hour\ vehicles}$$

$$Peak\ Truck\ Hour\ Motorcycles\ Factor = \frac{Motorcycles\ in\ the\ peak\ truck\ hour}{Total\ truck\ peak\ hour\ vehicles}$$

$$Peak\ Truck\ Hour\ Buses\ Factor = \frac{Buses\ in\ the\ peak\ truck\ hour}{Total\ truck\ peak\ hour\ vehicles}$$

$$Peak\ Truck\ Hour\ Medium\ Trucks\ Factor = \frac{Medium\ trucks\ in\ the\ peak\ truck\ hour}{Total\ peak\ truck\ hour\ vehicles}$$

$$Peak\ Truck\ Hour\ Heavy\ Trucks\ Factor = \frac{Heavy\ trucks\ in\ the\ peak\ truck\ hour}{Total\ truck\ peak\ hour\ vehicles}$$

$$Peak\ Truck\ Hour\ Automobiles\ Factor = 1 - \sum Peak\ truck\ hour\ factors\ for\ all\ other\ groups$$

16.3.3 Process – Existing Conditions

The following procedure is suggested. A spreadsheet should be created with rows for each link and columns for each of the link attributes for the existing conditions (A sample spreadsheet workbook with all of the sub-tables is available in Appendix A):

- Unique link identifier
- Link name
- Link length (mi.)
- Link type
- Posted speed (mph)
- 85th percentile speed (mph); (optional)
- LOS C volume
- Peak hour volume
- Peak truck hour volume
- Automobiles peak hour %
- Medium truck peak hour %
- Heavy truck peak hour %
- Motorcycle peak hour % (optional)
- Bus peak hour % (optional)
- Peak truck hour factor
- Automobile peak truck hour %

- Medium truck peak truck hour %
- Heavy truck peak truck hour %
- Motorcycle peak truck hour % (optional)
- Bus peak truck hour % (optional)

Separate spreadsheets can be used for each of the three volume scenarios as using individual tabs and a single file will result in more than 50 or more which can be hard to follow and review if a good color scheme and formatting is not used. A tab containing the link diagram should also be added but it can be a separate document if desired. The link identifier through the 85th percentile speed columns are the same for all scenarios.

The overall process is as follows:

1. Add the unique link numbering scheme, link name/description, length, type and posted/85th speeds.

2. Calculate the LOS C for each link based on its facility type

3. Convert the peak hour existing volumes to a directional link basis
4. On a separate tab, create a linked table with the headers (See Exhibit 16-3):
   - Link identifier
   - Link name
   - Peak hour volume
   - Initial medium truck peak hour volume
   - Initial medium truck peak hour factor
   - Final medium truck peak hour volume
   - Final medium truck peak hour factor

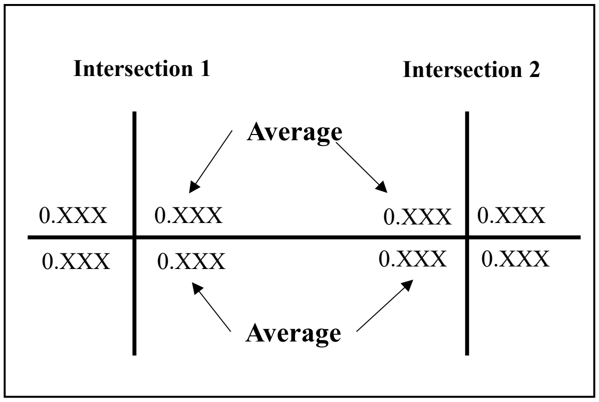
Exhibit 16-3 Example Medium Truck Factor & Volume Calculation Table

Link #	Link Name	Final 2017 (vph)	Initial Pk Hr Med Trk (vph)	Initial Pk Hr Med Trk Factor	Final Pk Hr Med Trk (vph)	Final Pk Hr Med Trk Factor
101	Beg Proj - 004CQ (SB)	1175	46	0.039	46	0.039
102	004CQ - 004CT (SB)	760	21	0.027	21	0.028
103	004CT - Rdwy 2 meets (SB)	820	26	0.031	26	0.032
104	Rdwy2 meets - N Uturn (SB)	820	26	0.031	26	0.032
105	N Uturn - Vandevert Rd (SB)	820	26	0.031	26	0.032
106	Vandevert Rd - Rdwy2 meets (SB)	695	20	0.028	20	0.029
107	Rdwy2 meets - S Uturn (SB)	695	20	0.028	20	0.029
108	S Uturn - 4 lanes (SB)	695	20	0.028	20	0.029
109	4 lanes - Sugarpine Butte (SB)	695	20	0.028	20	0.029
110	Sugarpine Butte - 2 lanes (SB)	695	20	0.028	20	0.029
111	2 lanes - USFS Boundary (SB)	695	20	0.028	20	0.029
112	USFS Boundary to end of project (SB)	695	20	0.028	20	0.029
201	Beg Proj - 004CV (NB)	895	62	0.069	62	0.069
202	004CV - 004CU (NB)	560	26	0.047	26	0.046
203	004CT - Rdwy 2 meets (NB)	610	28	0.046	28	0.046
204	Rdwy2 meets - N Uturn (NB)	610	28	0.046	28	0.046
205	N Uturn - Vandevert Rd (NB)	610	28	0.046	28	0.046
206	Vandevert Rd - Rdwy2 meets (NB)	585	27	0.046	27	0.046
207	Rdwy2 meets - S Uturn (NB)	585	27	0.046	27	0.046
208	S Uturn - 4 lanes (NB)	585	27	0.046	27	0.046
209	4 lanes - Sugarpine Butte (NB)	585	27	0.046	27	0.046
210	Sugarpine Butte - 2 lanes (NB)	585	27	0.046	27	0.046
211	2 lanes - USFS Boundary (NB)	585	27	0.046	27	0.046
212	USFS Boundary to end of project (NB)	585	27	0.046	27	0.046

5. The initial medium truck peak hour factor is computed by using the formula shown in Section 16.3.2 by dividing the total number of medium trucks in the peak hour by the total number of vehicles in the peak hour for a particular link from a single count. Values for factors should be to three decimal places. Repeat for all directional entering and leaving links at each count (i.e. intersection) location.

6. Two factor values will be generated on every link from Step 5, one leaving a previous intersection and one entering the next intersection unless it is an external link where there will be only one value. See Exhibit 16-4. Average these together so there is just one value per link and place in the medium truck factor table.

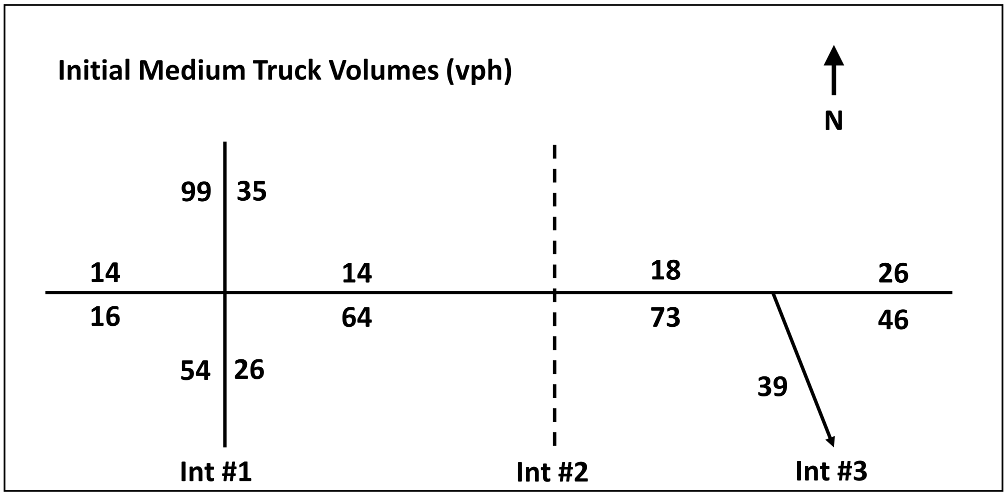
Exhibit 16-4 Averaging Entering & Leaving Factors



7. Multiply the initial medium truck peak hour factor by the peak hour volume to generate the initial medium truck peak hour volume. For example, from Exhibit 16-3, Link #101; the initial medium truck factor is 0.039 and the peak hour volume is 1175 vph. Multiplying these together gives an initial medium truck volume of 46 vph.

8. The initial medium truck peak hour volumes need to be balanced across all intersections. Balancing can be done via spreadsheet or by paper, but it is somewhat different than the balancing performed for project volumes as it is on a link basis rather than by turn movement. Balancing is done by summing the inbound and outbound volume and computing the difference. The difference in the in or out volumes is then spread around the intersection proportionately. It is generally best to split the difference between the ins and the outs to minimize the change at adjacent locations. Intersections with no minor legs (sink/source) included in the noise analysis scope only needs to reflect the drop or increase across the sink or source. This drop or increase is best reflected when it can be based on a count done at the location. These are also locations that can allow adjusting for differences where just an intersection balance cannot completely adjust for.

Example 16-3: Intersection Balancing



Medium truck peak hour volumes need to be balanced along a local east-west arterial shown above in the figure. This arterial intersects with another north-south arterial (Intersection #1), a local street (Intersection #2), and a ramp terminal (Intersection #3).

The intersecting roadways for Intersections #1 and #3 are also included in the noise analysis, but Intersection #2's are not. Intersection #2 had a count performed at this location, so this will be treated as a sink/source instead.

The first step will be to assess the differences between the in's and out's at Intersection #1:

Total In = 99 + 16 + 26 + 14 = 155 vph
Total Out = 35 + 14 + 54 + 64 = 167 vph
Difference = 167 – 155 = 12; so need to raise in's by 6 and lower out's by 6

The second step will be to determine the proportions of each in and out link as fractions of the total in and out volume checking to make sure that the proportions sum up to 1.000:

EB_{in} = 16 / 155 = 0.103
WB_{in} = 14 / 155 = 0.090
NB_{in} = 26 / 155 = 0.168
SB_{in} = 99 /155 = 0.639

EB_{out} = 64 / 167 = 0.383
WB_{out} = 14 / 167 = 0.084
NB_{out} = 35 / 167 = 0.210
SB_{out} = 54 / 167 = 0.323

The third step will be to calculate the adjustments for the in's and out's, rounding the results to make sure the resulting total adds up to the total change for the in and out:

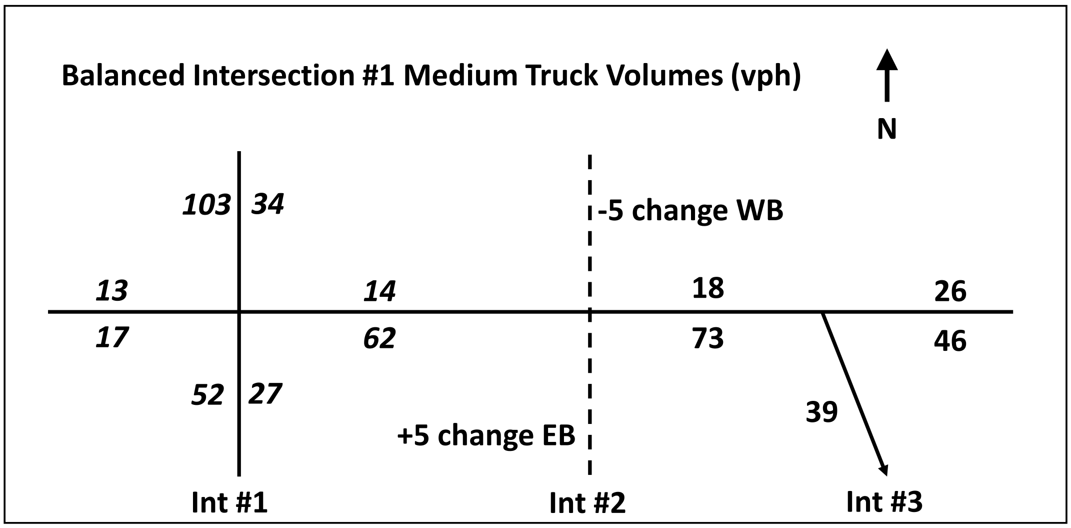
EB_{in} = 0.103 x 6 = 0.618 = 1
WB_{in} = 0.090 x 6 = 0.540 = 0

EB_{out} = 0.383 x 6 = 2.298 = 2
WB_{out} = 0.084 x 6 = 0.504 = 1

$NB_{in} = 0.168 \times 6 = 1.008 = 1$ $NB_{out} = 0.210 \times 6 = 1.260 = 1$
$SB_{in} = 0.639 \times 6 = 3.834 = 4$ $SB_{out} = 0.323 \times 6 = 1.938 = 2$

The last step will be to calculate the balanced Intersection #1 volumes for each in and out link which are shown as the italicized numbers in the figure below:

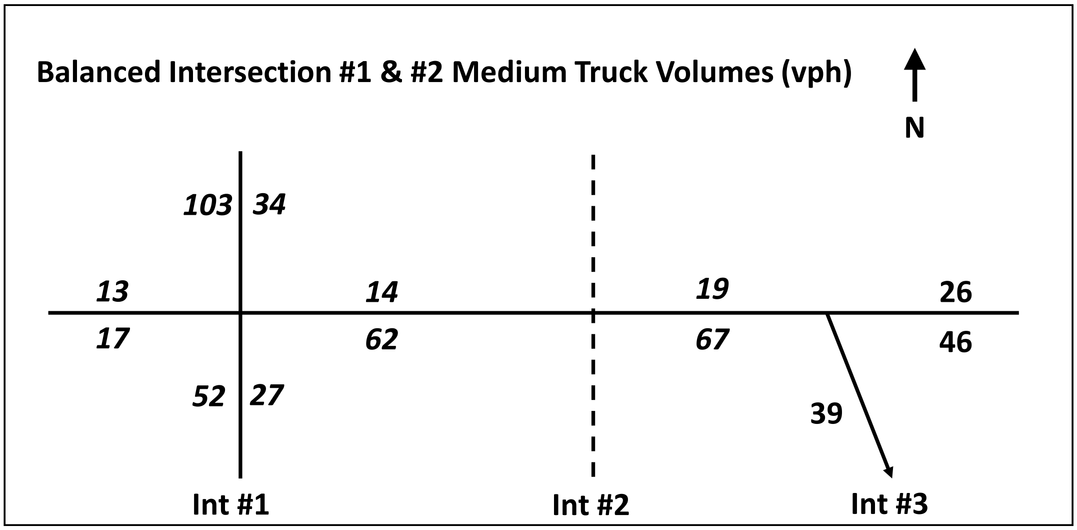
$EB_{in} = 16 + 1 = 17$ vph $EB_{out} = 64 – 2 = 62$ vph
$WB_{in} = 14 + 0 = 14$ vph $WB_{out} = 14 – 1 = 13$ vph
$NB_{in} = 26 + 1 = 27$ vph $NB_{out} = 35 – 1 = 34$ vph
$SB_{in} = 99 + 4 = 103$ vph $SB_{out} = 54 – 2 = 52$ vph



Since Intersection #1 is now balanced, it should be held constant when the adjustments for the Intersection #2 sink/source are done. The balancing at Intersection #1 increased the difference eastbound (i.e. from 9 to 11 vph) but did not affect the westbound difference of 4 vph. It is known from the count at Intersection #2, that the overall change across the intersection adds five vehicles eastbound and subtracts five vehicles westbound. In this case, add the 5 vph difference both to the EB_{out} and the WB_{in} of Intersection #1 to account for the change across Intersection #2:

Balanced $EB_{out} = 62 + 5 = 67$ vph Balanced $WB_{in} = 14 + 5 = 19$ vph

The resulting Intersection #2 italicized values are shown in the figure below.



The balancing for Intersection #3 is done the same as for Intersection #1, except that the EB_{in} and WB_{out} volumes are held constant.

Total In = 67 + 26 = 93 vph
Total Out = 46 + 19 + 39 = 104 vph
Difference = 104 – 93 = 11; so need to raise in's by 5 and lower out's by 6

Since there are only two inbound legs and one is held constant, all the inbound change is applied to the remaining inbound (WBin), so only outbound proportions are needed. Also, since the WB_{out} is held, its value needs to be subtracted from the total out to determine the split between the remaining outbound links.

Out Proportions:

EB_{out} = 46 / 85 = 0.541
SB_{out} = 39 / 85 = 0.459

In/Out Adjustments:

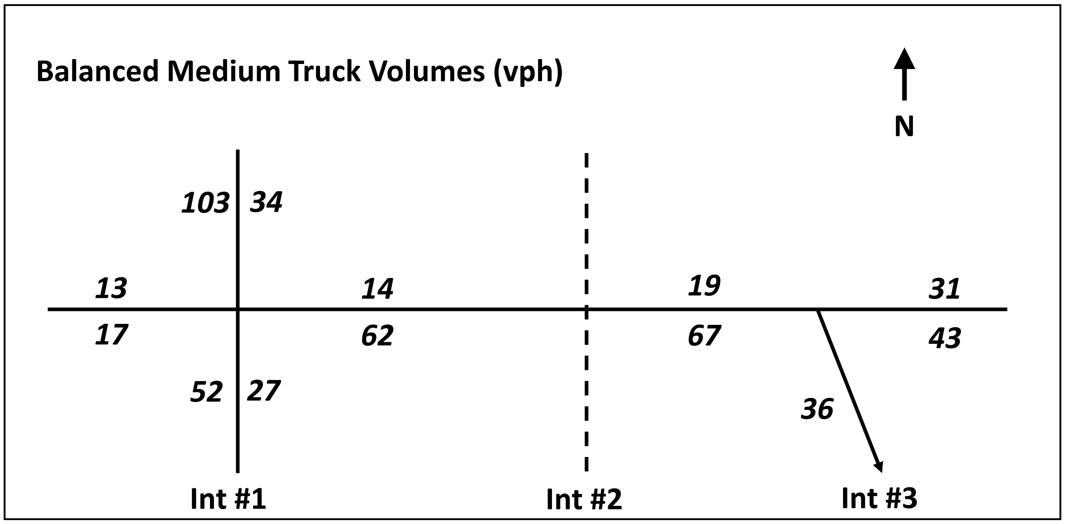
EB_{in} = No change
WB_{in} = 5

EB_{out} = 0.541 x 6 = 3.246 = 3
WB_{out} = No change
SB_{out} = 0.459 x 6 = 2.754 = 3

Resulting balanced volumes shown on figure below in italicized text:

EB_{in} = 67 vph (no change)
WB_{in} = 26 + 5 = 31 vph

EB_{out} = 46 – 3 = 43 vph
WB_{out} = 19 vph (no change)
SB_{out} = 39 – 3 = 36 vph



9. Once the medium peak truck volumes are balanced, enter the values as the final medium truck peak hour volume on the linked vehicle group spreadsheet. These are shown in the second column from the right in Exhibit 16-2 above.

10. Divide the final medium truck peak hour volume by the peak hour volume to obtain the final medium truck peak hour factor. This value should be linked back to the main spreadsheet tab. Following Link 101 in Exhibit 16-2; this would be dividing the final link medium truck volume of 46 vph by the link peak hour total traffic of 1175 vph to come up with the final medium truck peak hour truck factor of 0.039. In this case, the overall volume and factors did not change, as these links were held constant in the balancing process.

11. Repeat Steps 4 through 10 for the other peak hour volume groups: heavy trucks, motorcycles (optional), and buses (optional). Subtract the sum of the volume groups from 100% to obtain the automobile vehicle group percentages.

12. Like Step 4, create a linked table with the headers:
    - Link identifier
    - Link name
    - Peak hour volume
    - Initial peak truck hour volume
    - Initial peak truck hour factor
    - Final peak truck hour volume
    - Final peak truck hour factor

Exhibit 16-5 Example Peak Truck Hour Calculation Table

Link #	Link Name	Final 2011 30HV (vph)	Initial 2011 Pk Trk Hr (vph)	Initial Pk Trk Hr Factor	Final 2011 Pk Trk Hr (vph)	Final Pk Trk Hr Factor
1	OB Riley SB - N of OB Redmd	70	70	0.999	70	0.999
2	OB Riley SB - N of Cooley	80	80	0.999	80	0.999
3	OB Riley SB - S of Cooley	90	90	0.999	89	0.989
4	OB Riley SB - N of Empire	145	144	0.990	144	0.993
5	OB Riley SB - S of Empire	170	166	0.979	164	0.965
6	OB Riley NB - S of Empire	170	136	0.799	136	0.800
7	OB Riley NB - N of Empire	165	113	0.682	112	0.679
8	OB Riley NB - S of Cooley	65	61	0.938	63	0.969

13. From each of the counts, obtain the total link volume for the system peak truck hour chosen and enter the initial peak truck hour volume column (4th column from the left in Exhibit 16-5 above). Create a link to the previously calculated peak hour volumes and add those as shown in the 3rd column from left.

14. Create the initial peak hour factor by dividing the initial peak truck hour volumes from Step 13 by the peak hour volumes. If any values equal or exceed 1.000 then cap that link volume factor at 0.999 and readjust the initial peak truck hour volume to match. Note that in Exhibit 16-3 above this calculation would result in an initial factor of 1.000 after dividing the initial peak truck hour volume by the peak hour volume for Links #1 through #3. In this case the peak truck hour volume was the same as the peak hour volume. Links that reflect the actual peak truck hour will likely have volumes that exceed the peak hour volume which will result in overriding the calculation and adjusting volumes. The factor was adjusted from 1.000 to 0.999 but the volumes were small enough that the initial peak truck hour volume did not change.

15. Balance the peak truck hour volumes across the network in a similar fashion to Step 8.

16. Calculate the final peak truck hour factor to check that no values exceed 0.999. Modify the balanced volumes as needed until all factors are 0.999 or less. Note that in Exhibit 16-3 above, Link #1 and #2 needed the final peak truck hour factor calculation overridden back to 0.999, but that Link #3 had a slight balancing change which dropped the final factor to 0.989 which does not require adjusting.

17. Similar to Step 4 and Exhibit 16-2, create a linked table with the headers:
    - Link identifier
    - Link name
    - Peak truck hour volume
    - Initial medium truck peak truck hour factor

- Initial medium truck peak truck hour volume
- Final medium truck peak truck hour volume
- Final medium truck peak truck hour factor

This next set of calculations from this step through Step 20 repeats the medium and heavy truck factors (and any optional classifications) and volumes but this time for the truck peak hour.

18. Like what was done in Step 5, compute the initial medium truck peak truck hour factor by dividing the number of medium trucks in the truck peak hour by the peak truck hour volume computed in Step 16.

19. Repeat Steps 6 through 10 but for the medium trucks in the peak truck hour.

20. Repeat Steps 4 through 10 for the other peak truck hour volume groups: heavy trucks, motorcycles (optional), and buses (optional). Subtract the sum of the volume groups from 100% to obtain the automobile vehicle group percentages.

21. Check the final values for any errors by reviewing the number of buses (if used) and medium and heavy trucks in the peak truck hour to see if the values exceed the values in the peak hour. If not, the factors and volumes will need to be adjusted. Many times this may be caused by rounding errors. Typically, this will only be a few vehicle difference. With linked spreadsheets these changes are easily done and should reflect the final corrected values on the main tab.

22. Once all the vehicle group percentages are complete for both the peak hour and peak truck hour, compare the peak hour and the peak truck hour volumes with the LOS C volumes. Any volumes that exceed the LOS C volumes need to be capped at the LOS C volume. This means that any volume (that represents near, at, or over capacity conditions will likely require capping. Note that this capping process will result in volumes that will no longer balance with adjacent links, which is acceptable since the link network was completely balanced before this step.

The highlighted peak hour volumes shown in Exhibit 16-6 below are all higher than the corresponding LOS C volumes. These would all have to be reduced to be equal to the LOS C volumes as these represent the maximum volume that can be accommodated at LOS C. For example, for Link #27, the 2011 30th highest hour volume of 1010 vph would need to be reduced to 1000 vph for the existing conditions and the 2036 DHV of 1560 vph would need also need to be reduced to 1000 vph for the upcoming similar steps for the future no-build.

Exhibit 16-6 Volume Capping

Link #	Link Name	2011 LOS C Volume (vph)	2016 LOS C Volume (vph)	2036 LOS C Volume (vph)	2011 30HV (vph)	2016 DHV (vph)	2036 DHV (vph)
25	3rd St (US20) NB - N of Empire	1200	1200	1200	535	590	855
26	US20 NB - One-way Conn	1000	1000	1000	540	595	870
27	US20 NB - One-way Conn	1000	1000	1000	1010	1115	1560
28	US20 NB - S of Robal	1043	1209	1249	1075	1190	1655
29	US20 NB - S of Cooley	1600	1600	830	935	1045	1475
30	US20 NB - S of Mountainview	1600	1600	1600	1035	1165	1625
31	US20 NB - S of OB Red	1600	1600	1600	1015	1145	1605
32	US20 NB - N of OB Red	1600	1600	1600	820	905	1195

23. Any capped peak hour or peak truck hour volumes need to have the vehicle group percentages modified to reflect the reduced volumes. Reduce the individual volumes and factors so that the total volume of the vehicle sub-groups equals the reduced total peak hour or peak truck hour volume and that the percentages still add up to 100%.

The highlighted columns in Exhibit 16-7 show the 2036 DHV that needs to be capped based on the LOS C volume column to the left and the affected medium and heavy truck peak hour volumes. The auto volumes are just the total link DHV minus the sum of the heavy and medium trucks. Exhibit 16-8 shows the result of the capped DHV and its effects on the medium and heavy peak hour truck volumes. Note that the sum of the auto + medium truck + heavy truck equals the capped DHV.

Exhibit 16-7 Volume Adjustments Before LOS C Capping

Link #	Link Name	2036 LOS C Volume (vph)	2036 DHV (vph)	Final Pk Hr Med Trk Factor	2036 Final Pk Hr Med Trk Volume (vph)	Final Pk Hr Hvy Trk Factor	2036 Final Pk Hr Hvy Trk Volume (vph)	2036 Final Pk Hr Auto Volume (vph)
27	US20 NB - One-way Conn	1000	1560	0.055	86	0.034	53	1421
28	US20 NB - S of Robal	1249	1655	0.056	92	0.033	55	1507
29	US20 NB - S of Cooley	830	1475	0.056	82	0.034	50	1342
30	US20 NB - S of Mountainview	1600	1625	0.054	88	0.050	82	1455
31	US20 NB - S of OB Red	1600	1605	0.052	84	0.054	87	1434
32	US20 NB - N of OB Red	1600	1195	0.049	58	0.068	82	1055
35	US97 SB - N of Bowery	3022	1705	0.048	83	0.054	92	1530
36	US97 SB - S of Bowery	3022	1715	0.048	83	0.054	92	1540

Exhibit 16-8 Volume Adjustments After LOS C Capping

Link #	Link Name	2036 LOS C Volume (vph)	Capped 2036 DHV (vph)	Final Pk Hr Med Trk Factor	2036 Final Pk Hr Med Trk Volume (vph)	Final Pk Hr Hvy Trk Factor	2036 Final Pk Hr Hvy Trk Volume (vph)	2036 Final Pk Hr Auto Volume (vph)
27	US20 NB - One-way Conn	1000	1000	0.055	55	0.034	34	911
28	US20 NB - S of Robal	1250	1250	0.056	70	0.033	42	1138
29	US20 NB - S of Cooley	830	830	0.056	46	0.034	28	755
30	US20 NB - S of Mountainview	1600	1600	0.054	87	0.050	80	1433
31	US20 NB - S of OB Red	1600	1600	0.052	84	0.054	87	1430
32	US20 NB - N of OB Red	1600	1195	0.049	58	0.068	82	1055
35	US97 SB - N of Bowery	3022	1705	0.048	83	0.054	92	1530
36	US97 SB - S of Bowery	3022	1715	0.048	83	0.054	92	1540

16.3.4 Process – Future No-build

The process to complete the noise traffic data for the future no-build is done in a similar manner to the existing conditions but relies on the data relationships within the existing conditions rather than going back to the actual raw counts. This is why it is important to completely finish and check the existing conditions before starting on the future no-build.

1. Use the same spreadsheet layout as the existing conditions, either in a separate workbook or set of separate tabs.

2. Link ID's, length, type and speeds are the same as the existing conditions

3. A new set of LOS C volumes is needed using the future no-build volumes.

4. Convert the future no-build volumes to a directional link basis.

5. Create the same linked tables for each of the vehicle groups for the peak hour and peak truck hour conditions except automobiles.

6. The initial factors for the peak hour vehicle groups start with the final factors from the existing conditions. These are used to develop the initial volumes for the future no-build which are then balanced by comparing the ins and outs at each intersection and used to modify the factors to reflect the future conditions. Sink/source locations should be consistent with the drop or increase of the existing conditions with the appropriate growth to the future.

7. The initial peak truck hour volumes are created by multiplying the directional link future no-build volumes by the final peak truck hour volume factor from the existing conditions. These volumes are then balanced across the network consistent with how it was done in earlier steps. Once balanced, create an updated peak truck hour factor by dividing the final peak truck hour volumes by the future

no-build peak hour volumes to make sure that no values exceed 0.999. If so, then readjust the factor and rebalance volumes until the 0.999 criteria is satisfied.

8. Create all the peak truck hour volumes and factors by using the existing year final factors as the initials as done in Step 6.

9. Check the bus, medium truck, and heavy truck peak truck hour volumes to see if they exceed the values in the peak hour. If not, then adjust factors and volumes until they do. Also, review all the volumes to make sure that the future no-build volumes exceed (or at least equal for no growth areas) the existing condition volumes.

10. Compare the future no-build peak hours and peak truck hour volumes with the future no-build LOS C volumes and cap off any that exceed. Any capped values need to have the vehicle group percentages/volumes adjusted to match the lower values.

16.3.5 Process – Future Build

The future build data is based off a pivot from the future no-build data. If the build alignment is the same (same link network) with differing number of lanes and/or traffic control, then the build data is done similar to the future no-build. Differences will be mainly in the LOS C volumes, so creation of the future build data will be very quick as the volumes and factors will be the same other than different (likely less) instances of where volumes are capped.

If the build design year volume is different from the no-build because of latent demand issues stemming from pent-up congestion, then the hourly volumes will change, and the process will be same as doing the future no-build. In this case, use the final factors from the no-build future to create the initial future build factors and follow the future no-build process.

The challenge with the future build data is when the build alignment or network layout is different from the no-build alignment as the relationships between links is muddied. The peak hour volumes would have already been re-distributed onto the build network for the project analysis. The analyst will need to figure out separately the routing of the vehicle groups (i.e. heavy trucks) if they do not follow the same patterns as the peak hour.

The process will be generally the same as for the no-build future starting with the no-build volumes factors to create initial volumes to be balanced. The balancing may be more substantial with larger changes in the factors than what was done with the future no-build. LOS C volumes will need to be re-done for the build volumes. The checks such as the 0.999 peak truck hour factor and “Do the peak hour trucks exceed the peak hour trucks” are very important when checking the build conditions.

16.3.6 Final Product Submittal

When all the data for the applicable analysis scenarios has been entered for each link, all errors have been fixed, the data is ready to be submitted to the contractor noise staff and the Environmental Section. Copies of the work should always be submitted to the ODOT noise staff in the Environmental Section for their records as they may be directly reviewing the noise outputs or at least the recommendations from the noise analysis. The entire noise workbook can be sent for documentation or just a copy of the values in the first (front) tab. Exhibit 16-9 shows part of the final link data table (this table is 27 columns wide). Make sure that the corresponding link diagrams are also included on a tab or in a separate document.

Exhibit 16-9: (Partial Table) Example Link Data

Link #	Link Name	BMP	EMP	Posted Speed (mph)	Link Length (mi)	2017 DHV (vph)	No Build 2041 DHV (vph)	Build V3 2041 DHV (vph)	2017 NoBuild Peak Hr Auto (vph)	2017 NoBuild Peak Hr Med (vph)	2017 NoBuild Peak Hr Hvy (vph)	2017 NoBuild Peak Truck Hr Auto (vph)
101	Beg Proj - 004CQ (SB)	152.57	152.82	65	0.25	1175	1850	1850	1090	46	39	469
102	004CQ - 004CT (SB)	152.82	153.40	65	0.58	760	1080	1080	706	21	33	467
103	004CT - Rdwy 2 meets (SB)	153.40	153.67	65	0.27	820	1165	1165	760	26	34	506
104	Rdwy2 meets - N Uturn (SB)	153.67	154.75	65	1.08	820	1165	1165	760	26	34	506
105	N Uturn - Vandevert Rd (SB)	154.75	155.50	65	0.75	820	1165	1205	760	26	34	508
106	Vandevert Rd - Rdwy2 meets (SB)	155.50	155.89	65	0.39	695	960	1040	640	20	35	446
107	Rdwy2 meets - S Uturn (SB)	155.89	156.17	65	0.28	695	960	1040	640	20	35	446
108	S Uturn - 4 lanes (SB)	156.17	157.73	65	1.56	695	960	960	640	20	35	446
109	4 lanes - Sugarpine Butte (SB)	157.73	158.57	65	0.84	695	960	960	640	20	35	446
110	Sugarpine Butte - 2 lanes (SB)	158.57	158.78	65	0.21	695	960	960	640	20	35	446
111	2 lanes - USFS Boundary (SB)	158.78	159.11	65	0.33	695	960	960	640	20	35	446
112	USFS Boundary to end of project (SB)	159.11	159.61	65	0.50	695	960	960	640	20	35	446
201	Beg Proj - 004CV (NB)	152.57	152.82	65	0.25	895	1390	1390	783	62	50	819
202	004CV - 004CU (NB)	152.82	153.33	65	0.51	560	760	760	489	26	45	525
203	004CT - Rdwy 2 meets (NB)	153.33	153.67	65	0.34	610	840	840	537	28	45	549
204	Rdwy2 meets - N Uturn (NB)	153.67	154.75	65	1.08	610	840	840	537	28	45	549
205	N Uturn - Vandevert Rd (NB)	154.75	155.50	65	0.75	610	840	880	537	28	45	549
206	Vandevert Rd - Rdwy2 meets (NB)	155.50	155.89	65	0.39	585	800	880	514	27	44	486
207	Rdwy2 meets - S Uturn (NB)	155.89	156.17	65	0.28	585	800	880	514	27	44	486
208	S Uturn - 4 lanes (NB)	156.17	157.73	65	1.56	585	800	800	514	27	44	486
209	4 lanes - Sugarpine Butte (NB)	157.73	158.57	65	0.84	585	800	800	514	27	44	486
210	Sugarpine Butte - 2 lanes (NB)	158.57	158.78	65	0.21	585	800	800	514	27	44	486
211	2 lanes - USFS Boundary (NB)	158.78	159.11	65	0.33	585	800	800	514	27	44	486
212	USFS Boundary to end of project (NB)	159.11	159.61	65	0.50	585	800	800	514	27	44	486

It generally is more efficient for project flow if the traffic data scenarios are sent off as they are completed so the noise staff can complete their calibration work rather than waiting until everything is completed. Many times the existing conditions and future no-build scenarios can be done relatively early in the project analysis, while the future build needs to wait until the preferred alternative(s) is chosen and all roadway design modifications are frozen a.k.a "pens down."

16.4 Air Quality Traffic Data[1]

Like noise analysis, ODOT is responsible for ensuring that state transportation projects are developed within the Federal Highway Administration's air quality policies and procedures. To conduct the air quality analysis necessary for measuring compliance, the ODOT Environmental Section, or air quality consultant, requires specific data from the project traffic analyst. This request is typically made through the Air Quality Traffic Data Request, which is filled out by the air quality consultant or the assigned ODOT air quality specialist and delivered to the project traffic analyst.

The types of air quality analyses required depend on the project location, type, pollutant, project funding source, traffic data, and NEPA class of action (Categorical Exclusions (CE), Environmental Assessments (EA), or Environmental Impact Statements (EIS)). The NEPA process does not always involve quantitative or even qualitative air quality analysis but always requires documentation of compliance. Qualitative and quantitative analyses have differing levels of traffic data required. The air quality analyses, and their related traffic data discussed in this section are for project-level conformity only, this does not cover regional air quality conformity analyses that might be done for a MPO area, for example.
Make sure that any scoping-level clarifying assumptions and requirements are clearly established by the ODOT air quality specialist and/or consultant air quality staff before starting on generating the air quality traffic data. Project-level air quality analyses are always directly based on the project traffic analysis. The volumes and analysis used for the project analysis must be consistent with the values and information generated for the air quality analysis. For example, if volume forecasts were post-processed for the project analysis from model volumes, then the same post-processed forecasts need to be used in the air quality analysis. Mixing of post-processed volumes (see Chapter 6) for the project and only model-based volumes for the air quality analysis would not be acceptable as they have completely different methodologies and would not be consistent between each other. Post-processing involves using the relationship (growth trend) between two different model scenarios and applying that relationship to actual ground counts to create design hour volumes on a directional link-by-link basis. This is much different than using model volumes from a scenario which are mathematically generated from household and employment data and their relationship with the transportation network. This means that the air-quality (along with noise) traffic data needs must be considered in the development of the overall project scope.

16.4.1 Local Carbon Monoxide (CO) Analysis

The purpose of the project-level local CO analysis is to estimate the highest localized CO concentrations resulting from each project alternative to show the project conforms to the

[1] Air Quality Manual – Project Level v 1.0, Geo-Environmental Section, Oregon Department of Transportation, October 2018.

Clean Air Act Amendments. The highest CO concentration usually occurs near the highest volume or congested intersections. Salem is the only remaining CO maintenance area that is subject to a CO conformity analysis. The CO conformity analysis must show that the project will not cause or contribute to new violation of the standard, increase the frequency or severity of an existing violation, or delay the timely attainment of any standard or transportation control measures.

CO analyses can be either qualitative or quantitative. If a project has intersections that fall into the range of LOS A-C only, then just a qualitative analysis will be needed. The air quality analyst will need to document the overall conditions with the relative impacts of v/c ratio, LOS, delay, or other traffic analysis results that should be obtained from the project technical memorandums or directly from the project traffic analyst. If there are signalized intersections on the project which operates at a LOS D or worse, then a quantitative analysis will be needed. Calculation/organizational templates for developing the required CO traffic data are available on the Technical Tools website under the Volume Development section.

Quantitative CO Analysis Data Needs

The overall scope of data needs for quantitative CO analyses are based on the overall ranking of the final design alternative(s) project-area signalized intersections. The project traffic analyst should separately rank the top three signalized intersections by LOS and total entering volume (TEV) for both the build year (year of opening) and the design year (20-yr projection). In addition, intersection delay and v/c should be included as extra information used for helping to pick locations if the LOS/TEV approach is not clear enough. Coordination with ODOT Air Quality staff can be helpful here as they could help to indicate the intersection(s) of interest which could reduce the analysis burden. While the same scoped data needs are also necessary for the no-build condition, only the build condition signalized intersections are ranked.

However, since CO ambient concentrations are well below the standards and there is no chance of violating the CO standard, usually a single intersection can be used to draw a conclusion regarding project impacts. All other affected intersections, given there are no substantive geometric differences compared to the no-build, can be qualitatively discussed based on LOS and TEV.

The following data elements are needed for the top one (1) to three (3) intersections for each of the LOS/delay or TEV cases for the build and design years for both the AM & PM peak hours (or periods as applicable):

- Intersection lane configurations
- Signal controller type: Pre-timed, semi-actuated, or actuated
- Approach grade (%) :This can be obtained from the TransInfo Vertical Grade Report for ODOT-owned approaches, local jurisdictions, or possibly project design staff.
- Lane saturation flow rates (vph); including permitted and protected rates for turns
- Traffic volumes by lane (vph)

- Effective green time (s)
- Yellow time (s)
- Red time (s) = Cycle length – Yellow time – Maximum green time
- Phase times and overall cycle length (s)
- Clearance lost time (s) = Also known as the "extension of effective green time", generally assumed to be a default of 2 seconds, but could be longer for complex intersections.
- Free-flow speeds for each approach
- Arrival types for approaches (1 to 5):
    1. Worst progression; dense platoon at beginning of red
    2. Below average progression: dense platoon at middle of red
    3. Average progression: random arrivals
    4. Above average progression: dense platoon at middle of green
    5. Best progression: dense platoon at beginning of green (includes both HCM Arrival Type 5 and 6)

The volumes supplied by the traffic analyst should be balanced across intersections and links in a similar process to what is done for the noise analysis (See Section 16.3 or Chapter 6 for general balancing guidance). This should be the case if the volumes are directly taken from project analysis files.

Free-flow speeds can be obtained from available private speed data sources such as RITIS if enough historical data is available to project future speeds, post-processed from a travel demand model or estimated using posted speeds plus five mph if better data was not available. See Section 16.4.3 for the MSAT future no-build and build process steps for more information.

Most intersection parameters can be easily obtained or calculated by assembling a PDF file of the appropriate signalized input or output from Synchro, Vistro, Sidra Intersection, HCS, etc.

Arrival types can be estimated by viewing time-space diagrams on the progressed approaches or is best calculated using the platoon ratio. The platoon ratio indicates the quality of the signal progression. See the Platoon Ratio discussion in Chapter 19 of the Highway Capacity Manual for more information. The platoon ratio for the approach would be based on the exclusive and shared through lanes (i.e. through lane group) by using the green time of the through lane group movement. HCM Exhibit 19-13 is used to obtain the arrival type from the calculated platoon ratio.

The platoon ratio is defined as:

$R_p = P / (g/C)$

P = proportion of vehicles arriving during the through lane group green time (decimal); = 1 -P_{red} from Section 16.3.1 Other Information and Example 16-2.
g = effective green time (s)
C = cycle length (s)

Example 16-4: Arrival Type Calculation

This example is a continuation of Example 16-2. From Example 16-2 the proportions of traffic expected to stop (expressed as a decimal) for each isolated approach is:

$P_{redEB} = 0.503$
$P_{redWB} = 0.509$
The resulting proportion of traffic arriving on green is calculated as 1 – P_{red}:

$P_{greenEB} = 0.497$
$P_{greenWB} = 0.491$

The northbound and southbound movements are coordinated, but since the platoon ratio is based on the entire green time of the through movement, the isolated approach method is used to calculate the proportion arriving on green. If the coordinated method was used, it will result in platoon ratios exceeding the upper limit (i.e. 2.00).

P_{green} = (Total Split – yellow time – all-red time) /cycle length

From the data given in Example 16-2, the proportion of traffic arriving on green is calculated as:
$P_{greenNB} = (35.5 – 4.0 – 0.5) / 100 = 0.310$
$P_{greenSB} = (35.5 – 3.5 – 0.5) / 100 = 0.315$

From the Synchro timing window the effective green time and g/C ratio can be obtained. Since the g/C ratio is indicated it can be used as-is in the platoon ratio equation instead of doing the calculation with the effective green time and cycle length. The same consideration for coordinated signals in the north-south direction applies here where the subject intersection timing is used for the northbound approach and the upstream intersection is used for the southbound approach as both are the first signal in the respective directions.

Subject Intersection

TIMING SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Actuated Effct. Green (s)	6.0	66.7	66.7	6.3	58.6	58.6	23.4	23.4	—	23.4	23.4	—
Actuated g/C Ratio	0.06	0.67	0.67	0.06	0.59	0.59	0.23	0.23	—	0.23	0.23	—

The platoon ratio for each direction is computed as:

$R_{pEB} = 0.497 / 0.67 = 0.74$
$R_{pWB} = 0.491 / 0.59 = 0.83$
$R_{pNB} = 0.310 / 0.23 = 1.35$
$R_{pSB} = 0.315 / 0.23 = 1.37$

Comparing to the Platoon ratio thresholds in HCM Exhibit 19-13, the corresponding arrival type is:

Arrival Type EB = 2; (Unfavorable, below average)
Arrival Type WB = 2; (Unfavorable, below average)
Arrival Type NB = 4; (Favorable, above average)
Arrival Type SB = 4; (Favorable, above average)

The traffic data needs above included in the CO quantitative tool are then sent to the air quality analyst who uses two different modeling software packages. The first (MOVES) establishes the amount of pollutants that would be emitted by vehicle traffic in grams per mile and idling vehicles in grams/hour which uses the traffic volumes and free-flow speeds for each approach. The second (CAL3QHC) determines the concentration of the pollutant based upon a conservative dispersion algorithm in parts per million which uses the intersection-based signal timing data.

FHWA CO Categorical Hot Spot Analysis

The air quality analyst may also want to determine if the project could be classified under the FHWA "CO Categorical Hot-Spot Finding" to lessen the overall CO analysis needs. This requires additional data and has specific limits for each data parameter to determine if the project can use the categorical analysis methodology. More information on the parameters, scenarios and application of the finding is available here. The following traffic data elements are needed for both the build and the design year as shown in Exhibit 16-10 for each of the top three (or as determined by the air quality analyst) highest total entering volume (TEV) and worst LOS signalized intersections. The air quality analyst will need to provide the temperature and CO concentration parameters to complete the data requirements. The project traffic analyst should let the air quality analyst know if any of the data parameters below on any of the intersections are exceeded as that would invalidate the use of this option.

Exhibit 16-10 FHWA Categorical CO Traffic Data Parameters

Parameter	Acceptable Range	Notes
Analysis year	≥ 2022	Build and Design year
Area type	Urban or Rural	Minimum urban population of 5,000; otherwise use rural
Road approach grade (%)	≤ 6%	Maximum approach grade of all legs within 100’ of stop bar
Truck percent (%)	≤ 20%	Highest approach percentage for heavy trucks (FHWA Classes 6-13)
Peak hour approach speed (mph)	15 to ≤ 45 mph	All approaches must be within limits
Peak hour approach volume (vph)	≤ 2640 vph	Highest approach volume
Peak hour LOS	A-E	Intersection LOS
Intersection approach angle	≥75°7	Smallest angle between the intersecting roadways
Number of approach through lanes	≤ 4	Maximum among all approaches
Number of approach left turn lanes	≤ 2	Maximum among all approaches
Lane width (ft)	≥10 ft	Minimum width of all lanes
Median width (ft)	≥ 0 ft (Any)	

The geometric data in Exhibit 16-10 should be available in the project inventory and the traffic data should be available as part of the project traffic analysis. The approach peak hour average speed could be obtained from the available traffic analysis output such as Synchro, Vistro, etc. or better, from a calibrated microsimulation previously done for the project such as SimTraffic or Vissim. Posted speeds or existing year probe speed data could be used as a proxy if no other better data is available.

The first step in a CO analysis traffic data development is to rank the signalized intersections by the highest LOS and total entering volume (TEV). The CO template tool includes a ranking table which is filled out and used for the rest of the traffic data development. It is recommended to coordinate with the ODOT Air Quality Unit to confirm the number intersections needed as frequently the number of required locations is less. It is common practice to only model the top intersection because CO concentrations have dropped significantly below standards in Oregon with no risk of violating the NAAQS (National Ambient Air Quality Standards). See the ODOT Air Quality Manual for more information. Example 16-5 uses a sample project location to illustrate the use of the available CO templates for the quantitative and categorical analysis methods.

Example 16-5 Sample Project Quantitative & Categorical CO Traffic Data using Templates

The sample project area below had four signalized intersections which were ranked for both the 2025 build (year of opening) and the 2045 design year. This analysis was only done for the PM peak; however the template does allow for inclusion of the AM peak which is commonly also included.

For the build year, the highest LOS was C which is LOS rank #1. There were two intersections with LOS B and so the v/c column was used to decide that the Redwood & Dowell Rd intersection was to be LOS rank #2 with the US199 & Allen Creek Road intersection being #3. These three intersections were also found to have the highest TEV, so these three locations would be the ones analyzed for this case.

Scenario	Peak	Intersection	v/c	Intersection Delay(s/veh)	Intersection LOS	TEV (vph)	LOS Rank	TEV Rank
		US199 & Allen Creek Rd	0.59	17.9	B	3,000	3	1
Build Year 2025	PM	US199 & Dowell Rd	0.60	25.6	C	2,540	1	2
		Redwood Ave & Allen Crk Rd	0.82	8.9	A	1,280		
		Redwood Ave & Dowell Rd	0.65	11.7	B	1,320	2	3
		US199 & Allen Creek Rd	0.58	24.7	C	3,920	3	1
Design Year 2045	PM	US199 & Dowell Rd	0.84	54.5	D	3,465	2	2
		Redwood Ave & Allen Crk Rd	1.10	75.1	E	1,750	1	
		Redwood Ave & Dowell Rd	0.80	16.1	B	2,065		3

For the design year, conditions have gotten worse as expected but the intersections are not in the same ranking order as in the build year. The highest LOS is E at the Redwood & Allen Creek Road intersection which gets LOS rank #1 (note that this location was unranked in the build year). The US199 & Dowell Road intersection is LOS rank #2 and US199 & Allen Creek Road is #3. For TEV, the highest intersections in the build year are also in the same order for the design year. In this case the intersections to be analyzed for CO will include all four as these encompass the top three LOS and TEV locations.

The intersection data is entered into the quantitative CO template sheet for each intersection (for each year and hour analyzed. This includes various geometric (e.g. lane configurations and approach grade), volume (e.g. volumes and saturation flow) and signal timing/phasing (e.g. cycle length, yellow/all-red time) elements. For simplification, only Intersection #1 (based on the 2045 ranking above), Redwood Avenue and Allen Creek Road, for the 2045 PM Peak is shown. The resulting approach red time and arrival type by lane is calculated by the spreadsheet.

[Please enlarge/zoom-in as necessary to view]

Intersection 1	Redwood Ave & Allen Creek Rd					PM Peak						
Signal Controller Type	Actuated-Coordinated											
Cycle length (s)	120											
Clearance lost time default (s)	2											
Approaches		North (SB)			East (WB)			South (NB)			West (EB)	
Approach grade (%)		0%			0%			0%			0%	
Movements	L	T	R	L	T	R	L	T	R	L	T	R
Shared lane configuration	n/a	TR	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Number of lanes	0	1	0	1	1	1	1	1	0	1	0	2
Lane saturation flow rates (vph)		1514		1496	1559	1339	1496	1575		1496		2333
Lane volumes (vph)		10		15	1080	5	5	5		5		155
Phase movement		SBTR		WBLTR	WBLTR	WBLTR	NBLT	NBLT		EBLR		EBLR
Phase time (max green) (s)		24		87	87	87	24	24		87		87
Yellow time (s)		4		4	4	4	4	4		4		4
Red time (s)	120	92	120	29	29	29	92	92	120	29	120	29
Actuated Effective green time (s) (Synchro calc.)		9.8		100.2	100.2	100.2	9.8	9.8		100.2		100.2
Free-flow approach speed (mph)		35			35			35			35	
All-red time (s)		0.5		0.5	0.5	0.5	0.5	0.5		0.5		0.5
Actuated g/C ratio (Synchro calc.)		0.09		0.92	0.92	0.92	0.09	0.09		0.92		0.92
Platoon Ratio (interim calculation)	#DIV/0!	1.81	#DIV/0!	0.75	0.75	0.75	1.81	1.81	#DIV/0!	0.75	#DIV/0!	0.75
Arrival Type	#DIV/0!	5	#DIV/0!	2	2	2	5	5	#DIV/0!	2	#DIV/0!	2

If required, the intersection data is also entered into the Categorical CO spreadsheet to see if all the parameter limits are satisfied. Any value outside of the required range will be highlighted in red. The figure below shows the inputs for both the 2025 year of opening and 2045 design year and shows that all values fit within the required parameters.

Intersection 1	Redwood Ave (E-W) & Allen Creek Rd (N-S)							
Area Type :	Urban							
	2025 Build Year				2045 Design Year			
Approach	N	E	S	W	N	E	S	W
Grade (%)	0	0	0	0	0	0	0	0
Heavy Trucks (%)	0	1	0	1	0	1	0	1
Peak Hour Speed (mph)	35	35	35	35	35	35	35	35
Peak Hour Volume (vph)	10	1100	160	10	10	1475	10	255
Skew angle (deg)	90	90	90	90	90	90	90	90
Number of through lanes	1	1	0	1	1	1	0	1
Number of left turn lanes	0	1	1	0	0	1	1	0
Lane width (ft)	12	12	12	12	12	12	12	12
Median width (ft)	0	0	0	0	0	0	0	0
Peak Hour Intersection LOS	A				E			

For example, if the E-W direction had a large skew at 45 degrees, this would be less than the minimum angle (i.e. 75 degrees 7 minutes). If any parameter is exceeded, then this intersection cannot use this method and must use the standard Quantitative CO template and method. Once completed, both spreadsheets for each method are forwarded to the responsible air quality staff for use in their modeling.

Intersection 1	Redwood Ave (E-W) & Allen Creek Rd (N-S)							
Area Type :	Urban							
	2025 Build Year				2045 Design Year			
Approach	N	E	S	W	N	E	S	W
Grade (%)	0	0	0	0	0	0	0	0
Heavy Trucks (%)	0	1	0	1	0	1	0	1
Peak Hour Speed (mph)	35	35	35	35	35	35	35	35
Peak Hour Volume (vph)	10	1100	160	10	10	1475	10	255
Skew angle (deg)	90	45	90	45	90	45	90	45
Number of through lanes	1	1	0	1	1	1	0	1
Number of left turn lanes	0	1	1	0	0	1	1	0
Lane width (ft)	12	12	12	12	12	12	12	12
Median width (ft)	0	0	0	0	0	0	0	0
Peak Hour Intersection LOS	A				E			

16.4.2 Particulate Matter (PM_{10} or $PM_{2.5}$) Hot Spot Analysis

Most PM analyses will be qualitative unless they are a project of local air quality concern [as defined in 40 CFR 93.123(b)(1)] and as such are required to have a quantitative analysis. Any project exempt from CO analysis is also exempt from PM analysis. Qualitative analyses will have a short discussion prepared by the air quality analyst based on the highest traffic volume links, diesel truck percentages, and LOS for both the no-build and build conditions. This data may be gleaned from project reports or obtained directly from the project traffic analyst. This data must be documented using the PM10 and PM2.5 Project Level Checklist (provided by ODOT Environmental Section staff) and each PM project taken to interagency consultation by ODOT Air Quality staff. The traffic engineer responsible for the traffic data inputs must also attend the interagency consultation.

Only certain project types are subject to needing a PM hot spot analysis. Calculation/organizational templates for developing the required PM traffic data are available on the Technical Tools website under the Volume Development section.
A quantitative analysis may be required if the project has a substantial number or increase of diesel-powered vehicles; or affects build alternative intersections that operate at LOS D or worse along with a substantial number of diesel-powered vehicles. Generally these types are:

- New highway projects with a substantial amount of diesel vehicles or expansion projects that would have a substantial increase of diesel vehicles. Examples would be a project on a highway with at least 125,000 total bidirectional AADT with 8% or more diesel trucks (10,000 truck AADT) or a new interchange connecting to a major bus or intermodal terminal. See Exhibit 16-11 for heavy truck diesel fuel factors to help determine the number of diesel trucks. Thresholds may differ based on interagency coordination requirements, so actual application of this element is flexible.

- Projects that affect intersections that are currently at LOS D-F with a substantial amount of diesel vehicles (10,000 truck AADT) or those that will change to LOS D-F because of increased traffic volumes from a substantial amount of diesel vehicles related to the project. An example would be a highway widening project that affects a poorly operating intersection that has a substantial amount of diesel trucks. This condition occurs relatively infrequently and generally would only occur in the Eugene-Springfield metropolitan area.

- New bus and intermodal terminals that have a substantial amount of diesel vehicles congregating at a single location or terminal expansions that significantly increase the amount of diesel vehicles congregating at a single location. Examples would be anything determined to be a "regionally significant project" or a large bus terminal which has the number of arriving diesel buses increase by 50% or more.

- Projects in or affecting locations, areas, or categories of sites which are identified in the $PM_{2.5}$ or PM_{10} applicable implementation plan or a new implementation plan submission, as appropriate, as sites of violation or possible violation. Projects within the urban growth boundary in these cities may trigger a quantitative analysis: Eugene-Springfield, Lakeview, and La Grande. Exceptions to the UGB limit are the entire Rogue Valley metropolitan area and the larger-than-UGB titled "$PM_{2.5}$ Nonattainment Boundary" for Klamath Falls and Oakridge.

Projects that are mainly intended to improve traffic flow and speed and that do not have increases in delays (i.e. increase of idling vehicles) or capacity can be exempted from the need to do a quantitative PM analysis. These include:
- Intersection channelization; especially those with physical separators
- Roundabouts
- Intersection signalization
- Roadway reconfigurations
- Auxiliary lanes under one mile in length
- Ramp metering

For a project to remain under a qualitative analysis, it must demonstrate that it is not a local air quality concern. This requires identifying the roadways with the highest AADT and diesel truck percentages that are acceptable to the interagency group. The Environmental Protection Agency's (EPA) PM guidance suggests that projects below 125,000 (bidirectional) AADT or 10,000 diesel truck AADT (8%) are typically not a project of air quality concern. This screening analysis (see Example 16-6) should be documented with ODOT's Air Quality PM10 and PM2.5 checklist (available from ODOT Environmental Section) and be done using the build alternative for the future (20-yr) design year. The screening-level AADT's should be reported for all project roadways. For example, if a project on I-5 exceeded 125,000 AADT on a couple mainline sections then all the freeway mainline and assorted ramps would be reported for consistency surrounding this location. Other roads (e.g. crossroads, parallel frontage roads, local arterials) in the project area with substantially less volume and trucks should also be reported for consistency and documentation requirements.

Each link in the screening analysis needs to have the AADT and the daily percentage of heavy-duty trucks (FHWA vehicle class 6-13). This percentage needs to be further modified by the diesel fleet fraction. Alternative heavy duty vehicle fuel sources are becoming more common, especially in the future. Exhibit 16-11 shows the diesel fuel fractions for heavy trucks that should be used to estimate the percentage of diesel trucks. Interpolate as necessary for years that fall in between the years in the table, but note that the relationship is not linear, so interim years will need to be estimated along the curve. Use the 2035 value for all future years beyond 2035.

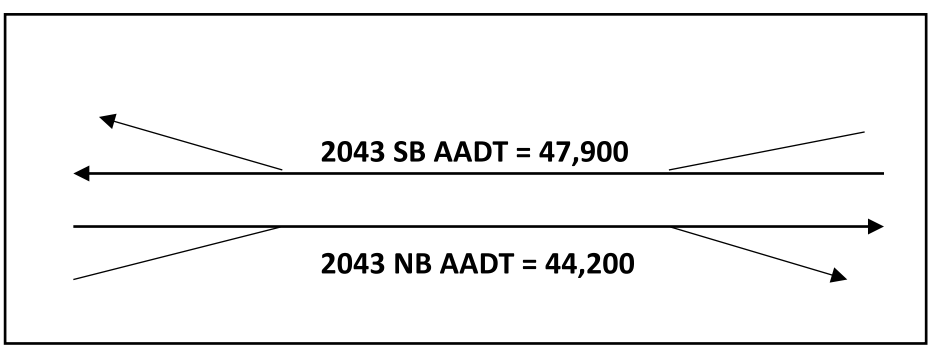
Exhibit 16-11 Heavy Truck Diesel Fuel Fraction

Year	Diesel Fuel Fraction
2020	1.000
2025	0.990
2030	0.941
2035+	0.880

An interagency coordination process must be initiated to confirm if a quantitative PM analysis is required. This includes the EPA, Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and either Oregon Department of Environmental Quality (DEQ) or if the project is in Lane County, then the Lane Regional Air Protection Agency. This group will decide if a quantitative analysis is needed and the specific methodology and scope of any additional traffic data.

Example 16-6 Qualitative Particulate Matter Screening Analysis

An auxiliary lane project is proposed on a freeway which has a projected 2043 no-build daily volume of 92,100 from the Future Volume Tables. There is a directional split of 52% southbound and 48% northbound and 12.6% heavy trucks (FHWA vehicle classes 6 – 13) in this section. The figure below shows the general configuration and the 2043 directional volumes.



The project was modeled in a travel demand model scenario and resulted in corresponding 2043 daily model link volumes for the no-build of 105,431 and a build of 107,843. Using the build volume in the screening analysis allows consideration of any latent demand shifts when traffic diverts from other slower links to the improved build section.

Using the difference method (see Chapter 6) to post-process the section:

Build volume = No-build volume + (Model Future Build volume – Model Future No-build volume)

92,100 AADT + (107,843 – 105,431) = 94,500 (rounded) which is less than 125,000 AADT. All other roadway sections would be below this level as this auxiliary lane portion has the highest volume.

However, 94,500 x 12.6% heavy trucks x 0.88 diesel fuel fraction (See Exhibit 16-XX) = 10,500 (rounded) which is higher than 10,000 diesel truck AADT. This converts into 5,450 southbound and 5,030 northbound diesel trucks.

It would be up to the interagency coordination to determine if the amount of the heavy diesel trucks in the project would require a quantitative PM analysis.

Quantitative PM Process – Future Build/No-build Conditions

Quantitative PM analyses involve use of the MOVES air quality analysis tool with sufficient traffic data needed to properly characterize the conditions over a typical day. Interagency coordination would be typically used to determine the scope of the analysis.

The recommended best-practice analysis approach should start with the future build conditions to minimize effort and time. The results from these inputs would be used by the air quality analyst to determine if the desired $PM_{2.5}$ concentration are below the National Ambient Air Quality Standards (NAAQS). If they are met, then the interagency consultation will determine if the analysis is complete. The traffic consultant does not determine this. If the NAAQS are not met, then mitigation or control measures will be needed (i.e. adding vegetation along the roadway or some level of redesign, etc.). Then the build analysis is repeated which may involve modifications to the traffic data inputs. Depending on the scale of the measures used, if any, it also may be necessary to calculate the future no-build conditions and test if the resulting build $PM_{2.5}$ concentrations are less than the no-build. This would require another set of traffic data inputs for the future no-build. If the build concentrations were determined to be less than the no-build then the NAAQS could be met, however, passing this test can be difficult, so this could introduce a level of iteration with multiple requests for updating the traffic data inputs.

A spreadsheet should be created with rows for each link and columns for each of the link attributes for the future build conditions below. All project area links need to have the attribute data created. Links outside of the project area are optional (based on guidance from the interagency consultation). Links, identifiers, and characteristics are set up in the same manner as for the noise analysis in Section 16.2.1. Most projects that are big enough to trigger air quality analysis also will have a noise analysis, so the noise analysis directional link spreadsheet should be used as a starting point to expand upon to expedite this analysis.

Intersections should be located on a separate tab and the listed attributes reported for all intersections. The interagency consultation will determine what intersections need to be included and what data is needed. Data needs could be more specific/detailed than shown based on the context of the project area, screening results, etc.

Link attributes

- Unique link identifier
- Link name
- Link length (mi)
- Grade (%)
- MOVES road type 1-5; Off-network (1), rural restricted (i.e. access via interchanges) (2), rural unrestricted (3), urban restricted (4) or urban unrestricted (5)
- Design speed (mph)
- Prevailing operating average speed (mph)
- Peak hour volume for morning (6-9 AM) & afternoon (4-7 PM) periods
- Average hour volumes for midday (9 AM – 4 PM) and overnight (7 PM to 6 AM) periods
- Hourly K-factors
- Vehicle classification for each period: light vehicles (Class 1-3), medium trucks (Class 4-5), and heavy trucks (Class 6-13)

Intersection attributes

- Total entering peak hour (AM & PM periods) or average hour volume (midday & overnight periods)
- AM or PM K-factor
- ADT to AADT seasonal adjustment factor
- Future build year directional AADT
- Light, medium, and heavy vehicle daily percentages
- PM Peak hour LOS

The project future year design hour volumes following Chapter 6 are used as-is. This usually will be at least the PM peak and possibly the AM peak hours. The AM/PM peak hour volumes are representative of each larger morning or afternoon three-hour period. There is no need to create multiple hours for each peak period. Available 24-hr counts or ATRs need to be used to create volume profiles which are used to determine the proportion of the daily volumes that are included in each of the midday and overnight periods (see Example 16-7 below). The hours shown above for the period durations are typical, but if the specific project is different than these should be changed to match local conditions.

Ideally these are same counts as used in the project analysis, so the average hour volumes are completely consistent with the peak hour volumes on a link-by-link basis. If that is not possible due to count duration limitations, they should be in the same general area, on the same or similar facilities, and within five years. The summed proportion across each period would be multiplied by the link volume and then divided by the number of hours in each period to determine the average hourly volume. Like with the noise analyses, the volumes for all four periods should be balanced across the links.

In addition, this same process can be used to help determine AM peak hour volumes if they are not available. The proportions of daily volumes (i.e. K-factors) from the 24-hour count will be shown for the AM peak hour period. Depending on the known local context, either use the hourly proportion (K-factor) for the actual AM system peak hour if known from other counts, or the highest directional AM hourly K-factor if the actual AM peak hour is not known. If the highest K-factor representing a certain AM peak hour is taken it needs to be the same across all counts and roadway directions for consistency as this would be an AM system peak hour (see Section 5.3 for considerations on choosing system peak hours).

Example 16-7 Midday & Overnight Average Hour Volume Calculation

A 24-hour count from a project is shown below with each hour's volume as a proportion of the daily total volume. The midday and overnight hours are highlighted in gray.

Hour	EB Volume	Daily Proportion	WB Volume	Daily Proportion
0	226	0.012	170	0.008
1	137	0.007	136	0.007
2	125	0.007	111	0.005
3	98	0.005	113	0.006
4	80	0.004	238	0.012
5	179	0.010	604	0.030
6	340	0.018	1151	0.056
7	697	0.038	1499	0.073
8	1071	0.058	1437	0.070
9	822	0.044	1205	0.059
10	829	0.045	1118	0.055
11	939	0.051	1139	0.056
12	1109	0.060	1172	0.057
13	1146	0.062	1156	0.057
14	1332	0.072	1230	0.060
15	1506	0.081	1232	0.060
16	1520	0.082	1319	0.064
17	1541	0.083	1320	0.065
18	1348	0.073	1221	0.060
19	960	0.052	878	0.043
20	807	0.044	753	0.037
21	656	0.035	571	0.028
22	592	0.032	395	0.019
23	440	0.024	290	0.014
Total	18500		20458	

Summing the hourly proportions yields:

- Eastbound midday (9 AM – 4 PM): 0.415
- Westbound midday: 0.403
- Eastbound overnight (7 PM – 6 AM): 0.232
- Westbound overnight: 0.208

These proportions would be applied to applicable link volumes. If a link had 10,000 ADT eastbound then this would result in 0.415 x 10,000 = 4,150 vehicles assigned to the midday period and 0.232 x 10,000 = 2,320 vehicles assigned to the overnight period. The average hour for each period would be determined by dividing this ADT by the number of hours in the period.

- Eastbound midday average volume = 4,150 veh / 7 hrs = 595 vph
- Eastbound overnight average volume = 2,320 veh / 11 = 210 vph

The westbound direction would be handled similarly, so if there were 10,000 westbound then there would be 4,030 vehicles for midday and 2,080 vehicles for the overnight period. This would result in 575 vph for the midday average hour and 190 vph for the overnight average hour.

In addition, if the AM peak hour was not available from the project analysis, then the highest hourly proportion (i.e. K-factor) would be picked if the peak hour was not known. In this case, the highest proportion is 0.073 in the WB direction representing the 7-8 AM peak hour. The corresponding K-factor for the non-controlling EB direction for this peak hour would be chosen (0.038) for consistency.

If the build alignment is the same (same link network) with differing number of lanes and/or traffic control, but the volumes are the same then the future build would likely be the same as the future no-build. If the build design year volume(s) is different from the no-build because of latent demand issues stemming from pent-up congestion, then the volumes will change, and the process will be same as doing the future no-build.

The challenge with the future build data is when the build alignment or network layout is different from the no-build alignment as the relationships between links gets muddied. The peak hour volumes would have already been re-distributed onto the build network for the project analysis. The analyst will need to figure out separately the routing of the heavy truck group and resulting link percentages if they do not follow the same patterns as the peak hour.

Design speeds can be the posted speed plus five mph for the no-build, but actual design speeds should be available for the build alternatives. Operating/prevailing speeds for links will need to be based on deterministic (i.e. Highway Capacity Software) or a calibrated microscopic (i.e. SimTraffic) analysis tool outputs. If future conditions are overcapacity, then HCS output may not include speed, so micro-simulation output may be necessary. Alternatively, future speeds could be post-processed from travel demand models. This would need to be based on the probe-based speed data (i.e. RITIS) for the existing conditions and a model link speed factor (i.e. future year model build link speed divided by the model base or reference year link speed).

The overall limitation of this process is based on the overall ability of the model to account for congested conditions, so the reported speeds are as accurate as possible. The ideal case would be to calibrate the model to speeds in addition to volume, however that is a practice that is not currently performed, and its potential success is untested. In general, use of an activity-based model or a dynamic traffic assignment model scenario would be preferred, if available, over a regular small city or MPO-level travel demand model. Raw unadjusted model speeds are not acceptable as ground-truthing is needed either through post-processing or calibration.

Vehicle classification data for light, medium and heavy vehicles should be obtained from the project counts. This usually would be already done for at least heavy vehicles for the peak periods in the project analysis which means that the medium trucks would be additionally created. The total of the heavy and medium trucks can be subtracted from the total hourly volumes to create the light volume totals. These total volumes for each classification are divided by the total volume for each period to determine the decimal proportion for each. Alternatively, if noise analysis traffic inputs were created earlier then these proportions are likely available for the peak periods which will reduce the data needed to be created.

The intersection attributes are mostly summing up the individual entering approach links for the peak/average hours and the daily volumes. The daily vehicle classification groupings will need to be created from the applicable 24-hr classification counts. It is unlikely that all counts in a project will be 24-hr classification counts, so shorter duration counts, or volume-only counts will need representative classification counts assigned to them. Intersection LOS analysis is only needed for the PM peak hour and in most cases, should be taken from the future build/no-build project analysis results. This analysis should be consistent with the current HCM methodology.

A tab containing the link diagram should also be added but it can be a separate document if desired. The link identifier through the speed columns is the same for all scenarios.

The overall process is as follows:

1. Add the unique link numbering scheme and link name/description, link length, link grade and MOVES road type

2. Add the known build design speed (or use posted speed + 5 mph). Calculate or post-process the link prevailing/operating speeds.

3. Use the future build directional link hourly volumes from the project or noise analysis from the PM or (if available) the AM peak hours. Use available 24-hour counts to determine hourly volume proportions (see Example 16-8) along to calculate the average hour volumes for the midday and overnight periods and the AM peak hours if needed. Apply a growth factor or post-processing to convert the average midday and overnight volumes to future no-build volumes and then to future build volumes following patterns used to originally create the AM/PM future build volumes.

4. For each of the four periods, balance the hourly volumes across the network on a link basis following a similar process to Section 16.3.3. Balancing is performed by summing the inbound and outbound link volume and computing the difference. The difference in the in or out volumes is then spread around the intersection proportionately. If differences are large then both the incoming and the outgoing volumes can raised or lowered to minimize the change. This is repeated for all intersections.

5. Use the counts to compute the initial AM/PM peak hour medium and heavy vehicle volumes for each link by multiplying the directional link hourly volume by the corresponding vehicle classification percentage. Average the medium and heavy truck percentages across the midday and overnight hourly periods to obtain the initial medium and heavy vehicle volumes for those periods.

   Depending on what may been developed previously (i.e. vehicle classification link allocations from a future build noise analysis), these may have to start with the existing or future no-build conditions. These are used to develop the initial volumes for the future no-build which are then balanced by comparing the ins and outs at each intersection and used to modify the factors to reflect the future conditions. Sink/source locations should be consistent with the drop or increase of the existing conditions with the appropriate growth to the future. Once the no-build future factors are developed, then these need to be translated over to the build network to make the necessary modifications to the factor data. For this step through Step 7, the process is like the noise traffic development process in Section 16.3.5.

6. Balance these initial medium and heavy truck volumes across the build network for each period. Subtract the total of the medium and heavy truck volumes from the total volumes to determine the total light vehicle volume.

7. Divide the balanced light, medium and heavy vehicle volumes by the total link volume to determine the decimal proportion of each classification grouping. Repeat for each of the four periods.

8. For each project-area intersection identified to be included from the interagency consultation, create the total entering volume by summing the entering link peak or average hour volume (depending on the period) for each of the four periods. Keep the intersection calculations on a separate tab.

9. Choose either the AM or PM peak hour and apply the corresponding peak hour K-factor (from the volume profile work in Step 3) to compute entering link ADT. Then use the Seasonal Trend Table (see Section 5.5.4) to determine the appropriate trend factor to use. The Seasonal Trend Table shows ratios of AADT to monthly ADT, so choosing the month(s) of the counts used will determine the necessary conversion factor. Interpolate for counts not at the beginning or middle of the month. Alternately, if available, use the AADT developed previously from the project analysis or create AADT from on-site or characteristic ATRs (see Chapter 5). Sum the entering link AADT to create the total intersection AADT.

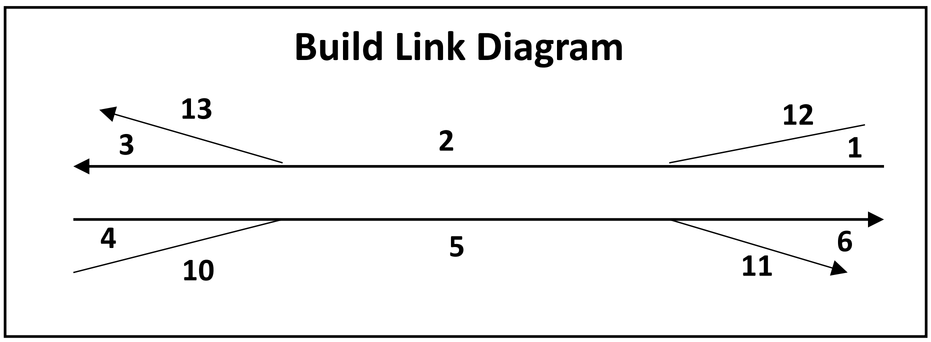
10. For each entering intersection link, determine the daily medium and heavy truck percentages from the classification counts or use percentages, if available, from the project or noise analysis for the future build year. Sum the medium and heavy trucks and subtract from 100% to determine the light vehicle percentages.
11. For each intersection but just for the PM peak period, record the intersection LOS

(D-F) from the future build (design) year traffic analysis on the intersection tab. If this has not been done (or available) then perform the intersection analysis following HCM methodology and APM Chapter 12 and 13.

12. Repeat Steps 1-12 for the future no-build if deemed necessary by the interagency coordination group.

Example 16-8 Quantitative PM Analysis

This example is a continuation of Example 16-7. From the interagency coordination discussions, it was decided that this auxiliary lane project should have a quantitative analysis of the future build conditions because diesel trucks exceeded 10,000 ADT. A build link diagram was established with a numbering scheme:



Link lengths and grades were obtained from ODOT inventory data. Design speeds were assumed to be the posted speed limit + 5 mph which would be 70 mph for the freeway mainline and 40 mph for the ramps. Since this the future 2043 build conditions, the operating speeds for the mainline links were developed using HCM freeway methodologies with the project area geometric assumptions [e.g. 12’ lanes, 6’ shoulders, three mainline lanes, a single auxiliary weaving lane, single lane ramps] and known project design hour volumes. Speeds for ramps were estimated from the design speeds.

Link #	Link Name	Link Length (mi)	Link Grade (%)	MOVES Road type	Design Speed (mph)	Prevailing Op. Speed (mph)
1	SB Fwy Upstream	0.18	0.0%	4	70	57
2	SB Fwy Between Ramps	0.99	0.0%	4	70	62
3	SB Fwy Downstream	0.28	2.0%	4	70	61
4	NB Fwy Upstream	0.46	-2.0%	4	70	63
5	NB Fwy Between Ramps	1.13	0.0%	4	70	63
6	NB Fwy Downstream	0.20	0.0%	4	70	60
10	NB on-ramp	0.25	-2.0%	4	50	45
11	NB off-ramp	0.13	0.0%	4	40	35
12	SB on-ramp	0.15	-1.0%	4	40	35
13	SB off-ramp	0.30	1.0%	4	50	45

Twenty-four hour counts on the freeway and ramp sections were used to develop volume profiles. An inspection of the hourly proportions (K-factors) revealed that the default AM peak (6-9 AM) was still correct but the PM peak was really 3-6 PM instead of the default 4-7 PM. The K-factors rise substantially in the peak periods then drop off afterwards as seen below in the figure. The ramp counts (not shown) also had the same peaking patterns.

Hour	Fwy NB Volume (vph)	Daily Proportion	Fwy SB Volume (vph)	Daily Proportion
0	264	0.008	303	0.009
1	239	0.007	192	0.006
2	221	0.007	217	0.007
3	292	0.009	258	0.008
4	506	0.015	357	0.011
5	1007	0.030	787	0.024
6	1781	0.054	1848	0.057
7	2199	0.066	2306	0.071
8	1889	0.057	1973	0.061
9	1900	0.057	1693	0.052
10	1788	0.054	1820	0.056
11	1791	0.054	1907	0.059
12	1927	0.058	1895	0.059
13	2023	0.061	1879	0.058
14	2068	0.062	1985	0.061
15	2381	0.072	2347	0.073
16	2565	0.077	2606	0.081
17	2447	0.074	2392	0.074
18	1777	0.053	1716	0.053
19	1258	0.038	1207	0.037
20	1122	0.034	956	0.030
21	984	0.030	714	0.022
22	504	0.015	565	0.017
23	352	0.011	373	0.012
Total	**33285**		**32296**	

Once the AM & PM peak periods were defined, then the remaining midday period and overnight period can be defined as 9 AM – 3 PM and 7 PM to 6 AM respectively. The AM & PM peak hours are used as representative hour for each period. The proportion of the day in the midday and overnight periods was summed and multiplied by the ADT and then divided by the total number of hours in each period to come up with an average hour value. This was repeated for all 24-hour counts. The resulting existing year volumes for each period were balanced across the network and then post-processed using NCHRP Report 765 techniques (see Section 6.12) to 2043 no-build future values. Then the 2043 no-build future was converted to 2043 build volumes using a factor developed by comparing the 2043 no-build and build model scenarios.

Lastly, the 2043 build volumes were balanced across the network to end up with the final peak and average hours shown below.

Link #	Link Name	2043 AM Pk Hr Volume (vph)	2043 PM Pk Hr Volume (vph)	2043 Ave Midday Volume (vph)	2043 Ave Night Volume (vph)
1	SB Fwy Upstream	2158	2728	2081	772
2	SB Fwy Between Ramps	2958	3451	2579	955
3	SB Fwy Downstream	2704	3226	2381	883
4	NB Fwy Upstream	2886	3252	2403	829
5	NB Fwy Between Ramps	3187	3605	2577	882
6	NB Fwy Downstream	2421	2839	2053	685
10	NB on-ramp	800	722	498	183
11	NB off-ramp	255	225	198	73
12	SB on-ramp	301	352	174	52
13	SB off-ramp	767	766	524	197

The available mainline freeway counts were used to develop the truck classification data for each period. The known AM/PM peak hour classification for medium (FHWA Class 4-5) and heavy vehicles (FHWA Class 6-13) was used directly as the peak hour is representative of the overall period. The medium and heavy vehicle classifications were each averaged across all hours consistent to how it was done for the volumes and converted into initial decimal proportions. There was no classification data available for the ramps, so it was assumed initially that these used the mainline percentages. These initial proportions were multiplied by the final build volumes to create a set of initial medium and heavy vehicle volumes with the AM peak shown as an example below.

Link #	Link Name	Final Build 2043 AM Pk Hr (vph)	Initial Med Trk Percent (decimal)	Initial Hvy Trk Percent (decimal)	Initial Med Trk AM Pk Hr (vph)	Initial Hvy Trk AM Pk Hr (vph)
1	SB Fwy Upstream	2158	0.039	0.131	84	283
2	SB Fwy Between Ramps	2958	0.039	0.131	115	388
3	SB Fwy Downstream	2704	0.039	0.131	105	354
4	NB Fwy Upstream	2886	0.040	0.119	115	343
5	NB Fwy Between Ramps	3187	0.040	0.119	127	379
6	NB Fwy Downstream	2421	0.040	0.119	97	288
10	NB on-ramp	800	0.040	0.119	32	95
11	NB off-ramp	255	0.040	0.119	10	30
12	SB on-ramp	301	0.039	0.131	12	39
13	SB off-ramp	767	0.039	0.131	30	100

Both the medium and heavy vehicles were then balanced across the network. The total of these was subtracted from the total hourly volume to compute the light vehicles (FHWA Class 1-3). Lastly, the final light, medium and heavy vehicle volumes were divided by the total hourly volume to determine the final vehicle proportions as shown below.

Link #	Final Balanced Lt Veh AM Pk Hr (vph)	Final Balanced Med Trk AM Pk Hr (vph)	Final Balanced Hvy Trk AM Pk Hr (vph)	Final Lt Veh Proportion (decimal)	Final Med Trk Proportion (decimal)	Final Hvy Trk Proportion (decimal)
1	1716	101	341	0.795	0.047	0.158
2	2455	115	388	0.830	0.039	0.131
3	2312	89	303	0.855	0.033	0.112
4	2490	99	297	0.863	0.034	0.103
5	2681	127	379	0.841	0.040	0.119
6	1963	115	343	0.811	0.048	0.142
10	690	28	82	0.863	0.035	0.102
11	207	12	36	0.812	0.047	0.141
12	240	14	47	0.797	0.046	0.156
13	656	26	85	0.855	0.034	0.111

After the link information is completed, the entering link volumes for the applicable intersections were copied into the intersection portion of the spreadsheet tool for each period as shown below. [Note: the intersection in this example is not an "standard intersection" but is used to illustrate the related connections and calculations. This simple case also could be considered equivalent to two one-way roadways intersecting.] The entering link volumes are summed to obtain the total entering volume for each of the four periods.

Intersection Name	Entering Link Dir	Entering Link Volume AM Peak Hr Build (vph)	Entering Link Volume PM Peak Hr Build (vph)	Entering Link Volume Midday Ave Hr Build (vph)	Entering Link Volume Overnight Ave Hr Build (vph)
Mainline & Ramp	NB	2886	3252	2403	829
	WB	800	722	498	183
	Total	**3687**	**3975**	**2900**	**1013**
		Peak Hour Int. LOS =	**C**		

The PM peak hour was chosen to create the total entering daily volume as the original volume development for the project was PM peak hour based. For the subject intersection, the corresponding peak hour K-factors for each entering link were chosen from the actual peak hour (4-5 PM) from the volume profile tab. Since AADT is desired, a conversion factor from the monthly to annual ADT is necessary. The Seasonal Trend Table (see Chapter 5) was referenced for the Interstate Urbanized trend and a mid-May count period to obtain the factor shown in the table below. The PM peak hour volume is divided by the K-factor first then multiplied by the ADT-to-AADT conversion factor second to calculate the total entering AADT.

Intersection Name	Entering Link Dir	Link K-factor PM	ADT to AADT Factor	Entering Link Volume Daily Build (AADT)
Mainline & Ramp	NB	0.077	0.9707	40968
	WB	0.079	0.9707	8904
	Total			**49872**

From the project build analysis, the corresponding daily medium and heavy truck percentages are added to the spreadsheet which also calculates the remaining light vehicle proportion as shown below.

Lastly, the PM peak hour LOS is added to the spreadsheet as shown in the first intersection table above.

Intersection Name	Entering Link Dir	Daily Lt Veh Percent (decimal)	Daily Med Trk Percent (decimal)	Daily Hvy Trk Percent (decimal)
Mainline & Ramp	NB	0.789	0.040	0.171
	WB	0.789	0.040	0.171
	Total			

16.4.3 Mobile Source Air Toxicity (MSAT) Analysis

Qualitative MSAT Analysis

Most projects will fall into FHWA category of ‘project with low potential for MSAT effects and only require a qualitative MSAT analysis. Example projects include those that improve operations without adding substantial capacity, minor widening, or new/revised interchanges. Projects can also increase emissions or relocate the roadway closer to sensitive areas such as residential areas, schools, churches, parks, sport fields, etc. if the future design year AADT is projected to be less than 140,000. Traffic data for the qualitative analyses require a narrative discussion of existing and future traffic volumes, vehicle mix and overall traffic routing patterns between the existing conditions, future no-build, and future build alternatives. Information for this discussion should be available from previously published traffic analysis technical memoranda or reports for the project.

To help with the qualitative discussion, some additional data may be requested:

- Regional annual vehicle miles traveled (VMT) and average regional speed, OR
- Project link ADT developed from short-term counts) and average speed
- Percent diesel by link

The regional annual VMT should be obtained from the applicable regional (metropolitan) travel demand model by summing up the VMT calculated for each link. This value needs to be using the daily link volume factored to an annual value and the link length. A model request should be completed for metropolitan areas with ODOT-constructed travel demand models (i.e. Albany, Bend, Corvallis, Grants Pass, and Medford). Model requests for the larger metropolitan areas (i.e. Portland Metro, Eugene-Springfield and Salem-Keizer) should be directed to the controlling organizations (i.e. Metro, Lane Council of Governments, and Mid-Willamette Council of Governments). The existing year can use the base model scenario, the future no-build can use the future model scenario, and the build future can use a future model scenario modified with the project. Existing and future model scenario years should be factored to match the actual project years.

Average regional speed can be obtained by averaging the calculated (i.e. link length divided by link travel time) link speeds from a daily volume assignment in a travel demand model across the entire regional area (e.g. a metropolitan area or city UGB). Alternatively, link speed can be obtained from dividing link VMT by link VHT (vehicle-hours traveled). This will not capture the full congestion effects, but any specific congested areas will be heavily diluted as a regional look will include lots of uncongested links. It is not practical to do a link-by-link speed assessment/post-processing across an entire regional area. This would be repeated for the existing, future no-build and future build model scenarios.

Most of this, if not all, could be done within the scope of the model request leaving just the scenario comparisons and discussion to the analyst. The resulting VMT and speeds for each year scenario should be relatively compared (versus directly using the actual link values) to create a meaningful discussion basis.

Project link ADT for all the scenario years (i.e. minimum of existing, future no-build, and future build) would be ideally obtained from the traffic analysis directly or by converting the balanced hourly volumes to directional links and factoring them like what is done for noise traffic data in Section 16.3. Alternatively, a travel model daily volume assignment for the project study area or specific affected facilities could be used from the closest base/reference year, future no-build, and future build scenarios.

The regional travel demand model can be used to create an average speed for each available period and for each scenario year as done for the regional process above but by using a project subarea (see Chapter 8) instead of the full model coverage. Alternatively, individual travel model link speeds could be averaged across the project study area or specific affected facilities. The existing year average speeds should be obtained for the same time periods from probe data sources such as RITIS on a link basis. Posted speeds should not be used for an MSAT analysis. The combination of these will post-process the model speed data between the existing year and the future no-build and between the future no-build and the future build. This will create the most accurate information and allows the direct use of absolute values in the discussion.

Percent diesel by link is determined by multiplying the diesel fuel fractions in Exhibit 16-12 by the vehicle classification percentages for automobiles and light, medium and heavy trucks (see Page 16-12 & 16-13). Interpolate as necessary for years that fall in between the years in the table, but note that the relationship is not linear, so interim years will need to be estimated along the curve. Consult the ODOT Air Quality Unit for values to be used with future years beyond 2035.

Exhibit 16-12 Auto & Light, Medium & Heavy Truck Diesel Fuel Factors

Year	Diesel Fuel Fraction			
	Auto (Class 1-2)	Light Trk (Class 3)	Medium Trk (Class 4-5)	Heavy Trk (Class 6-13)
2020	0.010	0.040	0.720	1.000
2025	0.010	0.030	0.680	0.990
2030	0.010	0.030	0.612	0.941
2035+	0.000	0.030	0.505	0.880

Example 16-10 Qualitative MSAT Analysis

This example is a continuation from Examples 16-7 & 16-9. Part of the interagency coordination also suggested that this operational auxiliary lane project perform a qualitative MSAT analysis. This project will widen the footprint of the freeway cross-section to the east and west by a lane which will bring it closer to a residential area that exists on the east side. Future projected build volumes (see Example 16-7) are less than the 140,000 AADT threshold, so a quantitative MSAT analysis will likely not be applicable.

While the previous examples used post-processed screening-level and project volumes, this example will use the regional travel demand model outputs obtained from a model request as the data source. The scope of most MSAT analyses is too large for an explicit link-by-link project assessment unless the volume data is already available, so a travel demand model would be the best tool choice. The regional VMT was obtained from the travel demand model for the existing, future no-build and build scenarios. From the table, the VMT increased about 1.7% per year from 2019 to 2043 which is commensurate with the increasing growth in the local area. The effect of the project increases the regional VMT by 0.23% over the no-build. For speed, the model daily link speeds for the project area links (see Example 16-8) were averaged together for all three scenarios. The improvements increase the daily average speed in the project area by 26% over the no-build and 8 % over the existing conditions.

Scenario	VMT (vehicle-miles)	Average Speed (mph)
2019 Existing	1,159,614	50
2043 No-build	1,635,794	42
2043 Build	1,639,504	54

Quantitative MSAT Analysis – Link Screening

Few projects will be applicable to a quantitative MSAT analysis. Currently, only the Portland Metro area has AADT's over 140,000 (sections of I-5, I-84, I-205 and US26) that could trigger this kind of analysis. Project impacts need to be in populated areas and:

- Create or significantly change a major intermodal facility that has the potential to concentrate high levels of diesel particulate matter in a single location by using a substantial number or increase of diesel vehicles, OR
- Create substantial capacity to urban roadways where the AADT is projected to be greater than 140,000 in the future design year.

The air quality analyst will need to submit a methodology memorandum to ODOT Environmental Section and FHWA. A link-based screening-level traffic assessment is required to determine the overall MSAT study area. This screening assessment should use available project-specific information consistent with the traffic analysis done for other parts of the project. This should be a comparison of the future no-build with the future build alternative. The screening criteria (for more information see FHWA's *"Frequently Asked Questions for Conducting Quantitative MSAT Analysis for FHWA NEPA Documents"*) used needs to be clearly described in the methodology memorandum and should use some form of the following criteria:

- AADT changes of +/- 5% or more on congested roadway links of LOS D or worse
- AADT changes of +/- 10% or more on uncongested links of LOS C or better
- Travel time changes of +/- 10% or more
- Intersection delay changes of +/-10% or more

The actual criteria used could use all or some of the above, or different equivalent metrics depending on the scope of the project (e.g. AADT changes of +/- 5% on all links). For example, performing a separate HCM-based intersection analysis to determine the effect of delay on adjoining links could be very intensive versus using simplified outputs from a travel demand model. However, while link travel time is an available transportation model output, the typical response to congestion is limited and may not show the full impacts of an alternative.

At a minimum, base (existing) link travel times would need to be established using RITIS (i.e. probe data) then post-processed with the base and future no-build transportation model link travel times to obtain the future no-build travel time. Then the build travel time could be factored up from the no-build by comparing the future no-build and build model link travel times. This post-processing could be skipped if the transportation model was calibrated for speed, but this is not current practice.

Because of the typical large project size and potential extensive impacts of a MSAT analysis, the link screening criteria shall be based on travel demand model outputs. The future no-build and build alternative volumes can be compared with a difference plot. to quickly identify the affected links. These plots can be used in multiple ways. Exhibit 16-

13 shows the change in volumes with one color representing increased volumes while the other color is a decrease. Equations can also be used with these, so one criterion could be showing any link with more than a 10% change in daily traffic or show a range for identifying demand-to-capacity thresholds to quickly highlight links. If the uncongested/congested sub-criteria are desired, then a 0.80 demand-to-capacity (d/c) threshold should be used to differentiate uncongested (LOS C or better) from congested (LOS D or worse) links.

Exhibit 16-13 Difference plot example

If a Visum-based model (whether trip-based or activity based, see Chapter 17) or sub-area (see Chapter 8) with some level of intersection detail (i.e. lane configurations, green time/cycle ratios, etc.) is used, then the intersection (i.e. nodal) delay could also be compared to identify all the adjoining affected links. The tagged links should be captured in a .csv formatted file so that further comparisons can be done in the model assignment software or in a spreadsheet can be done or can be used to as a start on the traffic data output.

This study area will include all the project roadway links and any additional links that experience substantial change in MSAT emissions. This is not a geographic-based study area as there could be roadways affected by the project considerably spaced from the actual project area especially if the project creates or enhances alternative routes or diversions. Projects that do not create substantial diversions or alternative routes such as a case of an isolated bridge crossing will have a smaller affected study area. These extra links could be wide-ranging and discontinuous from each other but should be in the general vicinity to be affected by the project. Identified links that are far removed from the project area should be investigated to see if it is a true impact or not.[2]

[2] FHWA HEP-15-056, FAQ on conducting Quantitative MSAT Analysis for FHWA NEPA Documents, 2016.

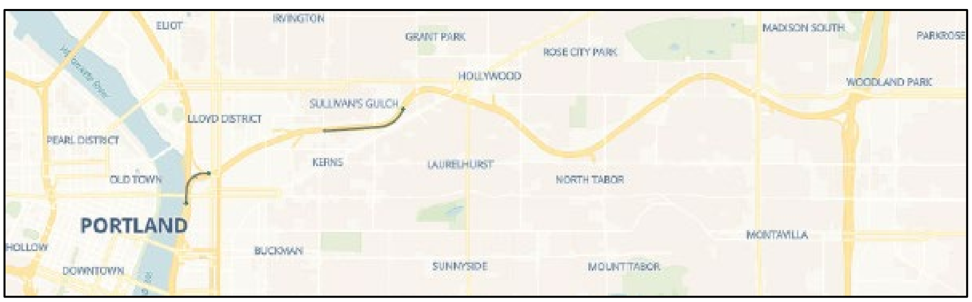
Example 16-11 Quantitative MSAT Screening

This and following MSAT examples use a "theoretical" widening of I-84 in Portland between I-5 and I-205 to four through lanes in each direction. This section of I-84 contains some of the highest volumes in the region at well over the 140,000 AADT MSAT analysis threshold. A project of this type that adds substantial system capacity to a congested section of freeway would be expected to have a noticeable impact on the surrounding area.

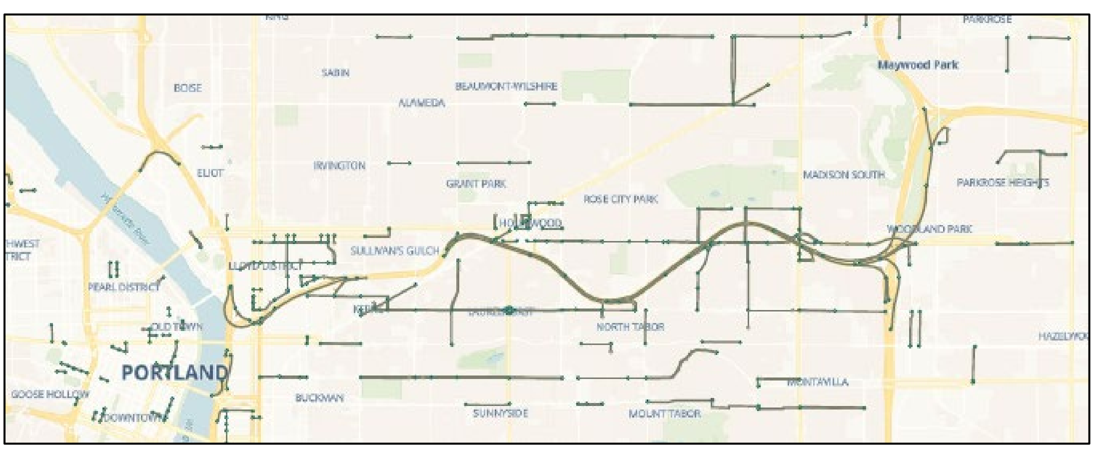
The (Portland) Metro travel demand model was used for the evaluation. The volume – level of service (LOS) criteria was used as this was thought to work the best with a travel demand model inputs and outputs. Link travel time could be generated from a model, but link congestion and the resulting delay tends to be understated so links could be inadvertently missed if this was the criterion used. The intersection volume delay criterion requires more detailed operational data than can be provided in a travel demand model.

A pair of volume difference plots were created which compare the 2045 no-build and build scenarios together with the capacity and volume change filtering conditions:

- Show links with demand to capacity ratios greater or equal to than 0.80 (approximates LOS C/D threshold) for the congested condition and where the daily volume changed by at least +/- 5% **OR**



- Show links with demand to capacity ratios less than 0.80 for the uncongested condition and where the daily volume changed by at least +/- 10%



Between the two screens, all the I-84 project links should be included in the quantitative (after all appropriate review and coordination) along with portions of I-5, I-205, I-405 and certain surrounding intersecting and parallel streets. For the following examples, a smaller subset of these roadway sections will be used to illustrate the quantitative method.

Quantitative MSAT Analysis

Once the affected directional links have been identified, the traffic analyst should coordinate with ODOT Environmental Section and the air quality analyst to review the overall traffic data request and finalize the MSAT methodology and data to be used.

> *The use of travel model-based data to simplify the overall calculation process for all scenarios (e.g. existing, future no-build, build) does mean that all the data is weekday-based. Obtaining weekend-based data would be very difficult and expensive for an MSAT-type scope. The most rigorous solution would have calibrated weekend model scenarios, but these would be special requests and likely not doable unless the model owner (or requestor) had access to numerous weekend-weekday counts (like 7-day hose tube counts) to do the calibration. Other than that, the same 7-day counts could be used to create conversion factors to translate weekday volumes to weekend before calculating VMT. This extra post-processing step would be required for all model scenarios and would be likely not be as accurate as trips and trips patterns are not the same on the weekend, so a simple conversion factor will not be able to fully account for all the changes.*

Data needs for quantitative MSAT analyses include:

- Unique link identifier
- Link length (mi)
- AADT
- Vehicle-miles traveled (VMT)
- MOVES road type (1-5).
  - Off-network (1)
  - Rural restricted (i.e. access via interchanges) (2)
  - Rural unrestricted (3)
  - Urban restricted (4)
  - Urban unrestricted (5)
- Average speed hourly fractions (%)
- VMT hourly fractions (%)

- Percent light vehicles (Class 1-3), medium trucks (Class 4-5), and (Class 6-13) heavy trucks (for use in determining MOVES "source types")

The following sections show the process for creating the VMT data for the existing conditions, future no-build, and future build scenarios. Example 16-11 started in the previous section is extended through all the scenarios to illustrate the calcaution process. A .zip file of all of the Excel workbooks used to create these examples is available on the Technical Tools page under the Volume Development dropdown for use as a sample file. The sheer scope of an MSAT-type analysis will likely require different workflows, tools, and input/output formats beyond these sample files, so these are not intended for use as step-by-step guides. Appendix 16C shows sample future-year traffic data inputs for MOVES showing VMT fractions by various dimensions.

Quantitative MSAT Analysis – Existing Conditions

The overall process is as follows:

1. Create a spreadsheet/database with the unique directional link numbering scheme, link name/description, link length and roadway type.
2. Determine the link VMT for all tagged links (or pre-determined districts or subareas if doing an area-wide analysis) by using a model daily volume assignment. The model year used should be the base or reference year closest to the project base year. If the model year used matches the project base year, then the model link values can be used as-is. If the model year is different, then the model year link volumes should be adjusted/interpolated to match the project base year.
3. Run a peak period assignment for each of the identified periods in the model and calculate VMT for the same links as for the daily computed in Step 2. Activity-based models (ABM) will have five periods (Early AM, AM peak, Midday, PM peak, and evening). Trip-based models will have at least two periods but could have more depending on the jurisdiction (AM peak, PM peak, Midday if available, other periods if available).
4. For ABMs, sum the peak period VMT in Step 3 and subtract it from the daily VMT in Step 2 to determine the night period VMT for each link. For trip-based models subtract the sum of the link VMT in Step 3 from the daily VMT in Step 2 to calculate the VMT daily remainder (up to 22 hours' worth) for each link.
5. For ABMs, use an averaged volume profile (or profiles as necessary to capture study area variations across the different facility types/functional classes) ideally generated from multiple representative (i.e. on-site or characteristic-based; see Chapter 5) ATR or 24-hour count locations to split each of the six link VMT periods (i.e. the five daily periods from Step 3 and the night period from Step 4) into hours. For trip-based models use the volume profile(s) described previously

to split the VMT remainder into the remaining hours not covered by the available hourly assignments.

Counts should be within five years of the existing analysis year, so overall volume patterns are representative. Since proportions are what are needed, the actual count value does not matter. These counts should be directional, if possible, to best match up with the known model assigned hours and have at least hourly breakdowns. Ideally, volume profiles should be developed for each facility type (i.e. freeway, ramps, arterials, etc.). More could be developed based on magnitude of volumes, functional class, or number of lanes if desired. Counts with similar base characteristics should be averaged together.

The daily volume profiles will need to be readjusted to exclude the periods or hours covered in Step 3, so the proportions just cover splitting up a particular VMT period or remainder. The adjusted volume profiles should be expressed in decimal percent fractions (e.g. 0.034) for each hourly fraction of the day and must sum to 1.000. The OTMS count report "Traffic Distribution by Hour" is the daily profile which is exportable in csv or Excel format which could be used to streamline these calculations.

Add the determined link VMT by hour to the spreadsheet to set up for the further fractional splitting in following steps. While formatting these VMT calculations can work by having the hours by columns, it will be more efficient to have the hours by rows as most data (e.g. count volumes, vehicle classification, speed data) is by column. This will avoid spending time needed to transpose the data.

6. Assign vehicle class counts to each specific facility or representative facility groups (i.e. subgroups like local arterials). Where possible, these should be the same counts obtained in Step 5 above. Ideally, single facilities should have a count for every section between major freeway or highway junctions. Vehicle class counts are ideally based on the FHWA 13-classes (See Chapter 3), but lesser number of classes can also work if motorcycles/passenger cars/passenger trucks (i.e. light vehicles; Classes 1-3), medium trucks/buses (Classes 4 & 5) and heavy trucks (Classes 6-13) can be identified. Vehicle class sources (e.g. counts, automatic vehicle classifiers) should have the longest duration possible (ideally 24-hr).

7. Determine the light vehicles (Class 1-3), medium trucks (Class 4-5) and heavy trucks (Class 6-13) vehicle percentages for each facility section or facility group by hour (if possible). Full day counts can determine specific percentages for each hour and allow creation of relative percentages through a vehicle class daily profile for applying to count locations or facility groups that do not have full daily coverage (this would allow use of short-term counts common on local streets). The three class groupings must sum to 100%. Average percentages from multiple counts for a facility group. Express the percentages in decimal form.

8. Multiply the hourly link VMT from Step 5 by each of the three hourly vehicle class group percentages determined in Steps 6 & 7 to determine the hourly VMT by vehicle class groupings.

9. For each of the specific facility sections or facility groups noted above use available probe-based data (e.g. RITIS), determine an average speed by hour for representative groups of links corresponding to a roadway section. Representative RITIS XD segment groups should be identified per direction (XD segments are directional) that correspond to roadway sections between major intersections or interchange ramps, to reduce as much as possible the number of required link speed calculations. Saving the XD segment selection will reduce time when repeating this with historical speeds in the future no-build. See the Oregon RITIS Handbook for more information on the analytical tools and settings.

   The speed calculations should be based on an average month. The ATRs in the project area, a representative ATR, or applicable seasonal trends should be checked to verify when to see when seasonal adjustments would be at 1.0 (typically April or October) which indicates average daily conditions.) Within RITIS, group together applicable XD segments as much as possible with links, but weight averaging by length is acceptable if a link bridges two or more XDs.

   Average speed can be best obtained using the Probe Data Analytics Performance Charts tool. Using the Map function to create a polygon around the selected road section, then deleting certain XD segments is best for identifying the directional analysis sections. Export the speed results for the selected segment, month, and time periods as an XML file which can be opened and edited in Excel.

   The Performance Charts tool will also produce a graphical speed profile if desired. Alternatively, the Massive Data Downloader (MDD) tool can be used if scripting and data analysis tools (outside of Excel as there will be too many records) are to be used to determine speeds over a large quantity of links. This will create a speed profile for each section or group.

10. Identify the applicable speed bin (labeled #1 through #16 below) for each hour for each link from the list below based on the speeds determined in Step 9. This is easily done using a lookup table in Excel to match up the reported average speeds and the speed bins.
    1. Speed < 2.5 mph
    2. 2.5mph ≤ Speed < 7.5mph
    3. 7.5mph ≤ Speed < 12.5mph
    4. 12.5mph ≤ Speed < 17.5mph
    5. 17.5mph ≤ Speed <22.5mph
    6. 22.5mph ≤ Speed < 27.5mph
    7. 27.5mph ≤ Speed < 32.5mph
    8. 32.5mph ≤ Speed < 37.5mph
    9. 37.5mph ≤ Speed < 42.5mph

10. 42.5mph ≤ Speed < 47.5mph
11. 47.5mph ≤ Speed < 52.5mph
12. 52.5mph ≤ Speed < 57.5mph
13. 57.5mph ≤ Speed < 62.5mph
14. 62.5mph ≤ Speed < 67.5mph
15. 67.5mph ≤ Speed < 72.5mph
16. 72.5mph ≤ Speed

11. For each link, parse the hourly link VMT by vehicle class from Step 8 into each of the 16 speed bins. This represents the finest level of VMT disaggregation by link.

12. Consolidate the binned link VMT by each roadtype. Sum the VMT for an individual hour and classification across all links of that roadtype. For example, for Roadtype 4 (urban restricted), light vehicle class, sum all link VMT for 12-1 AM for each of the 16 speed bins. Then repeat for 1-2 AM throughout the rest of the day. Then the same process would be repeated for the medium and heavy vehicles for Roadtype 4. This would continue to be repeated through all applicable roadtypes for the project.

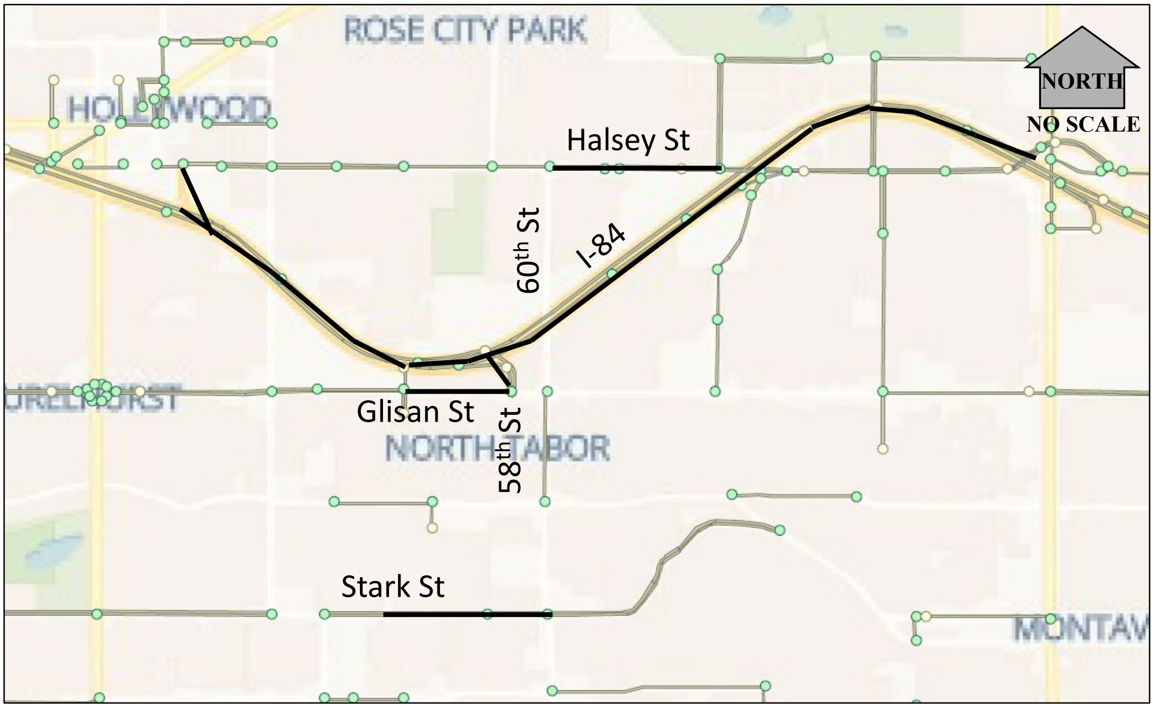
13. For each roadway type, sum the VMT across all the classes and speed bins to create an hourly VMT total. Sum this hourly VMT to create a roadtype VMT subtotal. Divide each roadtype VMT subtotal by the total sum of all the roadtype VMT's to create decimal fractions for each.

14. Sum up each of the hourly VMT by roadtype and classification records created in Step 12 to create an hourly total.

15. Divide the hourly VMT by roadtype, classification, and speed bin by the total hourly VMT by roadtype by classification from Step 13 to determine the VMT speed-based fractions in decimal form. Each hour in the resulting table needs to sum to 1.0000 (i.e. 100%).

Example 16-12 Quantitative MSAT Existing Conditions

This example continues the sample project started in Example 16-11. Traffic data will need to be developed for all chosen sections. A selection of roadway sections on mainline I-84, ramps and parallel roadways (shown in black) will have the VMT data developed in the next set of examples as shown in the figure below. Steps indicated in this example below correspond with the steps listed for the overall process above. Note that this only a small portion of the total number of links (shown in gray) that could be selected for this sample project.



Step 1

For each roadway link, a unique link ID was created (see Section 16.3.1 for link numbering guidance) along with the corresponding link description and roadway type. Note that ramps are treated the same as freeway links. From the travel model output, the link length and daily volume for each link were recorded as shown in the table below. Some roadway links are made up of multiple model links, so ADT was weight-averaged across those links.

Link ID	Link Description	Road type	Link length (mi)	ADT (vpd)
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	4	0.76	97000
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	4	0.40	85002
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	4	0.21	94344
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	4	1.40	88645
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	4	0.37	101779
500	58th St EB off-ramp	4	0.18	11998
501	58th St WB on-ramp	4	0.27	13134
502	60th St EB on-ramp	4	0.19	9342
503	Halsey St on-ramp	4	0.19	5825
504	43rd St off-ramp	4	0.36	11999
600	Glisan St EB; 55th St to 58th St	5	0.24	4684
601	Glisan St WB; 58th St to 55th St	5	0.24	5415
602	Halsey St EB: 60th St to 67th St	5	0.38	2862
603	Halsey St WB; 67th St to 60th St	5	0.38	5320
604	Stark St EB; 55th St to 60th St	5	0.50	1914
605	Stark St WB; 60th St to 55th St	5	0.50	2344

Steps 2-4

The link length and the ADT are multiplied together to obtain the total daily VMT for each link. From this value, known hourly VMT from each peak period needs to be subtracted. For the Metro model, any hour can be assigned, however, while doing 24 individual hours of assignments are possible, it is not practical from the modeler perspective since each hourly run takes almost a day. Representative hours were chosen for each of the five peak periods (Early, AM peak, Midday peak, PM peak, and Evening) as a balance between the model request effort and the analysis fidelity.

The hourly volume for each link for each of the hours is multiplied by the link length to determine VMTs shown in the table below. Links made up of the multiple model links were weight-averaged. The sum of the five hours is subtracted from the daily VMT calculation to determine the 19 hours' worth of VMT remainder that needs to be allocated over the rest of the day.

Link ID	DVMT (veh-mi)	Early VMT (veh-mi)	AM VMT (veh-mi)	Mid VMT (veh-mi)	PM VMT (veh-mi)	Eve VMT (veh-mi)	Rem VMT (veh-mi)
100	73720	2826	3995	4280	4572	3289	54758
101	34001	1292	1854	1982	2168	1925	24779
102	19812	736	1078	1146	1269	1011	14573
200	124103	7512	8448	7064	7113	5426	88539
201	37658	2177	2398	2182	2202	1713	26987
500	2160	88	112	122	107	124	1607
501	3546	140	121	230	235	203	2617
502	1775	52	94	95	118	92	1323
503	1107	47	57	69	70	59	806
504	4320	192	149	274	285	237	3183
600	1124	15	29	60	118	55	848
601	1300	70	149	63	56	30	930
602	1088	8	32	65	179	26	777
603	2021	75	303	95	118	33	1398
604	957	6	35	61	145	26	683
605	1172	40	154	61	84	23	811

Step 5

The next step is to identify representative ATR (either on-site or characteristic-based) or available 24-hour counts in the project area that can be used to develop a volume profile. A 24-hour count was located on I-84 in the example section along with all the identified ramps. ADT-only counts were found on the arterial streets which would be not sufficient to develop a volume profile, so a substitute count on US26 (Powell Blvd) will be used to develop factors for the surface streets. The ramp volume proportions were divided into eastbound and westbound directions and averaged together. All the three directional volume facility profiles (e.g. freeway, ramps, and arterials) were adjusted by removing the five assigned hours and re-calculating so the totals still summed to 100%. The hourly volume profile factors were then applied to the remaining VMT portion to distribute it across the other 19 hours as shown in in the partial table below.

Link ID	Link Description	Remaining DailyVMT	12AM	1AM	2AM	3AM	4AM
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	54758	970	554	501	605	994
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	24779	439	251	227	274	450
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	14573	258	147	133	161	265
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	88539	1407	824	686	1092	2506
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	26987	429	251	209	333	764
500	58th St EB off-ramp	1607	13	8	8	8	12
501	58th St WB on-ramp	2617	22	14	14	15	40
502	60th St EB on-ramp	1323	11	6	6	6	10

Steps 6-8

The next step was to work towards creating the classification breakouts for light (Class 1-3), medium (Class 4-5) and heavy vehicles (Class 6-13). The same directional counts on I-84 that provided the volume profile also had the full FHWA 13-class breakdown, so it will be used for the freeway segments. This will allow the vehicle proportions to vary by the hour. The number of light, medium, and heavy vehicles in each hour were divided by the total number of vehicles in each hour to create each proportion. This proportion was multiplied by the total hourly VMT to create the VMT by class as shown below in the partial table. It should be noted that the data was transposed to better match up with available inputs, so that the hourly data is by row instead of by column in the previous step.

Link ID	Link Description	Time	VMT by Hr	VMT by Class by Hr		
				Light	Medium	Heavy
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp					
		12AM	970	923	16	30
		1AM	554	500	14	40
		2AM	501	445	14	42
		3AM	605	542	14	49
		4AM	994	913	24	56
		5AM	2826	2626	76	124
		6AM	2983	2794	99	90
		7AM	3995	3767	128	99
		8AM	4050	3811	151	88

The ramp counts were volume only, but there was some high-level daily truck AADT information available for single and multiple unit trucks. In this case, single unit trucks were assumed to be equivalent to medium trucks and multiple-unit trucks were assumed to be equivalent to heavy trucks. The ramp counts were averaged together as they were generally similar which results in 2.8% medium trucks and 1.2% heavy trucks. Ramps have a mix of characteristics of the freeway and connecting arterials so a comparison average of the arterial and freeway segments together has 2.3% medium and 1.4% heavy trucks which is consistent (if no ramp truck information were available then this value could be used). In this case, the vehicle proportions will be flat across the day although the number of vehicles will change according to the available daily ramp volume profile. These proportions were multiplied by the daily volume ramp profile to create the ramp VMT by class as shown below.

Link ID	Link Description	Time	VMT by Hr	VMT by Class by Hr Light	Medium	Heavy
500	58th St EB off-ramp					
		12AM	13	13	0	0
		1AM	8	7	0	0
		2AM	8	7	0	0
		3AM	8	7	0	0
		4AM	12	12	0	0
		5AM	88	84	2	1
		6AM	86	83	2	1
		7AM	112	107	3	1
		8AM	162	155	5	2

For the arterial system, there was no available classification information. The same count on Powell Boulevard (US 26) that was used for developing the volume profile also had the full hourly classification data. Overall, it can be expected that truck proportions on city streets will be around a few percent. This count had an average daily truck percentage of 2.4% which is in the expected range, so it can be used as a proxy for the other sites on an hourly basis. The vehicle proportions were computed the same way as for the freeway segments. Note that variations in rounding based on calculated or value-only spreadsheet cells will cause some lines in the below table not to add up cleanly.

Link ID	Link Description	Time	VMT by Hr	VMT by Class by Hr Light	Medium	Heavy
600	Glisan St EB; 55th St to 58th St					
		12AM	14	13	0	0
		1AM	8	8	0	0
		2AM	8	7	0	0
		3AM	6	6	0	0
		4AM	5	4	1	0
		5AM	15	13	1	0
		6AM	21	19	1	0
		7AM	29	28	1	0
		8AM	65	62	2	0

Step 9

From a nearby ATR, April was determined to be the representative average month. The RITIS Performance Chart tool was used to develop the average speed by hour for April 2023 as this matches up the best with the available volume profile and classification data. The tool was run with matching as much as possible the link with the identified directional XD segments.

Step 10

Some links match up perfectly with the XD segments such as for Link 100 (I-84 EB from the Cesar Chavez Boulevard on-ramp to the 58th Street off-ramp). Other links do not, such as the remaining two eastbound I-84 links (Link 101 and 102) are only covered by a single XD segment. The westbound directional link (Link 200) is covered by three XD segments. The data was downloaded to Excel and a lookup table was used to match the speed bins with the reported average speeds as shown below in the partial table.

Link ID	Link Description	Time	Ave Speed (mph)	Speed Bin ID#
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp			
		12AM	61.5	13
		1AM	61.4	13
		2AM	60.6	13
		3AM	61.4	13
		4AM	62.8	14
		5AM	62.8	14
		6AM	61.5	13
		7AM	58.6	13
		8AM	49.4	11

Step 11

Once the hourly speed bins were identified for all the links, the light, medium and heavy vehicle hourly VMT totals were parsed into each of the 16 speed bins for each link. The partial table below shows the distribution for light vehicles for Link 100 between 12- 8 AM.

Link ID	Time	VMT Light Veh	VMT by Hr by Speed Bin - Light Veh 8	9	10	11	12	13	14
100									
	12AM	923						923	
	1AM	500						500	
	2AM	445						445	
	3AM	542						542	
	4AM	913							913
	5AM	2626							2626
	6AM	2794						2794	
	7AM	3767						3767	
	8AM	3811				3811			

Step 12

Next, the link VMT data was consolidated down to the roadtype by classification level. All the individual hours (i.e. 12-1 AM, 1-2 AM, etc.) were summed for each roadtype and classification (i.e. Roadtype 4 & Light vehicle, Roadtype 4 & Medium vehicle, etc.) as shown in the partial table below.

Roadtype	Class	Time	VMT by Hr by Speed Bin						
			5	6	7	8	9	10	11
4	Light	12AM	0	13	0	47	7	10	0
4	Light	1AM	0	7	0	30	4	6	0
4	Light	2AM	0	0	7	30	0	10	0
4	Light	3AM	0	0	7	33	0	11	0
4	Light	4AM	0	0	12	85	12	9	0
4	Light	5AM	0	0	84	185	180	50	0
4	Light	6AM	0	0	83	424	0	68	7594
4	Light	7AM	171	107	10425	0	90	0	0
4	Light	8AM	63	7561	0	0	128	0	6550

Step 13

The hourly VMT for each roadtype from Step 12 was summed across all the speed bins to create a subtotal. Each hourly subtotal was summed across the day to create a VMT total by roadtype. Each roadtype VMT total was divided by the total sum of all roadtype VMTs to create a decimal fraction.

Roadtype	Roadtype VMT Fraction
4	0.9754
5	0.0246

Steps 14-15

Each hour in the table above was summed across all speed bins to create a total. This was used to create the decimal speed fractions by dividing the hourly roadtype by classification by speed VMT data by the total hourly by roadtype by classification VMT. The partial table below shows the corresponding speed fractions for the previous table. For example, the highlighted 10,425 VMT for 7-8 AM for Speed Bin #7 (27.5 to 32.5 mph) results in a speed fraction of 0.6018. This means that for Roadtype 4 (urban restricted; freeway) between 7-8 AM for light vehicles (Class 1-3), 60.18% are traveling between 27.5 and 32.5 mph. Each row in the table will sum to 1.0000 (100%).

Roadtype	Class	Time	VMT by Hr by Speed Fractions						
			5	6	7	8	9	10	11
4	Light	12AM	0.0000	0.0039	0.0000	0.0140	0.0021	0.0030	0.0000
4	Light	1AM	0.0000	0.0037	0.0000	0.0161	0.0021	0.0032	0.0000
4	Light	2AM	0.0000	0.0000	0.0045	0.0191	0.0000	0.0064	0.0000
4	Light	3AM	0.0000	0.0000	0.0031	0.0147	0.0000	0.0049	0.0000
4	Light	4AM	0.0000	0.0000	0.0025	0.0180	0.0025	0.0019	0.0000
4	Light	5AM	0.0000	0.0000	0.0059	0.0129	0.0126	0.0035	0.0000
4	Light	6AM	0.0000	0.0000	0.0054	0.0277	0.0000	0.0044	0.4968
4	Light	7AM	0.0099	0.0062	0.6018	0.0000	0.0052	0.0000	0.0000
4	Light	8AM	0.0043	0.5212	0.0000	0.0000	0.0088	0.0000	0.4515

Quantitative MSAT Process – Future No-build

The future no-build computation process is similar to the existing conditions. The future no-build data is based off relational pivots from the existing information. This mainly involves updating the VMTs from future model data, and estimating changes to hourly volumes, vehicle classifications and speeds.

The overall process is as follows:

1. Copy the unique directional link numbering scheme, link name/description, link length and roadway type to a new spreadsheet or database file from the existing conditions.

2. Determine the link VMT for all tagged links (or pre-determined districts or subareas if doing an area-wide analysis) by using a model daily volume assignment. The future model year used should be the closest to the project future (horizon) year. If the future model year used matches the project future year, then the model link values can be used as-is. If the model year is different, then the model year link volumes should be adjusted/interpolated to match the project future year.

3. Run a peak period assignment for each of the identified periods in the model and calculate VMT for the same links as for the daily computed in Step 2. Activity-based models (ABM) will have five periods (Early AM, AM peak, Midday, PM peak, and evening). Trip-based models will have at least two periods but could have more depending on the jurisdiction (AM peak, PM peak, Midday if available, other periods if available).

4. For ABMs, sum the peak period VMT in Step 3 and subtract it from the daily VMT in Step 2 to determine the night period VMT for each link. For trip-based models subtract the sum of the link VMT in Step 3 from the daily VMT in Step 2 to calculate the VMT daily remainder (up to 22 hours' worth) for each link.

5. Obtain past hourly counts at each of the ATR or count sites used in the existing conditions analysis going as far back in the past as readily available. Ideally, this would be at least 10-15 years in the past or as far back as going forward to the future year (i.e. obtaining a count from 2003 corresponding to a 2023 base year and a 2043 future year. Skip the 2020 and 2021 pandemic years as counts will be substantially low and patterns significantly different. These counts ideally would be the same month and day of week as the ones done for existing conditions for as much consistency as possible, but holidays and known major regional events should be avoided. Using counts that can be averaged over multiple days would be best. While one past count is the minimum, having additional years reduces the potential for large shifts or negative values if the hourly proportions are shown to decrease over time. Any negative values will need to be manually corrected back

to zero which will mean that the profile will only sum close to 100% and not equal it. These cases would be likely in small volume hours so the overall impact would not be substantial. Convert each hour into a daily fraction expressed in decimal percents. Using linear extrapolation of the historic daily fractions, forecast the future hour-based daily fractions. If the forecasted future daily fractions are not significantly different from the existing, then continue to use the existing conditions daily fractions for the future-no-build analysis.

6. For ABMs, use the averaged volume profile hourly fractions from Step 5 to split each of the six link VMT periods (i.e. the five daily periods from Step 3 and the night period from Step 4) into hours. For trip-based models use the volume profile(s) described previously to split the VMT remainder into the remaining hours not covered by the available hourly assignments. The volume profiles should be expressed in decimal percent fractions (e.g. 0.034) for each hourly fraction of the day.

7. Add the determined link VMT by hour in Step 6 to the spreadsheet to set up for further fractional splitting in following steps.

8. Obtain past years (the same historic interval used in Step 5) state highway vehicle classifications for segments that match the existing year vehicle classification count locations from ODOT's TSM unit. These counts ideally would be the same ones that were used to develop the hourly profiles in Step 5. Using linear extrapolation (e.g. using Excel's FORECAST.LINEAR function) with available past and existing year vehicle classification group percentages, forecast the future year percentages. Relatively steep positive or negative trendlines between the historic reference year and the existing year may result in proportions higher than 1.000 or less than zero. These will need to be manually adjusted to correct the errors. Having more than two count years may mitigate some of these errors but will increase the data and time needs. Continue to use the existing year percentages if the forecasted future is not significantly different. Alternatively, if a noise analysis has been conducted, use that project build final link vehicle classifications in this step for consistency.

9. Use the vehicle class groupings determined in Step 8 and multiply by the hourly link VMT from Step 6 to determine the hourly VMT by vehicle class.

10. As was done with the existing conditions, use RITIS to find the earliest year available (e.g. 2016) and use the same XD segments. Within RITIS, group together applicable XD segments as much as possible with links, but weight averaging by length is acceptable if a link bridges two or more XDs. Average speed can be best obtained using the Probe Data Analytics Performance Charts tool. Using the Map function to create a polygon around the selected road section, then deleting certain XD segments is best for identifying the directional analysis sections. Export the speed results for the selected segment, month, and time periods as an XML file which can be opened and edited in Excel. The

Performance Charts tool will also produce a graphical speed profile if desired. Alternatively, the Massive Data Downloader (MDD) tool can be used if scripting and data analysis tools (outside of Excel as there will be too many records) are to be used to determine speeds over a large quantity of links. This will create a speed profile for each section or group.

11. Use forecasting functions like was done with the vehicle class with the existing year speed and the earliest base speed available and project the estimated future year speeds. Currently with around 10 years of available past speeds, projections will be generally reliable for around 10 years in the future (i.e. 2016 base speeds and 2025 existing year could produce 2035 future year speeds). For travel demand models, extrapolated data is generally acceptable to around five years extra (i.e. to 2040). However, speed projections do not necessarily continue at a linear rate over time, but the rate will tend to decrease, so the estimates may be too high or low, so the maximum future year (e.g. 2040 in this case) may be thought of as equivalent to horizon years beyond this date (e.g. 2045 for the corresponding 20-year design/horizon year that would normally be with a 2025 existing year).

12. Calculate the free-flow speed for each facility by adding five mph to each roadway speed limit (e.g. 60 mph for a 55-mph facility). Compare the free-flow speed with the projected future year speeds from Step 11 and reduce any speeds that exceed that value to the free-flow speed. In addition, use a practical crawl speed limit of 7 mph for any speeds that are projected to be less than this value.

13. Identify the applicable speed bin for each hour for each link from the list below based on the refined speeds determined in Step 12. This is easily done using a lookup table in Excel to match the reported average speeds and the speed bins.

1. Speed < 2.5 mph
2. 2.5mph ≤ Speed < 7.5mph
3. 7.5mph ≤ Speed < 12.5mph
4. 12.5mph ≤ Speed < 17.5mph
5. 17.5mph ≤ Speed <22.5mph
6. 22.5mph ≤ Speed < 27.5mph
7. 27.5mph ≤ Speed < 32.5mph
8. 32.5mph ≤ Speed < 37.5mph
9. 37.5mph ≤ Speed < 42.5mph
10. 42.5mph ≤ Speed < 47.5mph
11. 47.5mph ≤ Speed < 52.5mph
12. 52.5mph ≤ Speed < 57.5mph
13. 57.5mph ≤ Speed < 62.5mph
14. 62.5mph ≤ Speed < 67.5mph
15. 67.5mph ≤ Speed < 72.5mph
16. 72.5mph ≤ Speed

14. For each link, parse the hourly link VMT by vehicle class from Step 8 into each of the 16 speed bins. This represents the finest level of VMT disaggregation by link.

15. Consolidate the binned link VMT by each roadtype. Sum the VMT for an individual hour and classification across all links of that roadtype. For example, for Roadtype 4 (urban restricted), light vehicle class, sum all link VMT for 12-1 AM for each of the 16 speed bins. Then repeat for 1-2 AM throughout the rest of the day. Then the same process would be repeated for the medium and heavy vehicles for Roadtype 4. This would continue to be repeated through all applicable roadtypes for the project.

16. For each roadway type, sum the VMT across all the classes and speed bins to create an hourly VMT total. Sum this hourly VMT to create a roadtype VMT subtotal. Divide each roadtype VMT subtotal by the total sum of all the roadtype VMT's to create decimal fractions for each.

17. Sum up each of the hourly VMT by roadtype and classification records created in Step 15 to create an hourly total.

18. Divide the hourly VMT by roadtype, classification, and speed bin by the total hourly VMT by roadtype by classification from Step 16 to determine the VMT speed-based fractions in decimal form. Each hour in the resulting table needs to sum to 1.0000 (i.e. 100%).

Example 16-13 Quantitative MSAT Future No-build Conditions

This example continues the sample project analysis from Example 16-12. The same link sections and attributes such as link number, description and length were copied from the existing conditions. Indicated steps in the example correspond with the steps in the procedure above.

Steps 1-4

Daily and hourly volumes for the five assigned periods (5AM, 7AM, 12PM, 5PM, and 7PM) were captured from a future no-build model assignment. The link length and the ADT were multiplied together to obtain the total daily VMT for each link as shown below. From this value, the known hourly VMT from the peak periods was subtracted from the daily total as was done for the existing conditions to come up with the remaining VMT to be distributed over the remaining 19 hours of the day.

Link ID	DVMT (veh-mi)	Early 5A VMT (veh-mi)	AM 7A VMT (veh-mi)	Mid 12P VMT (veh-mi)	PM 4P VMT (veh-mi)	Eve 7P VMT (veh-mi)	Rem VMT (veh-mi)
100	91889	4150	5261	5428	5533	3938	67580
101	42865	1966	2508	2496	2628	2289	30978
102	24694	1097	1425	1428	1526	1202	18016
200	148333	8683	9828	8282	8641	5943	106956
201	44868	2562	2778	2583	2640	1896	32409
500	2474	98	117	162	128	145	1824
501	4134	195	131	288	260	237	3023
502	1988	59	98	106	133	103	1489
503	1705	58	68	127	135	69	1248
504	5125	273	224	310	322	276	3721
600	1120	14	21	61	104	54	866
601	1058	44	138	67	51	33	725
602	1249	9	33	84	187	24	911
603	2090	52	281	112	150	35	1460
604	765	4	22	46	108	20	565
605	844	19	112	43	63	12	595

Step 5

Past counts were located for the same sites for the existing conditions. The earliest counts were 2008 for the ramps and freeway segments and 2012 for the arterial segments. These will be used to create a trend line to project existing condition attributes with the first being the volume profile.

Step 6

For each of the freeway, ramp and arterial volume profiles, the hourly proportions were calculated for the earlier counts as done for the existing conditions. Then the proportions were adjusted so they summed to 100% after removing the five assigned hours since the VMT is known for those hours. These adjusted proportions for 2008 (for freeway and ramps) or 2012 (arterials) along with the 2023 adjusted proportions done for the existing conditions were used to establish a linear forecast trendline to 2045 (i.e. using the "FORECAST.LINEAR" Excel function). The partial table below for the freeway volume profile shows the final adjusted 2045 proportions which also summed to 100%. The black lines represent the known VMT hours (i.e. 5-6 AM and 7-8 AM) in the partial table.

	Trend to 2045			Trend to 2045		
	2008	2023	2045	2008	2023	2045
Hour	WB			EB		
0	0.011	0.016	**0.024**	0.015	0.018	**0.022**
1	0.007	0.009	**0.013**	0.010	0.010	**0.011**
2	0.006	0.008	**0.010**	0.009	0.009	**0.010**
3	0.009	0.012	**0.017**	0.008	0.011	**0.016**
4	0.021	0.028	**0.039**	0.016	0.018	**0.021**
5						
6	0.101	0.090	**0.074**	0.056	0.054	**0.052**
7						
8	0.050	0.066	**0.088**	0.068	0.074	**0.083**

In general, the 2045 profiles made sense as the hourly fractions generally decreased in the peak periods representing further flattening or spreading of the peak periods. This was heavily influenced by direction (i.e. inbound/outbound) and facility type. Having more years in the trend may improve these relationships, but that must be weighed against the additional time and data required. There was one case for the eastbound ramp profile in the 1-2 AM period that ended up with a slightly negative 2045 proportion (-0.001). This was caused by a substantial decrease in the inputs from 0.009 in 2008 to 0.005 in 2023. In this case, the value was manually changed to 0.000 which would represent no volume in that period but could be true for these lighter-volume ramps at that hour. This did cause the sum of the hourly eastbound ramp VMT not to match the total VMT, but the overall VMT difference was 6 to 7 vehicles-miles which translates to just a 0.3% error.

Step 7

The hourly volume profile factors were then applied to the remaining VMT portion to distribute it across the other 19 hours as shown in in the partial table below. This table can be compared with the one in Example 16-12 to see the differences between 2023 and 2045.

Link ID	Link Description	Total DailyVMT	Hourly VMT (veh-mi) 12AM	1AM	2AM	3AM	4AM
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	91889	1511	742	675	1072	1404
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	42865	693	340	310	492	644
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	24694	403	198	180	286	374
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	148333	2391	1175	1069	1697	2222
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	44868	725	356	324	514	673
500	58th St EB off-ramp	2474	4	0	3	8	15
501	58th St WB on-ramp	4134	16	13	14	7	54
502	60th St EB on-ramp	1988	3	0	3	7	12

Steps 8-9

A similar forecast process was used to create the 2045 no-build vehicle class proportions using the same classification counts used to develop volume profiles.

Freeway Segments	Westbound								
	Light			Medium			Heavy		
Hour	2008	2023	2045	2008	2023	2045	2008	2023	2045
0	0.905	0.925	**0.953**	0.027	0.021	**0.012**	0.067	0.054	**0.034**
1	0.890	0.896	**0.905**	0.026	0.042	**0.064**	0.084	0.063	**0.031**
2	0.888	0.846	**0.784**	0.031	0.069	**0.125**	0.081	0.085	**0.091**
3	0.858	0.890	**0.937**	0.041	0.042	**0.043**	0.101	0.068	**0.019**
4	0.917	0.930	**0.949**	0.028	0.031	**0.035**	0.055	0.039	**0.016**
5	0.956	0.958	**0.960**	0.019	0.019	**0.019**	0.025	0.023	**0.021**
6	0.961	0.953	**0.941**	0.014	0.021	**0.030**	0.025	0.027	**0.029**
7	0.961	0.948	**0.928**	0.015	0.025	**0.040**	0.023	0.027	**0.032**

After the initial computation of proportions, any 2045 values over 1.000 or negative were flagged. These are caused by a significant positive or negative trend between the input years. While the totals still add to 100%, they may not after doing the manual adjustments. Adjustments ideally were taken from the past count looking at adjacent hours to identify potential values that are a spike or a dip. Any changed value had cell comments added to document the original value and reasons for the adjustment. The 2023 values were not adjusted for consistency as these are already used within the existing year analysis.

Arterial Segments									
	Westbound								
	Light			Medium			Heavy		
Hour	2012	2023	2045	2012	2023	2045	2012	2023	2045
0	0.938	0.965	**1.018**	0.040	0.035	**0.027**	0.023	0.000	**-0.045**
1	0.964	0.963	**0.961**	0.036	0.037	**0.039**	0.000	0.000	**0.000**
2	0.935	0.982	**1.077**	0.047	0.009	**-0.066**	0.019	0.009	**-0.010**
3	0.957	0.991	**1.059**	0.011	0.000	**-0.022**	0.032	0.009	**-0.038**
4	0.964	0.979	**1.010**	0.020	0.017	**0.010**	0.016	0.004	**-0.020**

Steps 10-11

Like what was done for the existing condition, the RITIS Performance Chart tool was used to develop the average speed by hour for April 2016 which is the earliest available data. The tool was run with matching as much as possible the links with the identified directional XD segments. The 2016 data was downloaded to Excel and forecasting functions were used to project to 2035. The combination of 2023 existing and a 2016 base year allows for a projection of seven years forward to 2030 based on a seven year backwards look. Data can also be reasonably extrapolated beyond this point up to about five years to 2035. Year 2035 was also deemed equivalent to 2045 speeds considering the tendency to overstate the actual rate of change. Trials using years beyond 2035 in the projection calculations created too many unrealistic minimum and maximum speeds.

Steps 12-13

Free-flow speeds were calculated for each facility section and lookup tables were used to limit maximum speeds to the free-flow level and to identify the appropriate speed bin. Lastly, any speeds that were projected to be lower than seven mph were changed to this minimum speed and speed bins were changed to match as necessary. The partial table below shows the 2016 actual speeds (earliest year available), the 2023 existing year actual speeds, and the projected 2035 speeds. The highlighted 2035 speeds for Link 100 were projected to greatly exceed the free-flow and thus were limited to 60 mph based on the 55-mph speed. While the 2023 speeds also exceed the free-flow speeds, these are actual reported values and it is unknown exactly what conditions will be in 2035 for volumes, vehicle class, etc. so it is best to limit these speeds to the free-flow level.

Link ID	Link Description	Time	2016 Ave Speed (mph)	2023 Ave Speed (mph)	2035 Ave Speed (mph)	Speed Bin ID#
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp					
		12AM	56.0	61.5	60.0	13
		1AM	56.7	61.4	60.0	13
		2AM	57.3	60.6	60.0	13
		3AM	57.4	61.4	60.0	13
		4AM	56.9	62.8	60.0	13
		5AM	58.8	62.8	60.0	13
		6AM	59.1	61.5	60.0	13
		7AM	58.0	58.6	59.6	13
		8AM	57.7	49.4	35.2	8

Step 14

The rest of the process is the same as done for the existing conditions. Once the hourly speed bins were identified for all the links, the light, medium and heavy vehicle hourly VMT totals were parsed into each of the 16 speed bins for each link. The partial table below shows the distribution for light vehicles for Link 100 between 12- 8 AM.

Link ID	Time	VMT Light Veh	8	9	10	11	12	13	14
100									
	12AM	1268						1472	
	1AM	568						660	
	2AM	519						602	
	3AM	908						908	
	4AM	1129						1129	
	5AM	3502						3502	
	6AM	2845						2845	
	7AM	4120						4120	
	8AM	4595	4595						

Step 15

Next, the link VMT data was consolidated down to the roadtype by classification level. All the individual hours (i.e. 12-1 AM, 1-2 AM, etc.) were summed for each roadtype and classification (i.e. Roadtype 4 & Light vehicle, Roadtype 4 & Medium vehicle, etc.) as shown in the partial table below.

Roadtype	Class	Time	VMT by Hr by Speed Bin						
			5	6	7	8	9	10	11
4	Light	12AM	19	0	4	18	0	0	0
4	Light	1AM	11	0	3	14	0	0	0
4	Light	2AM	3	0	34	0	0	0	0
4	Light	3AM	7	0	15	0	0	0	0
4	Light	4AM	23	14	103	0	0	0	0
4	Light	5AM	0	56	258	204	0	0	0
4	Light	6AM	0	79	291	0	280	0	68
4	Light	7AM	0	10164	0	242	0	0	0
4	Light	8AM	7621	2472	292	4595	0	3376	0

Step 16

The hourly VMT for each roadtype from Step 12 was summed across all the speed bins to create a subtotal. Each hourly subtotal was summed across the day to create a VMT total by roadtype. Each roadtype VMT total was divided by the total sum of all roadtype VMT to create a decimal fraction. The VMT roadtype fractions did not change from the existing in this case because of the linear projections used to develop the future no-build data.

Roadtype	Roadtype VMT Fraction
4	0.9754
5	0.0246

Steps 17-18

Each hour in the table above was summed across all speed bins to create a total. This was used to create decimal speed fractions by dividing the hourly roadtype by classification by speed VMT data by the total hourly by roadtype by classification VMT. The partial table below shows the corresponding speed fractions for the previous table. Each hourly VMT row in the table sums to 1.0000 (100%).

Roadtype	Class	Time	VMT by Hr by Speed Fractions						
			5	6	7	8	9	10	11
4	Light	12AM	0.0037	0.0000	0.0008	0.0035	0.0000	0.0000	0.0000
4	Light	1AM	0.0047	0.0000	0.0014	0.0060	0.0000	0.0000	0.0000
4	Light	2AM	0.0013	0.0000	0.0168	0.0000	0.0000	0.0000	0.0000
4	Light	3AM	0.0019	0.0000	0.0044	0.0000	0.0000	0.0000	0.0000
4	Light	4AM	0.0051	0.0031	0.0226	0.0000	0.0000	0.0000	0.0000
4	Light	5AM	0.0000	0.0035	0.0161	0.0127	0.0000	0.0000	0.0000
4	Light	6AM	0.0000	0.0067	0.0249	0.0000	0.0239	0.0000	0.0058
4	Light	7AM	0.0000	0.5721	0.0000	0.0136	0.0000	0.0000	0.0000
4	Light	8AM	0.4113	0.1334	0.0158	0.2480	0.0000	0.1822	0.0000

Quantitative MSAT Process – Future Build

If the build alignment is the same (same link network) with differing number of lanes and/or traffic control, but the volumes are the same then the build data would likely be the same as the future no-build. If the build design year volumes are different from the no-build because of latent demand issues stemming from pent-up congestion, then the daily volumes will change, and the process will be same as doing the future no-build.

The overall challenge with the future build data is when the build alignment or network layout is significantly different from the no-build alignment, the relationships between links get muddied. The peak hour and/or daily volumes would have already been re-distributed onto the build network for the project analysis. The relative relationships between the no-build and build link volumes and VMT for the project study area would need to be determined so that they could be applied to the analysis. The analyst will need to figure out separately the routing of the separate vehicle classes and resulting VMT fractions if they do not follow the same patterns as in the future no-build. New links will need traffic redistributed onto them along with the likely redistribution of all the needed vehicle classes.

The overall process is as follows:

1. Modify the future no-build spreadsheet/database file with changed or new links, updated build descriptions, lengths and roadway types.

2. Determine the link VMT for all tagged links (or pre-determined districts or subareas if doing an area-wide analysis) by using a model daily volume assignment as shown in Steps 3 through 5 for the future build scenario. The future model year used should be the closest to the project future (horizon) year. If the future model year used matches the project future year, then the model link values can be used as-is. If the model year is different, then the model year link volumes should be adjusted/interpolated to match the project future year.

3. Run a peak period assignment for each of the identified periods in the model and calculate VMT for the same links as for the daily computed in Step 2. Activity-based models (ABM) will have five periods (Early AM, AM peak, Midday, PM peak, and evening). Trip-based models will have at least two periods but could have more depending on the jurisdiction (AM peak, PM peak, Midday if available, other periods if available).

4. For ABMs, sum the peak period VMT in Step 3 and subtract it from the daily VMT in Step 2 to determine the night period VMT for each link. For trip-based models subtract the sum of the link VMT in Step 3 from the daily VMT in Step 2 to calculate the VMT daily remainder (up to 22 hours' worth) for each link.

5. Compare the future build and the no-build scenarios to determine relative changes on links to create conversion factors for each applicable period to modify the no-

build VMT into the build. For example, a link loses 30% of its volume to a new route in a certain period so a 0.70 conversion factor would be applied to the no-build VMT for all hours in that period (i.e. midday, night, etc.) on that link to convert it into the build VMT.

6. Determine the specific hours to be grouped/assigned with the known hourly assignments (i.e. using 10 PM – 5AM as the hours that will use the 5 AM early period assignment) by inspecting the future volume proportions to see if there are any natural breaks for the peak periods. Some groupings may be arbitrary as proportions may be relatively even across multiple hours. Multiply the conversion factor by the no-build VMT for each link and hour to compute the build VMT values. [Note: use of the no-build VMT here has the no-build hourly volume proportion of the no-build remaining daily VMT built in, so no extra work is needed with the volume profiles developed for the no-build.] Subtract the hourly VMT from the remaining daily build VMT to check for the overall error as it will not match exactly due to rounding and the general simplification of using groups of conversion factors. Add the determined link VMT by hour to the spreadsheet to set up for the further fractional splitting in following steps.

7. Project links that are new or have been identified to have substantial volume shifts through the previously completed project analysis may also have substantial changes in vehicle classification percentages. Relationships between the no-build and build links need to be identified in the original project analysis. If a noise analysis has been completed, use those resulting final link vehicle classification percentages for project build links. The project build links can be used to identify representative facilities (i.e. similar types and characteristics such as functional class, volume ranges and number of lanes) to estimate the future vehicle class changes on roadways outside of the build study area. If build vehicle classification percentages are not available, follow a similar process as in Section 16.3 with starting with the future no-build percentages and the link total volumes to determine initial numbers of vehicles in each classification grouping. Modify these initial volumes with those found relationships/knowledge/estimation to create final volumes. Use the final vehicle class group volumes and the total link volumes to create the final resulting vehicle class percentages. If there is no substantial change in the VMT (i.e. changes less than +/- 20% such as VMT conversion factors in the 0.80 to 1.20 range from Step 6) on a link from converting the no-build future to the build future or if there is insufficient data to determine changes to the build conditions, then continue to use the future no-build vehicle classification percentages. The 20% limit is from the potential 10% error range in data from travel demand models plus the typical 10% needed for a noticeable or substantial change.

8. Use the vehicle class groupings determined in Step 7 and multiply by the hourly link VMT from Step 6 to determine the hourly VMT by vehicle class.

9. Post-process the future build and build link travel times and link length from the travel demand model scenarios to calculate a link speed. Model travel times do not completely account for control and congestion delays so model-based speeds would not match up well if used directly with field-based speeds. For each hourly scenario, sum up the model link travel times for each facility link in this analysis. Use the same hourly groupings used in Step 6 and assign link travel times to other hours to fill out the whole 24-hour period. Convert link travel times to speeds using the link length and create a no-build to build conversion (i.e. post-processing) factor. Multiply this factor with the future no-build average speeds to obtain the future build average speed. Limit maximum speeds to the free-flow speed and minimum speeds to the future no-build default (i.e. 7 mph).

10. Identify the applicable speed bin for each hour for each link from the list below based on the speeds determined in Step 9. Use the same lookup tables used in the future no-build.
    1. Speed < 2.5 mph
    2. 2.5mph ≤ Speed < 7.5mph
    3. 7.5mph ≤ Speed < 12.5mph
    4. 12.5mph ≤ Speed < 17.5mph
    5. 17.5mph ≤ Speed <22.5mph
    6. 22.5mph ≤ Speed < 27.5mph
    7. 27.5mph ≤ Speed < 32.5mph
    8. 32.5mph ≤ Speed < 37.5mph
    9. 37.5mph ≤ Speed < 42.5mph
    10. 42.5mph ≤ Speed < 47.5mph
    11. 47.5mph ≤ Speed < 52.5mph
    12. 52.5mph ≤ Speed < 57.5mph
    13. 57.5mph ≤ Speed < 62.5mph
    14. 62.5mph ≤ Speed < 67.5mph
    15. 67.5mph ≤ Speed < 72.5mph
    16. 72.5mph ≤ Speed

11. For each link, parse the hourly link VMT by vehicle class from Step 8 into each of the 16 speed bins. This represents the finest level of VMT disaggregation by link.

12. Consolidate the binned link VMT by each roadtype. Sum the VMT for an individual hour and classification across all links of that roadtype. For example, for Roadtype 4 (urban restricted), light vehicle class, sum all link VMT for 12-1 AM for each of the 16 speed bins. Then repeat for 1-2 AM throughout the rest of the day. Then the same process would be repeated for the medium and heavy vehicles for Roadtype 4. This would continue to be repeated through all applicable roadtypes for the project.

13. For each roadway type, sum the VMT across all the classes and speed bins to create an hourly VMT total. Sum this hourly VMT to create a roadtype VMT

subtotal. Divide each roadtype VMT subtotal by the total sum of all the roadtype VMT's to create decimal fractions for each.

14. Sum up each of the hourly VMT by roadtype and classification records created in Step 12 to create an hourly total.

15. Divide the hourly VMT by roadtype, classification, and speed bin by the total hourly VMT by roadtype by classification from Step 13 to determine the VMT speed-based fractions in decimal form. Each hour in the resulting table needs to sum to 1.0000 (i.e. 100%).

Example 16-14 Quantitative MSAT Future build Conditions

This example continues the sample project analysis from Example 16-13. Steps mentioned in the example correspond to the steps shown above in the procedure.

Step 1

The same link sections and attributes such as link number, description and length were copied from the future no-build conditions.

Steps 2-4

Daily and hourly volumes for the five assigned periods (5AM, 7AM, 12PM, 5PM, and 7PM) were captured from a future build model assignment. The link length and the ADT were multiplied together to obtain the total daily VMT for each link as shown below. From this value, the known hourly VMT from the peak periods was subtracted from the daily total as was done for the existing and future no-build conditions to come up with the remaining VMT to be distributed over the remaining 19 hours of the day.

Link ID	DVMT (veh-mi)	Early 5A VMT (veh-mi)	AM 7A VMT (veh-mi)	Mid 12P VMT (veh-mi)	PM 4P VMT (veh-mi)	Eve 7P VMT (veh-mi)	Rem VMT (veh-mi)
100	91889	4150	5261	5428	5533	3938	67580
101	42865	1966	2508	2496	2628	2289	30978
102	24694	1097	1425	1428	1526	1202	18016
200	148333	8683	9828	8282	8641	5943	106956
201	44868	2562	2778	2583	2640	1896	32409
500	2474	98	117	162	128	145	1824
501	4134	195	131	288	260	237	3023
502	1988	59	98	106	133	103	1489
503	1705	58	68	127	135	69	1248
504	5125	273	224	310	322	276	3721
600	1120	14	21	61	104	54	866
601	1058	44	138	67	51	33	725
602	1249	9	33	84	187	24	911
603	2090	52	281	112	150	35	1460
604	765	4	22	46	108	20	565
605	844	19	112	43	63	12	595

Step 5

The future build link VMT was divided by the future no-build link VMT to create a series of volume conversion factors as shown below. These will allow the future no-build volume profile to be translated to the build conditions. Links that have higher volumes in the build will have factors greater than 1. Links that have decreased volume in the build will have factors less than 1.

This is a good opportunity to check to see if the changes make sense. Inspection of the table shows about 10-20% increases for the mainline links (i.e. 100 & 200 series) on I-84 with higher changes on the ramp connections (i.e. 500 series) depending on the time of day. Local roadways (i.e. 600 series) have decreased volumes by around 25%, however some have higher increases in the overnight hours. Since capacity is being added to I-84 in this scenario, it would make sense to see higher volumes on I-84 and lower volumes on the close parallel routes.

Link ID		Early 5A (vph)	AM 7A (vph)	Mid 12P (vph)	PM 4P (vph)	Eve 7P (vph)
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	1.12	1.22	1.23	1.21	1.13
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	1.10	1.21	1.20	1.21	1.12
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	1.09	1.18	1.17	1.18	1.11
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	1.14	1.18	1.15	1.16	1.06
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	1.16	1.17	1.16	1.16	1.06
500	58th St EB off-ramp	1.31	1.30	1.45	1.26	1.18
501	58th St WB on-ramp	1.28	1.08	1.21	1.20	1.05
502	60th St EB on-ramp	1.01	0.88	0.93	0.97	1.03
503	Halsey St on-ramp	1.40	1.17	1.63	1.96	1.05
504	43rd St off-ramp	1.28	1.15	1.10	1.11	1.04
600	Glisan St EB; 55th St to 58th St	1.94	0.41	0.81	0.82	0.98
601	Glisan St WB; 58th St to 55th St	1.08	0.96	1.22	0.81	2.78
602	Halsey St EB: 60th St to 67th St	0.96	0.63	0.93	0.87	0.73
603	Halsey St WB; 67th St to 60th St	0.62	0.90	0.79	0.85	0.99
604	Stark St EB; 55th St to 60th St	0.92	0.42	0.61	0.81	0.87
605	Stark St WB; 60th St to 55th St	0.50	0.76	0.69	0.75	1.00

Step 6

These volume factors for the known assigned hours were used to translate the no-build volume profile to the build volume profile. For example, for Link 100, the 1.12 factor for the early 5 AM period was assigned to all hours for the early period. This required that certain hours be grouped together to be able to assign a growth factor. Inspection of the overall volume profile showed that from 12 AM – 6 AM should be grouped with the Early 5AM assignment, 7 – 8 AM for the 7AM Peak, 9 AM to 3 PM for the 12PM Mid, 4 – 6 for the 5 PM Peak, and 7 PM – 12 AM for the 7 PM Evening periods.

The no-build hourly VMT for each link (which is made up of the hourly proportion for each facility type multiplied by the no-build remaining daily VMT) is copied into the partial build spreadsheet as shown below. The 5AM values are italicized as these are already build VMT values from the known assignment.

Link ID	Link Description	Hourly VMT (veh-mi)					
		12AM	1AM	2AM	3AM	4AM	*5AM*
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	1302	640	582	924	1209	*4150*
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	601	295	269	427	559	*1966*
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	355	175	159	252	330	*1097*
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	2134	1049	954	1515	1983	*8683*
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	644	317	288	457	599	*2562*

The calculated no-build to build conversion factors are assigned to each of the applicable hours. The 5AM column is blacked out as it had a specific hourly assignment, so no conversion is necessary.

Link ID	Link Description	Assigned No-build to Build Conversion Factors					
		12AM	1AM	2AM	3AM	4AM	5AM
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	1.12	1.12	1.12	1.12	1.12	
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	1.10	1.10	1.10	1.10	1.10	
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	1.09	1.09	1.09	1.09	1.09	
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	1.14	1.14	1.14	1.14	1.14	
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	1.16	1.16	1.16	1.16	1.16	

The no-build VMT for each link and hour is multiplied by the corresponding no-build-to-build conversion factor shown above to calculate the build VMT for each link as shown below. The total hourly VMT was checked against the total daily VMT and there was about a 1% error between the two which was deemed acceptable because of rounding and use of these simplified blocks of conversion factors. With more known hourly assignments, the overall error could be less, but this will be an overall tradeoff with the sheer number of assignment runs needed.

Link ID	Link Description	Hourly Build VMT (veh-mi)					
		12AM	1AM	2AM	3AM	4AM	*5AM*
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	1453	714	649	1031	1350	*4150*
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	660	325	295	469	614	*1966*
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	388	191	173	275	361	*1097*
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	2440	1199	1090	1732	2267	*8683*
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	745	366	333	528	692	*2562*

Steps 7-8

The assigned hourly VMT conversion factors were averaged over the entire day to determine the average change to weigh the potential of vehicle class changes from the no-build to the build as shown in the table below with some selected hours shown. Bolded values indicate links with a greater than a 20% change. Most links (63%) had a change of less than 20% including all of the freeway links and most of the ramp links. These links also carry the vast majority of the total VMT (97.5%). The local streets have the smallest percentages of medium (around 3%) and heavy vehicles (0.5%). Changes in vehicle class on these remaining links will likely not have any substantive impact overall. In addition, there was a lack of available vehicle class data for the ramps and local streets, so those already have a higher built-in level of estimation.

In all, it was decided to keep the hourly vehicle class mix at the projected future no-build levels.

Link ID	Link Description	4AM	6AM	8AM	10AM	Ave Factor Change
100	I-84 EB; Cesar Chavez on-ramp to 58th St off-ramp	1.12	1.12	1.22	1.23	1.17
101	I-84 EB; 58th St off-ramp to 60th St on-ramp	1.10	1.10	1.21	1.20	1.15
102	I-84 EB; 60th St on-ramp to Halsey St off-ramp	1.09	1.09	1.18	1.17	1.14
200	I-84 WB; Halsey St on-ramp to 58th St on-ramp	1.14	1.14	1.18	1.15	1.13
201	I-84 WB; 58th St on-ramp to 43rd St off-ramp	1.16	1.16	1.17	1.16	1.14
500	58th St EB off-ramp	1.31	1.31	1.30	1.45	**1.32**
501	58th St WB on-ramp	1.28	1.28	1.08	1.21	1.19
502	60th St EB on-ramp	1.01	1.01	0.88	0.93	0.98
503	Halsey St on-ramp	1.40	1.40	1.17	1.63	**1.44**
504	43rd St off-ramp	1.28	1.28	1.15	1.10	1.15
600	Glisan St EB; 55th St to 58th St	1.94	1.94	0.41	0.81	1.18
601	Glisan St WB; 58th St to 55th St	1.08	1.08	0.96	1.22	**1.45**
602	Halsey St EB: 60th St to 67th St	0.96	0.96	0.63	0.93	0.87
603	Halsey St WB; 67th St to 60th St	0.62	0.62	0.90	0.79	**0.79**
604	Stark St EB; 55th St to 60th St	0.92	0.92	0.42	0.61	**0.77**
605	Stark St WB; 60th St to 55th St	0.50	0.50	0.76	0.69	**0.71**

Step 9

Obtaining the 2045 build speeds requires post-processing speeds calculated from travel demand model link travel times as this is the only source of information for the build alternative. The link travel times were converted into link speeds using the known link lengths. The projected 2035 no-build future speeds from extrapolated RITIS data are deemed equivalent to 2045 considering the tendency to overstate the actual rate of change. These “2045” values were used as the field input into the calculation. The process multiplied the extrapolated field speed data by a build/no-build ratio factor to obtain the build speeds.

Step 10

The same free-flow speeds from the future no-build were used for each facility section and lookup tables were used to limit maximum speeds to the free-flow level and to identify the appropriate speed bin. Speeds improved as expected as no hours fell below the minimum speed level, so no extra adjustments were needed. The partial table below shows the “2045” (i.e. equivalent to 2035) no-build future projected speeds from RITIS data, the 2045 no-build and build model link travel times and calculated speeds using the link lengths determined for the existing conditions, the post-processed 2045 build speeds and the resulting identified speed bin. The no-build projected average speeds from RITIS were previously limited to free-flow maximums, and in these cases, the build/no-build ratio (e.g. 46.5/41.5 for 12 to 6 AM below) would likely be greater than 1.0 which would create build speeds in excess of free-flow, so these speeds were also limited to the free-flow speed as shown below.

Link ID	Time	"2045" No-bld Ave Speed (mph)	2045 No-Build Link Trvl Time (min)	2045 No-build Link Speed (mph)	2045 Build Link Trvl Time (min)	2045 Build Link Speed (mph)	2045 Ave Speed (mph)	Speed Bin ID#
100								
	12AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	1AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	2AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	3AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	4AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	5AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	6AM	60.0	1.11	41.1	0.98	46.5	60.0	13
	7AM	59.6	1.48	30.8	1.21	37.7	60.0	13
	8AM	35.2	1.48	30.8	1.21	37.7	43.0	10

Step 11

The remainder of the process is the same as done for the existing and future no-build conditions. Once the hourly speed bins were identified for all the links, the light, medium and heavy vehicle hourly VMT totals were parsed into each of the 16 speed bins for each link. The partial table below shows the distribution for light vehicles for Link 100 between 12- 8 AM.

Link ID	Time	VMT Light Veh	8	9	10	11	12	13	14
100									
	12AM	1416						1416	
	1AM	634						634	
	2AM	579						579	
	3AM	1013						1013	
	4AM	1260						1260	
	5AM	3909						3909	
	6AM	3175						3175	
	7AM	5013						5013	
	8AM	5592			5592				

Step 12

Next, the link VMT data was consolidated down to the roadtype by classification level. All the individual hours (i.e. 12-1 AM, 1-2 AM, etc.) were summed for each roadtype and classification (i.e. Roadtype 4 & Light vehicle, Roadtype 4 & Medium vehicle, etc.) as shown in the partial table below.

Roadtype	Time	VMT by Hr by Speed Bin - Light Veh							
		4	5	6	7	8	9	10	11
4	12AM	0	24	6	22	0	0	0	0
4	1AM	0	14	0	23	0	0	0	0
4	2AM	0	3	34	8	0	0	0	0
4	3AM	9	7	17	3	0	0	0	0
4	4AM	0	47	0	132	0	0	0	0
4	5AM	0	0	56	337	262	0	0	0
4	6AM	0	0	79	374	359	0	0	95
4	7AM	159	126	112	215	9123	2578	0	0
4	8AM	392	0	556	8702	2611	1474	5592	2567

Step 13

The hourly VMT for each roadtype from Step 12 was summed across all the speed bins to create a subtotal. Each hourly subtotal was summed across the day to create a VMT total by roadtype. Each roadtype VMT total was divided by the total sum of all roadtype VMT to create a decimal fraction. The results show about a 0.6% VMT increase in Roadtype 4 (freeway) from the no-build (0.9754) and a corresponding decrease in the arterial share (0.0246). This reflects the greater freeway capacity of the build alternative and a general shift toward it from the surface arterial system.

Roadtype	Roadtype VMT Fraction
4	0.9813
5	0.0187

Steps 14-15

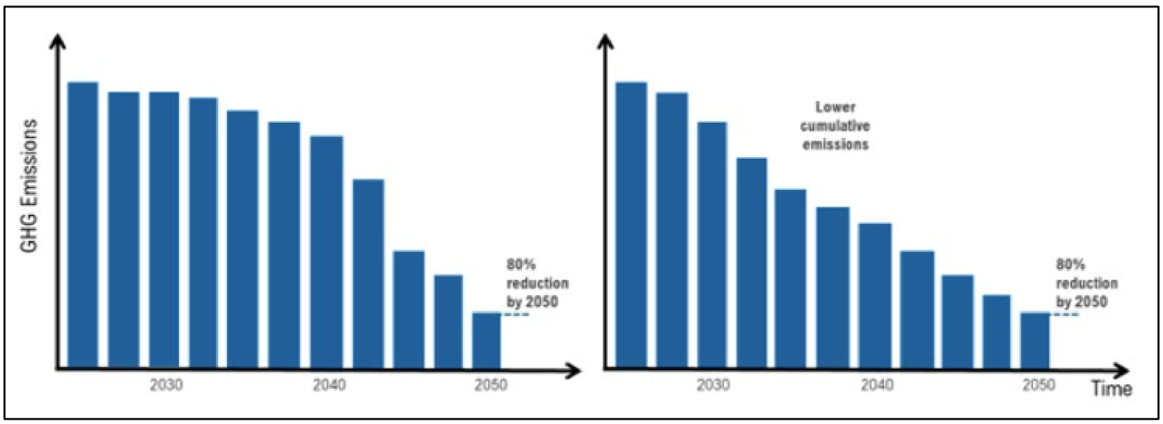
Each hour in the table above was summed across all speed bins to create a total. This was used to create decimal speed fractions by dividing the hourly roadtype by classification by speed VMT data by the total hourly by roadtype by classification VMT. The partial table below shows the corresponding speed fractions for the previous table.

Roadtype	Class	Time	VMT by Hr by Speed Fractions						
			5	6	7	8	9	10	11
4	Light	12AM	0.0044	0.0011	0.0041	0.0000	0.0000	0.0000	0.0000
4	Light	1AM	0.0053	0.0000	0.0089	0.0000	0.0000	0.0000	0.0000
4	Light	2AM	0.0012	0.0159	0.0038	0.0000	0.0000	0.0000	0.0000
4	Light	3AM	0.0017	0.0044	0.0007	0.0000	0.0000	0.0000	0.0000
4	Light	4AM	0.0090	0.0000	0.0256	0.0000	0.0000	0.0000	0.0000
4	Light	5AM	0.0000	0.0031	0.0185	0.0143	0.0000	0.0000	0.0000
4	Light	6AM	0.0000	0.0059	0.0281	0.0270	0.0000	0.0000	0.0071
4	Light	7AM	0.0060	0.0053	0.0102	0.4329	0.1223	0.0000	0.0000
4	Light	8AM	0.0000	0.0253	0.3960	0.1188	0.0671	0.2544	0.1168

16.5 Greenhouse Gas Emission (GHG) Analyses

GHG emissions (e.g. carbon dioxide, methane) measure the accumulation of carbon in the broader atmosphere that threatens the environment/climate system. GHG emission analyses may use similar tools and methods as used in the air quality analyses described in previous sections but GHGs are substantially different from the standard air quality pollutants (e.g. carbon monoxide). GHGs can persist for decades while most other pollutants disperse over a few minutes to days. GHGs are well mixed and do not have hot spots thus specific emission locations do not apply. GHGs have a resultant global impact which can impact precipitation patterns and long-term climate changes while air quality pollution tends to only affect local or regional areas population through respiratory issues. Capturing the impact of GHGs needs to go beyond just the on-road impacts of tailpipe emissions but also the accumulation over time which can have different impacts even if the desired target is met at the end as illustrated in Exhibit 16-14.

Exhibit 16-14 Two Accumulated Emission Trajectories[3]



This is normally done by considering the overall lifecycle emissions of the transportation system.[4] By calculating the GHG emissions in this way, they can be compared to Oregon's state and regional GHG reduction targets (e.g. 2024-27 STIP Handout).

GHG analyses include the three main types of annual (or daily) emissions:

- Fuel cycle (operational)
- Infrastructure cycle (construction, materials, and long-term maintenance)
- Vehicle cycle (manufacturing)

These three lifecycles and their interactions are illustrated in Exhibit 16-15. The fuel cycle captures operational emissions from on-road vehicles including the fuel efficiency

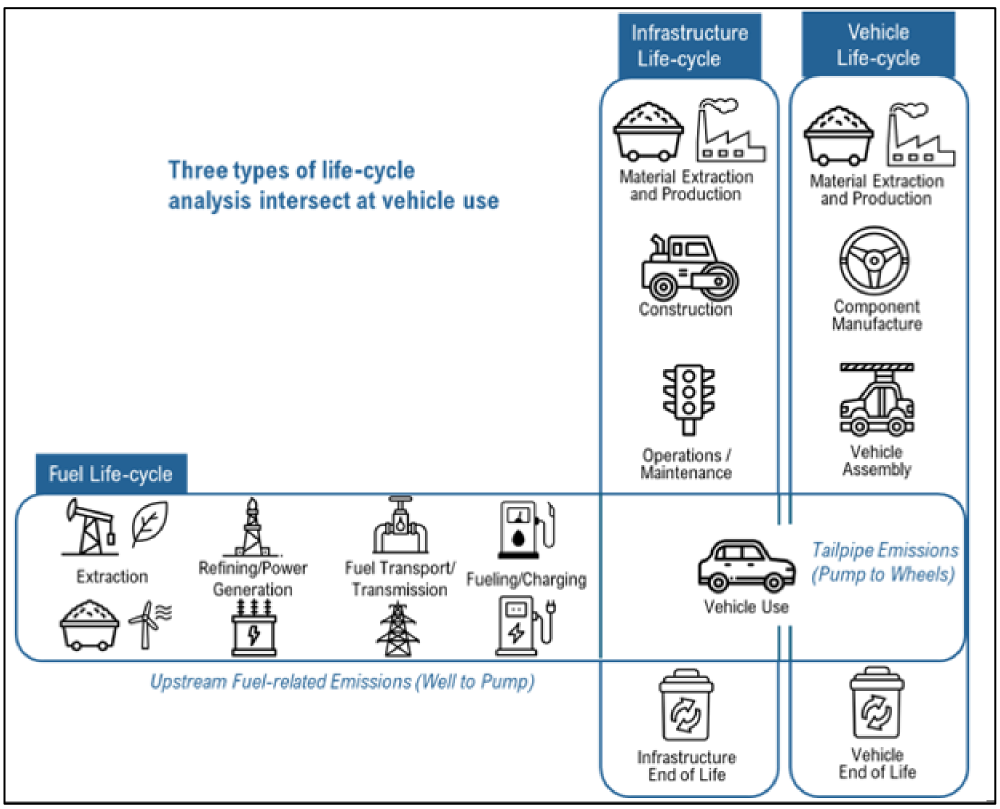
[3] From "Overview of Methods for Conducting GHG Analysis in the Transportation Planning Process", Michael Grant, ICF (TRB Annual Meeting, 2025).

[4] From "Overview of Methods for Conducting GHG Analysis in the Transportation Planning Process", Michael Grant, ICF (TRB Annual Meeting, 2025).

effect of recurring congestion if substantial. The infrastructure cycle captures emissions from construction and post-construction maintenance activities. This includes construction vehicles and materials used including any increased traffic congestion while the project is being built. Maintenance emissions are from vehicles used to perform maintenance activities (e.g. paving) periodically throughout the life of the project. The vehicle cycle captures manufacturing emissions from the impacts of materials used and following production such as steel making, battery lifecycle, and related automotive subassembly processes.

Both fuel (operational) and infrastructure (construction/maintenance) lifecycle emissions are quantified as accumulated impacts over time. The vehicle cycle with its emphasis on manufacturing is not covered by the analyses in this chapter.

Exhibit 16-15 GHG Emission Lifecycles[5]

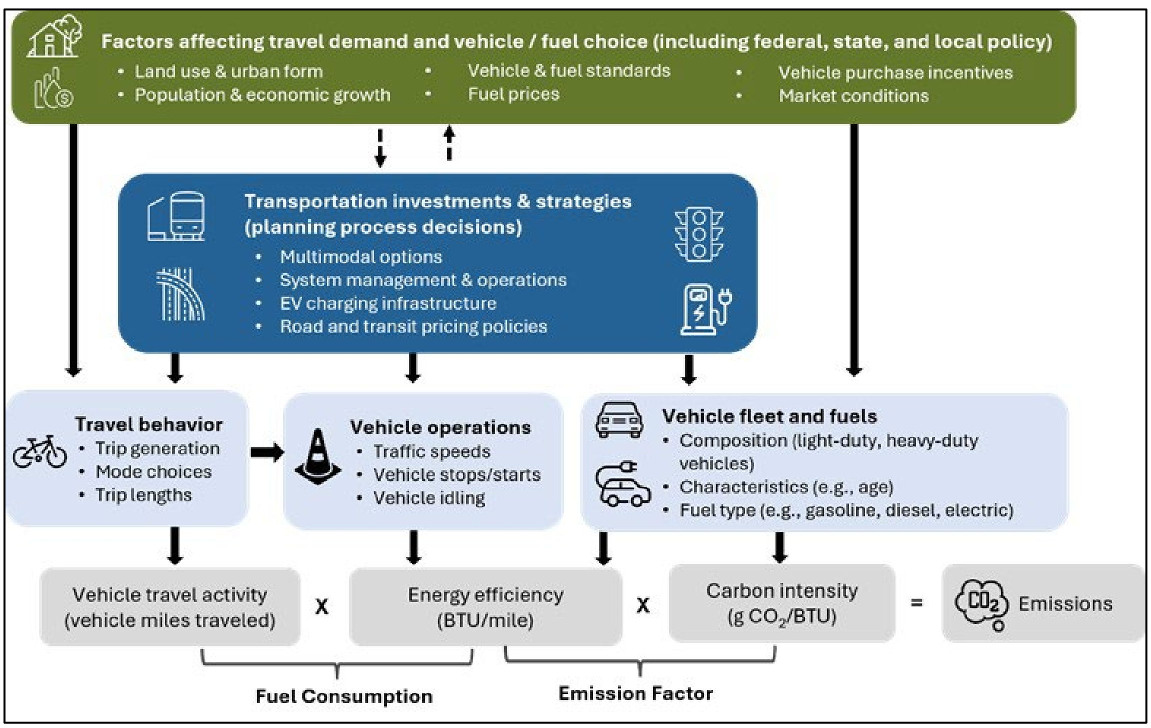


[5] From "Overview of Methods for Conducting GHG Analysis in the Transportation Planning Process", Michael Grant, ICF (TRB Annual Meeting, 2025).

Both tailpipe and lifecycle emissions (operational/user and construction emissions that result from fuel extraction, refining, and transport prior to use) are covered in the GHG calculation process in ODOT's Air Quality Manual and thus out of scope of this chapter.

Exhibit 16-16 below shows the key factors and policies that feed into the overall GHG calculation. The focus of the APM for GHG is on the production of the traffic data inputs consistent with the rest of the chapter. This means data, tools, and methods needed to support calculation of vehicle-miles traveled (VMT) for the traffic activity portion and speed-related data used that is combined with the emission factors. Application of emission factors and performing the resultant GHG calculations uses data provided by others (i.e. Air Quality/GHG analyst, Oregon Department of Environmental Quality MOVES staff) as noted throughout this chapter.

Exhibit 16-16 GHG Calculation Process Inputs[6]



[6] From "Overview of Methods for Conducting GHG Analysis in the Transportation Planning Process", Michael Grant, ICF (TRB Annual Meeting, 2025).

16.5.1 GHG Methodologies

> *The GHG guidance in this chapter (Section 16.5.2 through 16.5.4) shall only be used for planning-level analysis of ODOT projects outside of the NEPA process. The Section 16.6.5 MOVES-based emission rate method can also be used at a planning level.*

ODOT conducts technical analyses of climate change and GHG emissions during project planning. A climate lens is beginning to be employed in early project planning such as during STIP scoping of ODOT projects, largely based on what is included in the project scope and location-based attributes. In general, a planning-level analysis uses high-level estimates of activity and general design descriptions.

At the planning-level (non-NEPA), to account properly for the accumulated GHG impacts, this will still require a quantitative analysis. For example, a quantitative GHG assessment analysis will need to be performed when a project is proposed to be placed into the State Transportation Improvement Plan (STIP) for construction phase funding.

GHG planning-level analyses require a substantial amount of traffic data inputs. These inputs vary depending on the level of analysis and specific tools used along with the overall context of the project(s) being analyzed. The traffic analyst and the effort lead staff (whether being from ODOT or a consultant) will need to initially coordinate with the ODOT Environmental Section to determine the overall approach, level of analysis, tool requirements, data needs, staff resources, and schedule for the effort. Coordination should be ongoing through the life of the effort as ODOT Environmental staff will be reviewing the provided data, coordinating the latest emission rates with Oregon Department of Environmental Quality (DEQ), using the data in the determined tools and reviewing the output for consistency with expectations.

16.5.2 Tools and Project Types

Project-level GHG analyses require application of multiple tools to address the fullest range of project types. Tools can range from available individual software and spreadsheet calculators, combinations of tools in an overall process, to the custom creation of new tools or approaches. Exhibit 16-17 shows the GHG tools along with their corresponding project types. Some project types may have more than one applicable tool that could be used. Sketch tools are more appropriate for quicker analysis when less detail is available. GHG tools may either create traffic data (to be used in emission tools) or may calculate emissions directly.

In Oregon, the VisionEval tool is often used to estimate planning-level fuel lifecycle GHG emissions. As a strategic planning model, it represents “categories” of projects, and while it has an aggregate demand model, it does not have a network to code up individual projects. It is typically used to set a high-level roadmap, strategy, or vision, with more detailed tools used in implementation of long-range plans and projects. It can be used as a screening tool for quickly testing specific scenarios like doubling transit, impact of ITS operational programs, and alternative population growth or alternative fuel price or income forecasts. (See APM Chapter 7 for more on VisionEval/GreenSTEP family of tools).

Exhibit 16-17 Primary Planning-level GHG Tools and Corresponding Project Types

<table>
<tr><th>Tool</th><th>Tool Type[5]</th><th>Project Type[6]</th></tr>
<tr><td>SWIM[1]</td><td>Traffic</td><td rowspan="3">Roadway widening
New roadways
Roadway reconfigurations
Turn restrictions
Tolling</td></tr>
<tr><td>Regional Travel Model</td><td>Traffic</td></tr>
<tr><td>MOVES[2]</td><td>Emission</td></tr>
<tr><td>MOVES[2]</td><td>Emission</td><td>Roadway widening
New roadways
Roadway reconfigurations
Channelization
Turn lane improvements
Traffic control changes
Shoulder improvements
Resurfacing
Horizontal & vertical realignments</td></tr>
<tr><td>CMAQ[3]</td><td>Emission</td><td>Adaptive traffic control systems
New sidewalks, bike lanes, mid-block crossings, etc.
New traffic signals
Signal turn phasing changes
New signalized left turn lanes
Signal coordination/synchronization
Conversion to single/multilane roundabouts
Adding two-way left turn lanes
Roadway reconfigurations
Electric vehicles and charging infrastructure
Transit increased frequency, added stops, and new vehicles
Transit bus upgrades/replacement with low/no emission vehicles
Variable message signs
Variable speed limits</td></tr>
</table>

ICE[4]	Emission	New roadways Roadway widening Lane widening & shoulder improvements Roadway realignments Pavement reconstruction and resurfacing Bridges (new, reconstruction, or widening) New parking facilities (surface lot or structure) New rail facilities (heavy or light; either underground, at-grade or elevated) Bus rapid transit (new or lane conversions, stations) New or resurfaced multi-use paths New sidewalks, or restriped bicycle lanes

[1]Statewide Integrated Model
[2]Motor Vehicle Emission Simulator
[3]Congestion Mitigation & Air Quality
[4]Infrastructure Carbon Estimator
[5]The traffic-based tools need emission data and the emission-based tools need VMT & speed data to compute GHG.
[6]Curb ramp projects are a common project type but these are not covered by any existing tools and will require new approaches to assess emission impacts.

VMT data for these tools most commonly comes from SWIM or other travel demand models. VMT can also be estimated on a "on-road" basis from HPMS (i.e. daily volume times segment length) or DEQ-provided odometer data, the upcoming ODOT Research household-based VMT, or household survey data, etc. Assumptions could be made on speed data to help calculate the factors used in Exhibit 16-21. While most of the alternative VMT sources mentioned here are likely better suited to the sketch-level methods, other applications are possible. If any alternative VMT source is desired to be used, then these need to be investigated by the proposer for suitability and approved for use by the ODOT Air Quality Unit and/or the Climate Office.

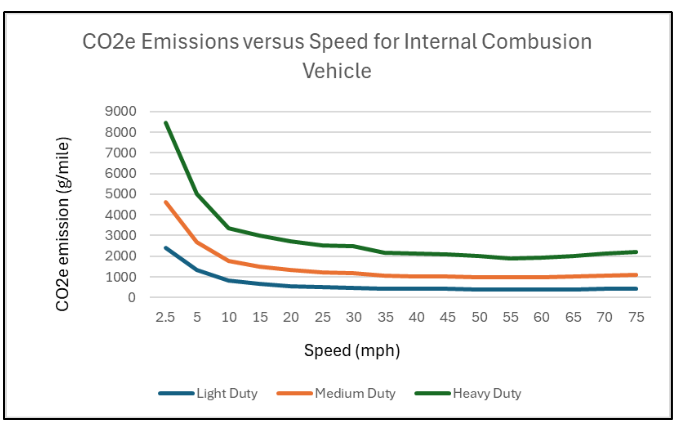
16.5.3 GHG Emission Elements

Information presented here in this section provides background and context relating to the fuel cycle (operational/user emissions) and the infrastructure cycle, (construction/materials/maintenance emissions) and their related inputs to calculate accumulated impacts that are used to develop the supporting GHG traffic data.

1. Fuel Cycle (Operational) Emissions

Operational emissions are sensitive to traffic volume, speed, roadway type (e.g. freeways), and vehicle classification. Exhibit 16-18 shows the impact of speed on carbon dioxide (GHG) emissions. Higher speeds and heavier vehicles produce higher emissions with heavy trucks producing the most per mile (approximately three times passenger cars based on MOVES data). This chart represents the operations of a fully internal combustion engine and would be expected to be less dynamic with hybrid and battery electric vehicles, and even vehicle electric stop/start technology. Speeds will be ideally based on probe data (e.g. RITIS) for existing conditions and post-processed travel demand model speeds for future conditions (see Section 16.4.3 for more detail on speed post-processing). Activity-based models (ABM) or dynamic traffic assignment (DTA) techniques can further improve the post-processed results. See Chapter 8 for more information on DTA and Chapter 17 for travel demand models including ABM. Ideally, the travel demand model would be calibrated to speed, but this is not in practice currently.

Exhibit 16-18 Smoothed & Congested Speeds vs GHG Emissions for internal combustion vehicles[7]



*Includes fuel cycle emissions; derived from EPA MOVES5

[7] Barth, M. and K. Boriboonsomsin. Real-World Carbon Dioxide Impacts of Traffic Congestion. Transportation Research Record: Journal of the Transportation Research Board, No. 2058, 2008, pp 163-171.

Calculation of annual accumulated emissions require several time periods both over a year (i.e. seasonal as emissions do vary and are accounted for in the emission rates) and time of day (i.e. by hour). Calculation of the required VMT fractions by speed, time, roadway, and vehicle classification are shown in Section 16.4.3 (MSAT analyses) and in Section 16.5.7. Typically a travel demand forecasts an average day with VMT by speed across the various hours of that day, which is then annualized by multiplying by 365.

Study area boundaries: Analysis boundaries should extend beyond the actual physical improvement limits as effects usually extend further, especially under congested conditions. Boundaries on arterials, expressways or freeways should extend to the next signalized intersection or interchange. If the extent of congestion is known either from available documentation or from RITIS tools, then the boundaries should encompass the congested extent. If time permits, it may be best to create a model scenario and track the substantial change (i.e. +/- 10% or greater change) from a roadway project such as a roadway reconfiguration or expansion to determine the overall extent.

Traffic volume forecast growth: The relative change between the existing year and the future and/or interim years for the build or no-build can be captured by breaking down the growth into yearly fractions forecasted by the travel demand model to create an unique volume set for each standard year (i.e. existing/base, opening/build, and design) and all desired interim years. If a calibrated model sub-area analysis was used, then the model volumes produced could be used directly as outputs. If a full travel demand model scenario was used to develop the original project volumes, then the relative change could be post-processed (following Chapter 6 and NCHRP Report 765) using available existing year AADT or hourly counts to tie the forecasted volumes to a realistic base value. Alternatively, for large scale/county/regional analyses, like for the MSAT process, growth would be generally based on the applicable travel demand model base and future no-build and build scenarios.

Calculating VMT in five-year increments is important to properly capture the substantial change in emission rates per mile as the expected transition to electric vehicles during the next 30 years occurs. VMT can be assumed to be a linear interpolation, which would be combined with the non-linear forecast of emission rates reflecting the vehicle adoption curve. This is discussed further in Step 3 (Combined Accumulated Emissions). An example of interpolating modeled VMT to match the emission rate dimensions (speed bin and vehicle type) and then calculating the accumulated emissions over the project lifecycle are included in Section 16.5.7.

Travel models should use the standard assumptions for adding new capacity (new through lanes) in build scenarios. Certain auxiliary lanes may add capacity such as turn lanes and longer weaving lanes, while some will not such as climbing/passing lanes, accel/deceleration lanes and shorter weaving lanes. See Appendix 10A for guidance on determining capacity thresholds for auxiliary lanes. See Section 6.12.2 for determining the risk of your project for latent and induced demand, leading to adjustments in the analysis approach to capture those effects.

Travel demand models may have difficulty in assessing the full benefits of improvements depending on detail level (i.e. ABMs would likely have less issues than a standard trip-based model). These may need to be augmented by sketch-level analyses and related more-detailed facility-level assumptions.

Analysis of VMT data in metropolitan areas has specific GHG targets (OAR 660-044-020/025) which work out to be VMT per capita targets, as they assess local actions "beyond vehicle and fuel technology". As such, while these targets were set with the VisionEval model, progress can be assessed with a travel demand model, without combining VMT with emission rates, as noted in this chapter. See Appendix 17B for the methods assumed in the TSP analysis, including how to pull the specific household-based VMT defined in these rules.

Reoccurring and non-reoccurring congestion: Regardless of methodology, the AADT and VMT values should reflect reoccurring and non-reoccurring congestion so the effect of volumes, incidents, events, and severe weather can be captured. Use of peak spreading techniques or potentially dynamic traffic analysis if warranted or available (See Chapter 8) should be used if the project area has persistent congestion when peak periods extend across multiple hours or portions of the day. In general, traffic data needs to be provided by speed, roadway type (i.e. freeway, arterial, or ramp), vehicle type (i.e. light vehicles, medium trucks, and heavy trucks) and by individual hours which are the same requirements for an MSAT analysis in Section 16.4.3. This will enable calculation of accumulated emissions over all hours and all days of the year and interpolating that data into interim years.

Under congested conditions the initial base speed inputs should always be using the prevailing operating speed rather than a posted speed limit. Posted speeds should not be used in a GHG analysis as they are not generally representative of conditions. Posted speeds could easily overstate speeds in congested areas while understating the same areas under free-flow (e.g. night operation) conditions. These could be based on a combination of private probe data sources (e.g. RITIS) for the existing conditions with travel demand models either with a full model or a sub-area defining the changes over time (typically in five-year increments) for future years. FREEVAL (see Chapter 11), a calibrated micro-simulation, a calibrated-for-speed travel demand model, or post-processing travel demand model link speeds will help calculate speeds that could be used in the GHG emissions analysis.

Travel demand models typically only account for reoccurring congestion because of roadway capacity limitations. Regional MPO models usually do a better job estimating speeds as the overall process is more rigorous with activity-based models providing better values than trip-based ones. Regardless of model type, travel model speeds should not be used directly as these models do not validate speed outputs as direct use of these could over/underestimate the potential GHG emissions. Ideally, a travel demand model would need to be calibrated for speed or at the very least model link speeds must be post-processed with known probe speeds, so the reoccurring congested speeds are correctly represented (see Section 16.4.3 in the MSAT future no-build and build calculation steps) over each modeled period. Even with post-processing, resulting speeds may be too high or low and thus need to have bookend speed values established and speeds modified to match those upper and lower bounds. Future year and interpolated years have a high uncertainty for speeds as congestion does not grow in a linear matter over time.

For analyses with substantial non-reoccurring congestion, using RITIS Probe Data Analytics Congestion Scan or Causes of Congestion tools can quickly evaluate the existing year conditions over that entire year to for substantial impacts from incidents, weather, construction/other full/partial closure events that are beyond the typical reoccurring congestion patterns. These impacts can be evaluated on travel time, user delay or speed basis which can be incorporated into the analysis (e.g. assuming a lower operational average speed).

Alternatively, operational models (see Chapter 11) at the meso or micro scale can be constructed to evaluate the effects of incidents, special events, and adverse weather conditions (see Appendix 11F for guidance on developing related adjustment factors). These models can be complex and time-consuming to construct, however, if the operational analysis used these reliability methodologies already, extra time would not be necessary. However, if it desired to include the effects of weather on future no-build and build alternatives, including interim years, then this will require the extra effort to modify these models for projected future impacts.

The ODOT Climate Office can help identify information sources/guidance to better include future severe weather risks due to climate change impacts. These models also better capture the effects of queue spillback in reoccurring congestion. Micro-simulation is too detailed for a reliability analysis for a regional area but could be developed to provide congested speeds on a facility-level basis. There is potential for mesoscopic simulation to help fill in the non-reoccurring data knowledge gap for larger areas, but those tools have not been explored at the time of this writing.

Planning-level analyses covering larger areas involving many roadways, can use the SHRP2 reliability screening methodology shown in Section 11.5 for any freeway, multilane highway and urban arterial facility. This process could be potentially semi-automated with the use of consistent input/output datasets and scripts to provide more robust reporting of the variation in speeds so important in GHG analysis.

Emission rates: These usually include the effects of different fuels and fleet mixes at different speeds, roadway type, vehicle/fuel types in the overall rate. Section 16.5.5 provides approach for MOVES-travel model methods. The emission rate method can be applied by the travel modeler with emissions data provided by ODEQ. For more involved MOVES inventory methods additional coordination is needed with the AQ analyst. Emission rates are applied outside of the traffic data development process, which for the 16.5.6 is a straight-forward post-processor on the travel model outputs (Figure 16-21).

Contact the ODOT Air Quality lead for more details and any seasonal requirements needed (i.e. identification of specific periods to be used).

Uncertainty: Given the general low-level of details available, especially at the scoping level even for construction phase projects where many of the GHG analyses are done, and the companion inherent assumptions that also must be taken (e.g. disaggregation to speed bins and vehicle types, EV adoption and vehicle size assumptions in MOVES forecasts) will mean that there could be considerable uncertainty in the final results. Traffic volumes can easily vary 10% across days with similar characteristics. Travel demand models usually have an uncertainty range of 10-20% as volume calibration is only done on certain links with most in higher functional classes, so it is unlikely to be able to have full confidence in values in less than +/- 10% - 20%. Where possible, reporting results over a range may be better than an explicit value. When full details are available as part of a refinement planning effort it should be possible to have confidence in values down to a +/- 10% range.

2. Infrastructure (Construction, Materials & Maintenance) Emissions

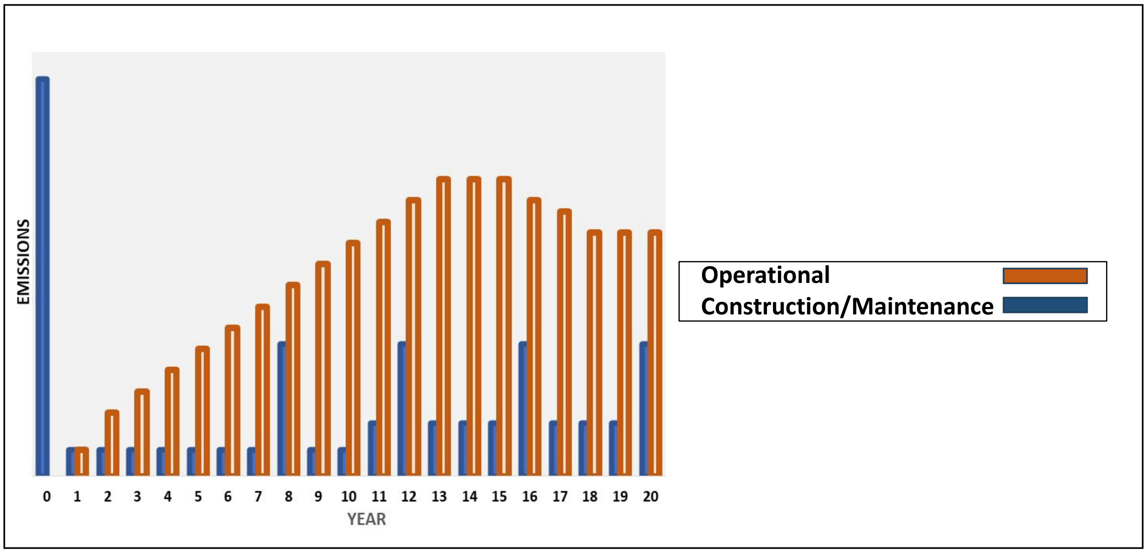
Construction emissions include the embodied emissions used in the materials used to build the project as well as from construction traffic delays. Maintenance emissions are from fuel and materials used in routine activities such as re-surfacing. Both types of emissions are best calculated in FHWA's sketch-level Infrastructure Carbon Estimator (ICE) spreadsheet tool. The tool requires a minimal set of data to calculate yearly GHG estimates (See Section 16.5.4). The tool can output total cumulative emissions over the project horizon (e.g. could be any duration; 20 or 30 years is typical), or alternatively, the annual average of the time period selected. Traffic data inputs should be created for each analysis year using the same assumptions as used for the fuel cycle (operational) emissions for consistency.

3. Combined Accumulated Lifecycle Emissions

Emissions from both the operational/user and construction/maintenance aspects need to be combined cumulatively for the life of the project as it is the accumulation of lifecycle GHG emissions over time that has the impact on the climate, instead of just relying on the typical base, year of opening, and future year data points. These accumulated emissions represent the overall project impact which is the difference between the no-build and the build conditions. For GHG reporting, these emissions will need to be converted to lifecycle, rather than tailpipe emissions, including upstream fuel cycle and electricity emissions. This fuel lifecycle accumulated GHG allows tracking progress against the state's 2050 GHG reduction goals represented in the Statewide Transportation Strategy (STS) and the Oregon Transportation Emissions Website.

Exhibit 16-19 shows how the fuel cycle (operational) and infrastructure (construction/maintenance) emissions occur over time. Initially there is a large construction emission as a project is built, but then maintenance emissions occur at regular intervals as part of normal minor or major maintenance activities. The operational emissions track the normal growth of traffic volume over the project horizon. The exhibit shows the GHG emissions that accumulate from a single build scenario. A no-build scenario would be similar but without the initial construction emissions and would have differing levels of operational and maintenance emissions following. Reported accumulated emissions are normally the change between the no-build and build conditions.

Exhibit 16-19 Accumulated Emissions[8]



Typically, this calculation of project impact (build vs. no-build) is suggested to be done in five-year increments via a series of interim years covering the time span between the base year and 2050, or project year horizon. The interim years are necessary since fleet electrification and thus GHG emission rates will not follow a linear curve over time. In contrast, traffic data (VMT by vehicle type) for these interim years can be assumed to be more linear which allows for interpolation to simplify the analysis burden. Accumulated impacts should be calculated for all analysis levels (see Sections 16.5.4 through 16.5.6).

The air quality analyst will take the interim year traffic data inputs and use the appropriate emission tools (e.g. CMAQ sketch -level, ICE, or MOVES regional or project-level) to produce an estimate of GHG lifecycle fuel (operational) and infrastructure (construction/material/maintenance) emissions for the same interim years All interim years would be summed to estimate the total accumulated effect for fuel cycle (operational) and infrastructure (construction/maintenance) lifecycle GHG emissions.

Creation of discrete volumes for interim years would be preferred as this would have less

[8] From "Overview of Methods for Conducting GHG Analysis in the Transportation Planning Process", Michael Grant, ICF (TRB Annual Meeting, 2025).

consistency issues as growth change may not be the same across the period. Discrete volumes allow for multiple inflection points to be added which could have more or less growth than previous or subsequent periods. However, project budget, schedule and data availability may not allow this level of work, so interpolation becomes the next best choice. Having five-year interpolated increments will allow for reasonable inflection points that will track the emission rate change appropriately without creating a huge level of effort.

No-build scenario interim year AADT/VMT and vehicle fractions should be interpolated from existing (base year) & future no-build years. The same can be done between build year (year of opening) and future build (design) year for the build scenario. Section 16.5.7 shows a process that can be used to interpolate interim year values for VMT by speed and vehicle type. Generally, each project operational analysis would have scenarios for an existing base year, a future no-build and a future build as each of these three builds on each other. Since interpolation will be needed to create interim years for the build scenario, a build year (year of opening) scenario will also be needed. Without a year of opening scenario the future no-build growth factors would need to be used to extrapolate the interim build years, but these no-build growth factors will not be the same as the build growth factors which would produce inconsistent results

Unlike volumes, speeds are generally not linear, so straight-line interpolation or extrapolation may not be as accurate. The interpolated interim year volumes can be input into a calibrated micro-simulation, travel demand model, or a deterministic facility analysis software tool (e.g. FREEVAL, Highway Capacity Software, etc.) to calculate corresponding speeds. These calculated speeds could be combined with other volume-based sources (e.g. ATRs, roadway tube classification counts) so that the relationship of speed and volume can be shown ideally in the project or local area so a likely curvilinear projection or speed profile can be developed to parse the VMT data of each vehicle type into each speed bin. Speed changes, especially for trucks, can show substantial GHG reduction even if VMT is not changed. Given the complexity in interpolating both speeds and vehicle type, it is important to check for reasonableness in the resulting values, especially if the project is designed to have different effects on different vehicle groups, such as a truck-only lane.

Currently, the available historic probe speed data will not cover the required 20+ year set of future congested link speeds to determine the resulting interim years in a typical project via regression, so alternative sources will be needed. A future forecast can be supported by looking back just as far as going forward (i.e. 10 years of historical data could support a projection 10 years in the future). Stretching the projections beyond the historical basis for all the desired interim years will likely not be accurate as the representation of the past is not necessarily what the future will be reflecting (i.e. adoption of electric vehicles, impact of CAVs, etc.). Also, speeds could be easily over or underestimated with long-term extrapolation and may need to be capped or minimum speeds established (see the MSAT future no-build section Steps 11 & 12 for more information).

Post-processing travel demand model speeds will be likely the most straightforward way of obtaining multiple interim future year speeds for multiple segments. This will require a robust existing field speed base from probe data (e.g. RITIS) which will be applied to a speed factor from the model (i.e. future model speed divided by the base model speed for each needed segment). The overall limitation of this method is the ability of the model to capture link and nodal congestion. An activity-based model (see Chapters 7 & 17) or a dynamic traffic assignment model scenario (see Chapter 8) would be superior to a standard three or four-step travel demand model, but these are much more complex to create.

Other Oregon locational (or national although this is not preferred) data for use in speed projection could be used if nothing else is available, but ideally the base area/facility characteristics should be as close as possible. For Oregon sources, use of the ATR characteristic seasonal trend groupings (see Chapter 5) can help identify the most applicable areas including any known caveats. One of the important caveats that likely directly applies to this section is that Interstate/freeway sources should not be used on other facility types as it is known that the characteristics are considerably different.

16.5.4 Sketch-level Methods [for Non-NEPA Planning Analyses]

Fuel Cycle (Operational) Emissions

The "Handbook for Analyzing Greenhouse Gas Emission Reductions in Western States" is an additional source of sketch-level project type applications for computing GHG reductions. The GHG methodologies are modified from California and uses state-specific data used to support planning-level analyses in Arizona, Colorado, New Mexico, Oregon, and Washington. The guidance covers all the emission sectors, not just transportation. Within the transportation sector, measures and related calculation methodologies, default values and related guidance are broken into seven groupings:

- *Land use – includes transit-oriented development and street connectivity*
- *Trip reduction programs – includes transportation demand management volunteer and mandatory programs, ridesharing, vanpools*
- *Parking/Pricing management – includes EV charging, on-street parking costs*
- *Neighborhood design – includes pedestrian/bike network improvements, bike facilities, car/bike/scooter share programs*
- *Transit – includes transit network coverage/frequency improvements, bus rapid transit, shelter improvements, transit-supportive roadway treatments (queue jumps, bus lanes, transit signal priority, etc.)*
- *Clean vehicles and fuels – includes EV, natural gas/propane, ethanol and biodiesel-fueled fleet purchases*
- *School programs – includes school bus programs, Safe Routes to School projects*
- *Additional project and project element types are included in Appendix 16D.*

Data requirements, like the CMAQ & ICE tools, are generally light with defaults or guidance on recommendations given. These may include general planning-level data such as number of miles of bike lanes or percentages of bus routes or data elements that are traditionally available from travel demand models such as average trip length. Appendices show specific state defaults and input data for additional reference.

The sketch-level method is used for simple applications where full MOVES-level details are not needed. For federal reporting, FHWA maintains a CMAQ (Congestion Mitigation & Air Quality) toolkit webpage where the tools and reference materials are stored. These Excel-based spreadsheet tools are based on national vehicle fleets and fuel source assumptions, however many of the modules below can accommodate specific vehicle mixes (e.g. heavy truck percentages) or fuel/VMT sources to customize the tool as much as possible to the specific area. There will be differences between the built-in assumptions and Oregon's such as for the proportion of electric vehicles assumed in the fleet used to calculate the GHG values. It is always a tradeoff on level of effort vs level of detail on deciding whether to accept a default or use a specific value, but these differences are generally acceptable at this sketch-planning level in order to save on effort. If available, Oregon-based data is preferred. CMAQ methods can be supplemented, particularly for Oregon-reporting, with other sketch-tool methods included in this section.

The most common project types that may come up in a scoping, programming, or operational process that also have CMAQ tools available. The below tool list is not inclusive:

- Adaptive Traffic Control Systems
- Bicycle and Pedestrian Improvements – Adding new sidewalks, bike lanes, mid-block crossings, etc.
- Congestion Reduction & Traffic Flow Improvements – New traffic signals, adding turn phases, adding signalized left turn lanes, traffic signal coordination, single/multilane roundabout intersection conversions, adding two-way left turn lanes (TWLTL). Roadway reconfigurations (e.g. road diets) can also be assessed using a combination of the TWLTL and bicycle/pedestrian modules.
- Electric Vehicles (EV) & EV Charging Infrastructure – replacement of conventional vehicles and development of EV charging infrastructure
- Transit Service & Fleet Expansion – Increased frequency, added stops, and new vehicles
- Transit Bus Upgrades & System Improvements – replacement of conventional buses with electric vehicles or replacement/retrofit with cleaner/alternative fuels
- Travel Advisories - VMS (Variable message signs) and VSL (variable speed limits)

These tools generally require a moderate number of inputs and the air quality staff doing the GHG calculations can handle some of them (e.g. Project evaluation year). Depending on the specific tool and project type, there are many inputs that the project traffic analyst will need to provide as shown for each following tool. Tool modules can be combined as many project types will have multiple elements. The data inputs or related calculations needed to create them for each project analysis should be kept on separate tabs with the Excel spreadsheet tool for organization purposes. Some default inputs are based on national data, however these generally do not match too well with Oregon, so state-based data is preferred where possible. The new 2025 Oregon Travel Survey data results should be used, or if not available, data from the earlier 2010 Oregon Household Activity Survey.

Traffic data inputs need to be calculated for all analysis years (base, future and all needed interim years) to be able to assess for accumulated lifecycle GHG impacts.

Outputs depend on the tool, but most modules have both traffic performance and emission output summaries. Performance outputs can include items such as VMT, capacity, volume, speed, and travel time across peak, off-peak or daily conditions for both the existing and proposed conditions. All the tool modules below output CO_2 and (equivalent) CO_{2e} reductions that reflect the changes between the existing and proposed conditions. The CO_{2e} emission outputs can be used directly in reporting the GHG results. The performance outputs can be used to help explain and add context to the GHG results (e.g. reduced delay or VMT) by the appropriate air quality/GHG/environmental staff.

It should be noted that the CMAQ tool, since it was developed for air quality pollutants, does not typically account for the full lifecycle emissions. Lifecycle emissions are beyond the scope of this tool and should be coordinated with the ODOT Air Quality analyst before starting work. In some cases the emission rate data tables (Section 16.5.6, Figure 16-20) may be useful. If warranted, future guidance may provide more standardized methods to expand to lifecycle. Even with just the tailpipe portion, emissions accumulated over the lifetime of the project are still possible.

CMAQ Adaptive Traffic Control System Traffic Inputs

This toolkit is intended for application for projects that implement a new adaptive traffic signal control system on an existing signalized corridor.

- **Area type** – Rural or urban
- **Corridor length (mi)** – Distance from center of first signalized intersection to last signalized intersection for each adaptive system extent
- **Number of signalized intersections** – Number of consecutive signalized intersections included in the adaptive system. If there is an intersection gap in the proposed corridor, then each section should be analyzed separately.
- **Total peak hours per day** – Total average weekday peak hours across all peak periods (i.e. AM, PM, etc.). Ideally, this would be based on a visual inspection of a volume profile determined from 48-hr roadway tube classification counts (at least a single or an averaged set of multiple counts if volumes change by more

than 10% along the corridor) in the corridor. Future and interim year conditions could use the peak hour spreading techniques in Chapter 8 to modify the volume profile either with or without a travel demand model.

- **Free-flow speed or posted speed limit (mph)** – A probe-data based free-flow speed is preferred for existing conditions. If probe data is not available, see HCM 7th Edition Equation 18-3 for estimating urban street segment free flow speed. This is a function of speed limit, median type, curb presence, access density and parking. If the posted speed changes along the corridor, weight-average the calculation. Future and interim conditions should use estimation methods or defaults shown in APM Appendix 11A to estimate the free-flow speed if the parameters in the HCM equation cannot be estimated sufficiently.
- **Total volume on corridor (vph) –** Average of both directions of the weekday peak and non-peak hourly volumes. Summing the volumes for the peak and non-peak periods and average to a single hour for both based on the counts used to determine the total peak hours per day above. Average daily volumes (ADT) can be used with a representative K-factor to create peak hour volumes if count-based peak hour volume are unknown. For future and interim conditions, the weekday peak and non-peak volumes will need to be projected to the desired future year following Chapter 6 procedures.
- **Existing total corridor delay (s/veh)** – Calculate total corridor delay as an average of both directions using existing conditions probe data travel times compared to the free-flow travel time using the and the free-flow speed above. Future and interim year delays will need to be estimated from future projected volumes and deterministic analysis software to estimate average speeds and or travel time and intersection control delay (see Chapters 11 through 13) or microsimulation (See Chapter 15) if a separate project analysis is available. Travel demand models (See Chapter 17) can be used as a last resort for speed/travel time determinations if the produced speeds can be accurately calibrated to existing conditions or at least shown that they are representative of actual observed speeds, especially for congested areas.
- **Truck percentage –** Calculate the heavy truck percentage (FHWA Class 6-13) for peak and non-peak periods from a classification count done on the corridor or a representative one elsewhere that has similar characteristics (see Chapter 5). The count, ideally, would be the from the same group of counts used along the corridor that was used to develop other values for this tool. These values need to be an average of any classification counts done on the corridor and with both directions averaged together. Future conditions should use the same percentages as calculated for existing.
- **Corridor delay reduction per vehicle (s/veh)** – Value is optional. This should only be used if there are actual delay reductions available such as from a deployed system or from a microsimulation of a deployed system from a project-level analysis. Like with the total corridor delay, this value needs to be shown for the peak and non-peak periods and based on an average of both directions along the entire corridor.

CMAQ Bicycle and Pedestrian Improvements

This toolkit is intended for any project type that is estimated to divert trips from the automobile mode to the bicycle or pedestrian mode. It is recommended that these projects are included in a travel demand model scenario so that the potential mode shift can be accurately calculated.

> *It is recommended that Bicycle and Pedestrian LTS (See APM Chapter 14) be evaluated for projects under this toolkit to assess the impact on those modes, such as from longer crossing distances and higher AADT.*

- **Daily individual motorized trips by mode –** Number of one-way trips by passenger vehicles (FHWA Class 2 & 3) on a daily basis before and after the project. Small point-level (i.e. intersection) projects can use an available classification count (See Chapter 3) or existing classification data for state highways. Multiply trips by two if directional volumes are not available. Larger corridor and area-type projects should be modeled in travel demand model scenarios with and without the project. These scenarios should include the entire project area plus an appropriate buffer area equal to the typical regional modal trip length (i.e. ¼ mile for walking or a maximum five miles for biking) to capture any trip diversions.
- **One-way trip distance source –** For small projects or ones where travel demand models are not used, choose "Average" but for any projects that use travel demand models to calculate the number of diverted trips above, choose "Distribution."
    - **Average trip distance (mi)** – For any project with the Average trip distance source, use Oregon-based travel survey data over the default national values available.
    - **Distribution of trip distances (%) –** Use the available model trip distribution for determining the diverted trips for the following distance bins: < 1 mile, $1 \leq x < 2$ miles, $2 \leq x < 3$ miles, $3 \leq x < 4$ miles, and $4 \leq x \leq 5$ miles.

CMAQ Congestion Reduction & Traffic Flow Improvements

This toolkit contains several different project types separated into different modules: intersections, traffic signal synchronization, roundabouts, and two-way left turn lanes (typically added in rural to urban cross-section roadway upgrades or reconfigurations).

The MOVES-based methods shown in Section 16.5.5 are best for roadway expansion and some smaller roadway projects over use of this CMAQ tool.

The intersection module is intended for a single typical four-legged intersection. Intersections with three legs or more than four will be likely more of an approximation. The module covers the following intersection project types:

- New traffic signal replacing two-way or all-way stop control.
- Adds or modifies left or right turn phasing
- Adds a new left turn lane with corresponding left turn phasing

It is recommended that Bicycle and Pedestrian LTS (See APM Chapter 14) be evaluated for projects under this toolkit to assess the impact on those modes, such as from longer crossing distances and higher AADT.

Intersections

- **Area type** – Rural or urban
- **Business district** – Select "yes" if located within a central business district (CBD).
- **Total peak hours per day** (hrs) – Total average weekday peak hours across all peak periods (i.e. AM, PM, etc.). Ideally, this would be based on a visual inspection of a volume profile determined from 48-hr roadway tube classification counts (at least a single or an averaged set of multiple counts if volumes change by more than 10% along the corridor) in the corridor. Alternatively, probe speed data (e.g. RITIS) could be used to determine the peak periods for existing conditions. Future and interim year conditions could use the peak hour spreading techniques in Chapter 8 to modify the volume profile either with or without a travel demand model. If unknown, the default four hours (assuming two-hour AM & PM peaks) can be used.
- **Existing intersection traffic control type** – Signalized or un-signalized
- **Existing AADT, Roadway 1 (vpd)** – Sum of the AADT for both approach directions for the main subject roadway. Volumes can be obtained from the Transportation Volume Tables or created from ADT or peak hour volumes with seasonal and K-factors as appropriate (see Chapter 5).
- **Existing peak hour volume (vph)** - Average of both directions of the weekday peak period volumes. Sum the volumes for each individual peak hour (if known) and average to a single hour. Average daily volumes (ADT) can be used with a representative K-factor to create peak hour volumes if count-based peak hour

volumes are unknown. For future and interim conditions, the weekday peak and non-peak volumes will need to be projected to the desired future year following Chapter 6 procedures.

- **Existing number of lanes** – Total number of through lanes in one approach direction only. If the number of through lanes is different per direction, use the highest value.
- **Truck percentage (%) –** Calculate the heavy truck percentage (FHWA Class 6-13) for peak and non-peak periods from a classification count done on the corridor or a representative one elsewhere that has similar characteristics (see Chapter 5). The count, ideally, would be from the same group of counts used along the corridor obtained from OTMS that was used to develop other values for this tool. These values need to be an average of any classification counts done on the corridor and with both directions averaged together. Future conditions should use the same percentages as calculated for existing.
- **Existing delay per vehicle for Roadway 1 (s**) **-** Calculate total delay per vehicle in terms of the greater delay value of the two directions. Ideally, this value would be from using existing conditions probe data (e.g. RITIS) travel times compared to the free-flow travel time using. Future and interim year delays will need to be estimated from future projected volumes and deterministic analysis software to estimate average speeds and or travel time and intersection control delay (see Chapters 11 through 13) or microsimulation (see Chapter 15) if a separate project analysis is available. Travel demand models (see Chapter 17) can be used as a last resort for speed/travel time determinations if the produced speeds can be accurately calibrated to existing conditions or at least shown that they are representative of actual observed speeds especially for congested areas.
- **Existing left and right-turn phases for Roadway 1** – Choice of "yes" or "no". If intersection is unsignalized, use "no."
- **Proposed cycle length (s)** – Use the known cycle length for the intersection. Otherwise, defaults of 60, 90 or 120 seconds for two, three or four-phase intersections, respectively can be used. The tool default is 90 seconds.
- **Proposed number of left-turn lanes for Roadway 1 & 2** – Enter in the number of left turn lanes for both roadways that will be constructed.
- **Proposed left and right turn phases for Roadway 1 & 2** – Choose "Yes" or "No" depending on whether protected left and right turn phases for both roadways will be used.
- **Green time to total cycle time (g/C) for Roadway 1 & 2** – Enter in the estimated g/C ratio for both roadways. The sum of the two roadways must sum to 1. Ideally, this will come from the existing deterministic project traffic analysis or can be estimated using an HCM-compatible analysis using appropriate defaults and values consistent with the other tool inputs.

Volumes, cycle length, g/C ratio or delay may need to be modified by the analyst if computed existing v/c is over 1.0 to arrive at a v/c ratio ≤1.0 as tool does not produce any emission reductions at v/c's that exceed capacity.

Traffic Signal Synchronization

This module is only intended for coordination of existing traffic signals, and not for adding new ones. New signals are covered in the section above on intersections.

- **Road type** – Choice of rural or urban
- **Corridor length (mi)** – Length of the signal coordination project. The default is one mile if the exact length is unknown.
- **Number of signalized intersections** – Number of signalized intersections affected by the project with a required minimum of two sites.
- **Number of lanes** - Use the number of through lanes for one approach direction.
- **Posted speed limit (mph)** – Use the weight-averaged posted speed limit along the project corridor.
- **Average cycle length (s)** – Average the cycle length for the traffic signals along the corridor using the existing timing. Defaults of 60, 90 or 120 seconds for two, three or four-phase intersections, respectively can be used.
- **Truck percentage (%)** - Calculate the heavy truck percentage (FHWA Class 6-13) for the peak periods from a classification count done on the corridor or a representative one elsewhere that has similar characteristics (see Chapter 5). The count, ideally, would be the from the same group of counts used along the corridor that was used to develop other values for this tool. These values need to be an average of any classification counts done on the corridor and with both directions averaged together. Future conditions should use the same percentages as calculated for existing.
- **AADT (vpd)** - AADT volumes for both directions and all lanes from the Transportation Volume Tables or created from ADT or peak hour volumes with seasonal and K-factors as appropriate (see Chapter 5). This should be the average value along the corridor if there are multiple data points. Alternately, travel demand model link daily volumes (averaged across all links that make up a particular segment by direction) can be used for existing and future volumes if actual count data is unavailable.
- **Peak hour volume (vph)** - Averaged over the length of the segment, for both directions and all lanes by direction for the weekday peak hour volumes. Average daily volumes (ADT) can be used with representative seasonal factors, daily K-factor and directional D-factors to create weekday peak hour volumes if count-based peak hour volume are unknown (see Chapter 5). For future conditions, the existing volumes will need to be projected to the desired future year following Chapter 6 procedures. Alternately, travel demand model link volumes (averaged

across all links that make up a particular segment by direction) can be used for existing and future volumes if actual count data is unavailable.

- **Existing corridor travel time (min)** – Calculate total corridor travel time as an average of both directions using existing conditions probe data (e.g. RITIS) travel times.
- **Total peak hours per day (hrs)** - Total average weekday peak hours across all peak periods (i.e. AM, PM, etc.). Ideally, this would be based on a visual inspection of a volume profile determined from 48-hr roadway tube classification counts (at least a single or an averaged set of multiple counts if volumes change by more than 10%) in the corridor. Alternatively, probe speed data (e.g. RITIS) could be used to determine the peak periods for existing conditions. Future and interim year conditions could use the peak hour spreading techniques in Chapter 8 to modify the volume profile either with or without a travel demand model. If unknown, the default four hours (assuming two-hour AM & PM peaks) can be used.

Roundabouts

This module is for a new roundabout installation replacing a typical stop or signal-controlled intersection. Single or double lane roundabouts with three or four legs can be analyzed with this tool.

It is recommended that Bicycle and Pedestrian LTS (See APM Chapter 14) be evaluated for projects under this toolkit to assess the impact on those modes, such as from longer crossing distances and higher AADT.

- **Area type** – Rural or urban
- **Business district** – Select "yes" if located within a central business district (CBD).
- **Existing total peak hours per day (hrs)** - Total average weekday peak hours across all peak periods (i.e. AM, PM, etc.). Ideally, this would be based on a visual inspection of a volume profile determined from 48-hr roadway tube classification counts (at least a single or an averaged set of multiple counts if volumes change by more than 10% along the corridor) in the corridor. Alternatively, probe speed data (e.g. RITIS) could be used to determine the peak periods for existing conditions. Future and interim year conditions could use the peak hour spreading techniques in Chapter 8 to modify the volume profile either with or without a travel demand model. If unknown, the default four hours (assuming two-hour AM & PM peaks) can be used.
- **Existing intersection traffic control type** – Choice of either signalized or unsignalized
- **Existing approach AADT (vpd)** – Approach (directional) AADT volumes from the Transportation Volume Tables or created from ADT or peak hour volumes with seasonal and K-factors as appropriate (see Chapter 5). Alternately, travel

demand model link approach daily volumes can be used for existing and future volumes if actual count data is unavailable.

- **Existing approach peak hour volume (vph)** – Calculate or use the peak hour volume for each approach. Average daily volumes (ADT) can be used with a representative seasonal factors, daily K-factor and directional D-factors to create peak hour volumes if count-based peak hour volume are unknown (see Chapter 5). For future conditions, the existing volumes will need to be projected to the desired future year following Chapter 6 procedures. Alternately, travel demand model link approach volumes can be used for existing and future volumes if actual count data is unavailable.
- **Existing approach truck percentage (%) -** Calculate the heavy truck percentage (FHWA Class 6-13) ideally for the peak periods but could also be based on daily volume from a classification count done on the corridor or a representative one elsewhere that has similar characteristics (see Chapter 5), HPMS data, or other accepted source. The count, ideally, would be the from the same group of counts used along the corridor that was used to develop other values for this tool. Future conditions should use the same percentages as calculated for existing unless project traffic projections are available that show it differently. Otherwise the default six percent value can be used if there is no other information available.
- **Existing approach delay (s)** – Enter the existing and future no-build delay for the existing intersection. Actual field data for each intersection is highly preferred, which can be gathered through a special study or through a probe-data tool such as RITIS. If field data is not available, then a calculated value can be obtained from an HCM-compatible intersection traffic analysis which might be available for the project.
- **Existing approach number of lanes** – Choice of either one or two approach lanes
- **Existing approach left and tight turn lane percentage** – Calculate from a turning movement count done at the subject intersection for existing conditions, from future no-build projected traffic (see Chapter 6) or alternatively from a travel demand model-based select link analysis (see Chapter 17).
- **Proposed number of circulating lanes** – Choose one or two circulating lanes that the proposed roundabout will have. If unknown, use the default one lane as most roundabouts are single lane.

Two-Way Left Turn Lanes

This module is intended for conversion of an unseparated median segment between any two major intersections (either stop or signal-controlled) into a two-way left turn lane (TWLTL). This project type is commonly part of rural to urban upgrades or as part of a roadway reconfiguration (e.g. road diet). If volumes change more than 10% or the number of lanes change across an intersection, then that location should be considered a "major" intersection for the purposes of this tool and the segment broken into new segment(s). A separate set of input data is required for each separate segment. A single segment may include any number of accesses or minor roadways.

It is recommended that Bicycle and Pedestrian LTS (See APM Chapter 14) be evaluated for projects under this toolkit to assess the impact on those modes, such as from longer crossing distances and higher AADT.

- **Area type** – Rural or urban
- **Segment length (mi)** – Length of project converting median to TWLTL or the default value of 0.25 mile can be used if specific detail is unknown.
- **Number of lanes** – Number of through lanes in both directions (either two, four or six).
- **Free-flow speed (mph)** – Use the weight-averaged speed limit along the length of the segment. This is slightly different from other free-flow definitions, but it represents the mid-block speed between signalized intersections
- **Total peak hours per day (hrs)** - Total average weekday peak hours across all peak periods (i.e. AM, PM, etc.). Ideally, this would be based on a visual inspection of a volume profile determined from 48-hr roadway tube classification counts (at least a single or an averaged set of multiple counts if volumes change by more than 10% along the corridor) in the corridor. Alternatively, probe speed data (e.g. RITIS) could be used to determine the peak periods for existing conditions. Future and interim year conditions could use the peak hour spreading techniques in Chapter 8 to modify the volume profile either with or without a travel demand model. If unknown, the default four hours (assuming two-hour AM & PM peaks) can be used.
- **Number of access points** – Use aerial imagery to determine the total number of access points which include all minor streets, driveways, and parking lot entrances on the right (curb) side for a single direction. Both directions will need to be quantified separately.
- **Average percent of left and right turning vehicle per access point** (%) – The percentage of vehicles that turn right and left into each access point on the segment. These need to be averaged across each segment by direction. This typically will not be available unless full specific traffic analysis and volume development has been performed for the project. In many cases, an access point by access point turning movements will not be available save for special high-detailed efforts (e.g. access studies, safety studies, or possibly microsimulations). This can be estimated from available turning movement counts for each segment, or representative counts from similar areas or from travel demand model node intersections with zone centroid connectors using a select-link analysis to determine the turning movement percentages (see Chapter 17).
- **Truck percentage (%)** - Calculate the heavy truck percentage (FHWA Class 6-13) ideally for the peak periods but could also be based on daily volume from a classification count done on the corridor or a representative one elsewhere that has similar characteristics (see Chapter 5). The count, ideally, would be the from the same group of counts used along the corridor that was used to develop other

values for this tool. These values need to be an average of any classification counts done on the corridor and but done separately by direction. with both directions averaged together. Future conditions should use the same percentages as calculated for existing unless project traffic projections are available that show it differently.

- **Peak hour traffic volume (vph)** – Averaged over the length of the segment, by direction for the peak hour volumes. Average daily volumes (ADT) can be used with a representative seasonal factors, daily K-factor and directional D-factors to create peak hour volumes if count-based peak hour volume are unknown (see Chapter 5). For future conditions, the existing volumes will need to be projected to the desired future year following Chapter 6 procedures. Alternately, travel demand model link volumes (averaged across all links that make up a particular segment by direction) can be used for existing and future volumes if actual count data is unavailable.
- **AADT (vpd)** – Directional AADT volumes from the Transportation Volume Tables or created from ADT or peak hour volumes with seasonal and K-factors as appropriate (see Chapter 5). Alternately, travel demand model link daily volumes (averaged across all links that make up a particular segment by direction) can be used for existing and future volumes if actual count data is unavailable.

CMAQ Electric Vehicles & EV Charging Infrastructure

Replacing conventional internal combustion vehicles with electric versions will reduce operating (fuel cycle) emissions. This toolkit covers the replacement of conventional vehicle fleets with electric vehicles along with the development of charging infrastructure for restricted or full access across a couple of modules. Multiple light and heavy vehicle types can be evaluated outside of transit buses (see the transit bus upgrade section below).

EV Purchases/ Restricted Access EV Charging Infrastructure

This module can calculate emissions from an EV purchase project and/or development of restricted (non-public) charging infrastructure. The user can either use the default VMT and/or vehicle replacement number data or enter in their own specific estimates.

- **Restricted access infrastructure checkbox -** Where public vehicle charging is not permitted.
- **Replacement vehicle type –** Corresponds with MOVES vehicle types: passenger car/truck, school bus, refuse truck, single-unit short/long haul truck and combination short/long haul truck. Will need to do multiple calculations if multiple vehicle types are included.
- **Model year of conventional fuel vehicle –** Use a weight-averaged or representative single year if multiple years are included. Alternatively, individual years can be done separately.
- **Conventional fuel type –** Either gasoline or diesel

- **Annual VMT of vehicles to be replaced (miles)-** Use an estimate of how many miles each vehicle type will travel per day, aggregated to an annual basis (may or may not include holidays and weekends) and summed across all vehicles of that type. Travel demand model output may be used to estimate VMT along with external vehicle classification data from classification counts or fleet registration data to estimate vehicle fractions to estimate VMT by vehicle type.
- **Number of conventional vehicles to be replaced-** Estimate number of vehicles to be replaced

The information below is only needed if restricted-access charging infrastructure is desired:

- **Vehicle type to be charged at the facility –** Could be the same type as above. Corresponds with MOVES vehicle types: passenger car/truck, school bus, refuse truck, single-unit short/long haul truck and combination short/long haul truck. Will need to do multiple calculations if multiple vehicle types are included.
- **Model year of EVs-** Use a weight-averaged or representative single year if multiple years are included. Alternatively, individual years can be done separately.
- **Charging access –** Indicate whether the distance to the charging infrastructure will increase or decrease from the conventional fueling infrastructure.
- **Change in total annual VMT (miles)-** Estimate the change in total annual VMT traveled for charging at the restricted access location(s).

Unrestricted Access EV Charging Infrastructure

This module should be used only for the development of public vehicle charging projects. This module assumes that conventional vehicles are replaced by electric vehicles on a 1 to 1 basis.

- **Total vehicle count in study area (veh) –** The study area is variable. This can range from one specific charging site to a whole regional corridor. Vehicles within the study area should be assumed to mostly travel and fuel within the study area. Travel demand model zonal/demographic relationships could be used to determine the number of passenger vehicles based on household income and population otherwise use of aggregated vehicle registration data could be used. Commercial vehicle numbers could be estimated from aggregated vehicle registration data assuming that data is available. Volume growth projections from travel demand models, SWIM, or even historical volumes could be used as proxies to help estimate future years.

- **EV market share –** Estimate vehicle market penetration for the evaluation year. Exhibit 16-20 shows estimated EV penetration from DEQ for various vehicle types other than transit buses. Multiple years will require multiple iterations of the calculation.

Exhibit 16-20 Estimated EV Share

Year	Estimated EV Share (%)			
	Auto (Class 1-2)	Light Trk (Class 3)	Medium Trk (Class 4-5)	Heavy Trk (Class 6-13)
2020	3.0	0.0	0.0	0.0
2025	12.1	3.0	1.0	1.0
2030	28.7	11.9	7.1	5.0
2035+	52.0	31.0	19.2	11.0

- **(Vehicle) Source type distribution for vehicle activity and populations –** Can use the default annual VMT and vehicle count as-is or ideally modify the input table with known data. Travel demand model output may be used to estimate VMT along with external vehicle classification data from classification counts or fleet registration data to estimate vehicle fractions and to estimate VMT by vehicle type. Activity-based model output could be used to estimate individual vehicle populations as these track trips on an individual person basis.

CMAQ Transit Bus & Fleet Expansion

This toolkit is intended for any transit project that has the potential to divert travel from automobiles to transit with new routes, schedules, stops, and vehicle purchases being the most common. It includes a change in both passenger vehicle (mode shift) and transit vehicle miles travelled. A travel demand model scenario is preferred to create the vehicle-miles traveled (VMT) and mode shifts for the transit and automobile modes.

The VisionEval model (both regional and state versions) provides a good mi-level tool for assessing the impact of transit fleet and fuel changes. To learn more about these tools contact the ODOT Climate Office Data & Analysis group.

- **Transit bus VMT before and after project** – Travel demand model scenario-based VMT of the transit vehicles for the no-build (closest reference or base year) case and for a model scenario containing the transit project(s). Transit miles should be increased to represent both in-service miles (with passengers), and non-service miles. Transit provider GTFS schedule data may also be useful to identify bus VMT for existing schedules and/or future schedules created with the ReMIX tool (i.e. for transit route planning, schedule building and visualization).

- **Allocations of (transit vehicle) analysis years** – Transit vehicle analysis year VMT / total fleet VMT distribution. Vehicle model year distributions including any specific route assignments or general use assumptions (i.e. only used in cease of breakdowns) will need to be obtained from the transit agency/operator or can use the national defaults in the toolkit. These distributions can be applied to the total VMT to determine the overall VMT distributions by model year.
- **Allocation of transit vehicle fuel types –** Fuel types include gasoline, diesel, CNG (MOVES-based emission rates) and a full range of alternative fuels (based on US Department of Energy AFLEET alternative fuel factors that modify the MOVES rates) such as biodiesel, battery electric, and hybrids (not exhaustive). Fuel Type VMT/ Total Fleet VMT distribution. Vehicle fuel type distributions will need to be ideally obtained from the transit agency/operator or can use the values shown for medium trucks in Exhibit 16-20 as buses fall into the vehicle Class 4 type. These distributions can be applied to the total VMT to determine the overall VMT distributions by fuel type. These can be modified across different scenarios to show the effect of transitioning buses from internal combustion to electric power. Fuel assumptions should be consistent with DEQ's fleet fuel allocations.
- **Allocation of road types** – Road type VMT / Total Fleet VMT distribution. The two base road types considered are grade-separated highways and all other roads (i.e. arterials, collectors and local streets). Both road types need to be also split between rural and urban areas.
- **Passenger Vehicle Activity Type –** Input choice of either VMT or total number of trips.
- **Passenger Activity (VMT or trips) -** Annual travel demand model derived VMT or annual total number of automobile trips in the transit district service area. This may require creating a model scenario with districts to group the transportation analysis zones together to simplify the quantification of the information. Historic activity may be available from the National Transit Database (NTD).
- **Average One-Way Trip Distance (miles) –** Travel demand model derived average trip distance for the automobile mode in the transit district service area. Use values from the Oregon Travel Survey to determine this. In addition, the National Transit Database may have trip lengths for the desired transit agency.

CMAQ Transit Bus Upgrades & System Improvements

This multiple module toolkit is intended for projects that involve replacing diesel and compressed natural gas (CNG) buses with cleaner/alternative fuels and direct replacement of conventional buses with battery electric no emission vehicles.

The VisionEval model (both regional and state versions) provides a good mi-level tool for assessing the impact of transit fleet and fuel changes. To learn more about these tools contact the ODOT Climate Office Data & Analysis group.

Electric (EV) Transit Bus Replacement

This module is used for determining the emission impacts from replacing conventional transit buses with EV transit buses. The user can either use the default VMT and/or vehicle replacement number data or enter in their own specific estimates.

- **Restricted access infrastructure checkbox -** Where public vehicle charging is not permitted and if this component is part of the project.
- **Model year of current transit buses –** Use a weight-averaged or representative single year if multiple years are included. Alternatively, individual years can be done separately.
- **Fuel type of current transit buses –** Either diesel or CNG
- **Number of transit buses to be replaced-** Number of vehicles to be replaced; should be available from the transit district if not directly available in the project description.
- **Total annual VMT of transit buses to be replaced-** Use an estimate of how many miles the replaced buses travel per day, aggregated to an annual basis (may or may not include holidays and weekends) and summed across all vehicles. These estimates may be available from the subject transit district or could be estimated using service days, schedules, and typical actual routes used mapped in GIS. Travel demand model output could also be used to estimate VMT for the transit mode if available. Otherwise use transit provider GTFS schedule data.
- **Model year of replacement transit buses -** Use a weight-averaged or representative single year if multiple years are included. Alternatively, individual years can be done separately.
- **Change in fueling distance –** Indicate whether the distance to the charging infrastructure will increase or decrease from the conventional fueling infrastructure.
- **Distance changed for fueling (miles) -** Estimate the change in total annual VMT traveled for charging at the restricted (no public use) access location(s).

The below data items are only required if restricted-access fueling infrastructure is included in part of the project. Model year and fuel type of replacement buses would also be needed for this section, but that is the same data as required above.

- **Change in fueling distance –** Indicate whether the distance to the new restricted access fueling infrastructure will increase or decrease from the current fueling infrastructure.

- **Distance changed for fueling (miles) -** Estimate the change in total annual VMT traveled for fueling at the restricted (no public use) access location(s).

Non-EV Transit Bus Replacement (or drop-in fuel changes such as renewable diesel)

This module is used for determining the emission impacts from replacing conventional transit buses with newer diesel, CNG or alternative-fuel (non-EV) transit buses. The user can either use the default VMT and/or vehicle replacement number data or enter in their own specific estimates.

- **Restricted access infrastructure checkbox -** Where public vehicle fueling is not permitted and if this component is part of the project.
- **Model year of current transit buses –** Use a weight-averaged or representative single year if multiple years are included. Alternatively, individual years can be done separately.
- **Fuel type of current transit buses –** Either diesel or CNG
- **Number of transit buses to be replaced-** Number of vehicles to be replaced; should be available from the transit district if not directly available in the project description.
- **Total annual VMT of transit buses to be replaced-** Use an estimate of how many miles the replaced buses travel per day, aggregated to an annual basis (may or may not include holidays and weekends) and summed across all vehicles. These estimates may be available from the subject transit district or could be estimated using service days, schedules, and actual routes mapped in GIS. Travel demand model output could also be used to estimate VMT for the transit mode if available. Otherwise use transit provider GTFS schedule data.
- **Model year of replacement transit buses-** Use a weight-averaged or representative single year if multiple years are included. Alternatively, individual years can be done separately.
- **Fuel type of replacement transit buses** – Diesel, CNG, biodiesel, renewable diesel (drop-in), hybrids, liquified natural gas, dual fuel vehicles or hydrogen fuel cell. Multiple fuel types will require multiple runs of this calculation.

The below data items are only required if restricted-access fueling infrastructure is included in part of the project. Model year and fuel type of replacement buses would also be needed for this section, but that is the same data as required above.

- **Change in fueling distance –** Indicate whether the distance to the new restricted access fueling infrastructure will increase or decrease from the current fueling infrastructure.
- **Distance changed for fueling (miles) -** Estimate the change in total annual VMT traveled for fueling at the restricted (no public use) access location(s).

Transit Bus Diesel Retrofit

The toolkit also has a module for retrofitting diesel-powered 40’ low-floor transit buses with varying emission reducing exhaust and filtering technologies. These will address CO, NOx, and particulate matter pollutants and not CO_2/CO_{2e}, so it does not apply to GHG estimation.

CMAQ Travel Advisories

This toolkit is intended for projects that implement variable message signs (VMS) or variable speed limits (VSL). Travel advisories can modify driver behavior and smooth overall operations as drivers prepare for slowdowns due to weather, congestion or incidents which can contribute to lowering emissions.

- **Period of activity** – Choice of operational hours: either peak hours, or more commonly, peak and non-peak hours.
- **Hours of activity (hrs) –** Average number of peak hours and (optional) non-peak hours that the advisory is active or projected to be active per day. Alternately, the six-hour default can be used. An average/typical value should be obtained from the ODOT Region or applicable city/county operational centers.
- **Peak and non-peak volumes before conversion (vph)** – Average hourly vehicles per hour in a single direction across all lanes for peak and non-peak hours of advisory operation. Average daily volumes (ADT) can be used with a representative daily K-factor and directional D-factors to create peak hour volumes if count-based peak hour volumes are unknown. Non-peak hour volumes would need to be averaged from on-site or representative 16+ hour counts or automatic traffic recorders or used to create a non-peak hour daily conversion factor to be applied to a source of ADTs (or AADTs such as the Transportation Volume Tables if seasonal adjustments were applied to convert these into ADTs). Alternatively, peak hours could be obtained from a travel demand model if the project was in an urban area and the values were post-processed. The ability to easily get non-peak hours from a travel demand model will depend on the model used, so it may be easier to rely on physical count sources instead.
- **Peak and non-peak speeds before conversion (mph)** – For current conditions, probe speed data (e.g. RITIS) should be used to determine the peak speeds and optional non-peak speeds in the study section. Alternatively, post-processed travel demand model speeds, available project micro-simulations or the posted speed limit can be used for future speeds.
- **Peak and non-peak volumes after conversion (vph); Optional –** Only needed if volumes are predicted to be significantly different during the hours of operation after project completion. This will require available micro-simulations or a post-processed travel demand model scenario (assuming that this project is part of a larger effort with substantial modellable elements) or an external source that indicates the potential volume diversion/change that could be obtained with a VMS/VSL project.

- **Peak and non-peak speeds after conversion (mph); Optional -** Only needed if speeds are predicted to be significantly different during the hours of operation after project completion. This will require available micro-simulations or a travel demand model scenario (assuming that this project is part of a larger effort with substantial modellable elements) or an external source that indicates the potential speed improvements that could be obtained with a VMS/VSL project.
- **Corridor length (mi)** – Total number of miles along the corridor that the VMS/VSL project impacts
- **Heavy duty traffic (%)** – Truck percentage on affected VMS/VSL corridors obtained from available traffic counts, automatic vehicle classifiers, HPMS sample data, etc.

Infrastructure Cycle Emissions

Infrastructure emissions are in addition to the Fuel Cycle (Operational) emissions noted above.

Infrastructure Carbon Estimator (ICE)[9]

The Infrastructure Carbon Estimator (ICE) from FHWA is a comprehensive sketch-planning tool for evaluation of the lifecycle energy and emissions of transportation infrastructure construction, maintenance, and use. The tool includes considerations for material production and transport, energy and fuel used in construction equipment, routine maintenance, and impacts of construction-caused vehicle traffic delay. It is typically assessed in addition to user emissions from other sections (e.g. 16.5.4 or 16.5.5).

- ICE can cover multiple roadways and related project types such as new roadways (not including sidewalks or bike lanes)
- Roadway widening (adding new lanes)
- Roadway rehabilitation (standalone maintenance)
- Lane widening & shoulder improvements
- Roadway realignments
- Pavement reconstruction and resurfacing
- Bridges (new, reconstruction, or widening)
- Culverts
- New parking facilities (surface lot or structure)
- New rail facilities (heavy or light; either underground, at-grade or elevated)
- Bus rapid transit (new or lane conversions, stations)
- New or resurfaced multi-use paths
- New sidewalks, or restriped bicycle lanes
- Signing and lighting

[9] From "Overview of Methods for Conducting GHG Analysis in the Transportation Planning Process", Michael Grant, ICF (TRB Annual Meeting, 2025).

These infrastructure cycle (construction) emissions would be added to fuel cycle (operational) emissions of the project, calculated through the separate GHG analyses and tools noted earlier in this section. GHG results can be presented on an annualized or accumulated basis, viewed by material, life-cycle phase, or by infrastructure type.

ICE tool traffic inputs are limited to establishing the total number of lane and/or centerline miles, number of interchanges, number of bicycle and pedestrian lanes or sidewalks, VMT, and speed of each applicable facility type and any parking spots (i.e. carpool lot) needed for each project. The tool also needs input on mitigation strategies. These include alternative fuels and vehicle hybridization, vegetation management, snow fencing and removal, and in-place roadway recycling. The baseline, business-as-usual, and maximum potential deployment for each strategy need to be specified.

Directional ADT (see Chapter 5) is also needed for determining construction delays on any roadway segments that will require lane closures as part of the subject project. The ADT could be based on project-level volumes, or it could use scoping level AADT values if more specific ADT was not known. If AADT is used as the source, then appropriate seasonal factors are needed to convert these to the peak month ADT. Estimated project-days required for lane closures and percentage of lanes closed are also needed to estimate construction delays. Input on lane closures will likely require coordination from ODOT Region design/workzone or District maintenance staff depending on the specific project.

Workzone/construction delays can also be calculated through several other tools and methods which bring in additional details beyond the ICE tool such as workzone reduced speeds and capacity factors (e.g. closed lanes or shoulders, reduced lane widths or side clearances) which could produce more specific local values.

Simpler methods of calculating construction delay are shown in Section 10.6.8 for a specific roadway section assuming hourly demand volume and capacities are known. Specific workzone -reduced capacities can be added along with durations to determine daily delays. These can be computed by using HCM-based tools (see Chapter 11) or sometimes these are defaulted to specific workzone capacities that are specified by ODOT Traffic Section or region traffic analysts. This would need to be repeated for different volume scenarios (i.e. weekday vs. weekend, or seasonal impacts) to expand the delay calculations to cover an extended period. The PPEAG screening method also shown in Section 10.6.8 could also be used to calculate section delays. A more detailed methodology for specific roadway sections would be the HCM reliability methodology using the Highway Capacity Software (HCS) tool (see Section 9.3.6 and Chapter 11).

16.5.5 Use of MOVES-based Methods

The two methods for estimating fuel cycle emissions using the EPA MOVES software tool are Emission Rates and Inventory methodologies. Details about each methodology are in subsequent sections. Coordination with ODOT's Air Quality Unit in the

Environmental Section will be necessary to discuss the necessary context and determine and document which methodology applies.

- **MOVES Emission Rates Method** (CO_{2e}) - This methodology may be preferred for regional, area, or scoping-level, planning analyses after coordination with ODOT Environmental Section staff. There is the potential of only the largest projects affecting the final GHG results if done on a regional or system-wide scale, so supplementing this with the sketch-level methodology may be preferable to understand contributions of individual projects. This methodology is applicable to most of the project types listed in Exhibit 16-17 and could also be mixed with the sketch level methods, e.g. to add in elements that are not captured in a travel model, such as EV chargers, many bike/ped improvements or TDM programs. This method is not intended for use in air quality conformity as that must follow certain federal regulations.
- **MOVES Inventory Method** - This methodology is generally compatible with larger-scale infrastructure projects. Like with the MSAT air quality analysis, substantial differences between the no-build and build scenarios may only be noticeable with larger-scope projects or substantial bundles of smaller projects. Smaller projects, and projects outside non-attainment areas, are best served by the sketch or emission rate methods.

Use of either methodology requires that emissions are accumulated over the planning horizon to determine the overall lifecycle-based GHG. Accumulated emissions will require repeating the analysis for multiple interim years (i.e. five-year intervals). See Section 16.5.3 for more details on lifecycle accumulated emissions.

16.5.6 MOVES Emission Rate Method (CO_{2e})

The MOVES Emission Rate method is one of the two methods used to calculate fuel cycle emissions using the EPA MOVES software tool. Project-specific information is processed after running MOVES to develop lookup tables of emission rates. Generally, the number of MOVES runs are less with this method without loss of precision as local travel and emissions data (e.g. VMT) is used instead of widespread use of national defaults. The ODOT and ODEQ staff are available to provide emission rate look-up tables so local analysts do not have to run MOVES. MOVES or other GHG calculating tools, or other external sources are not discussed in the APM other than providing context. Please refer to the Air Quality Manual or the Air Quality Unit for more information on MOVES, project-level GHG calculations, etc.

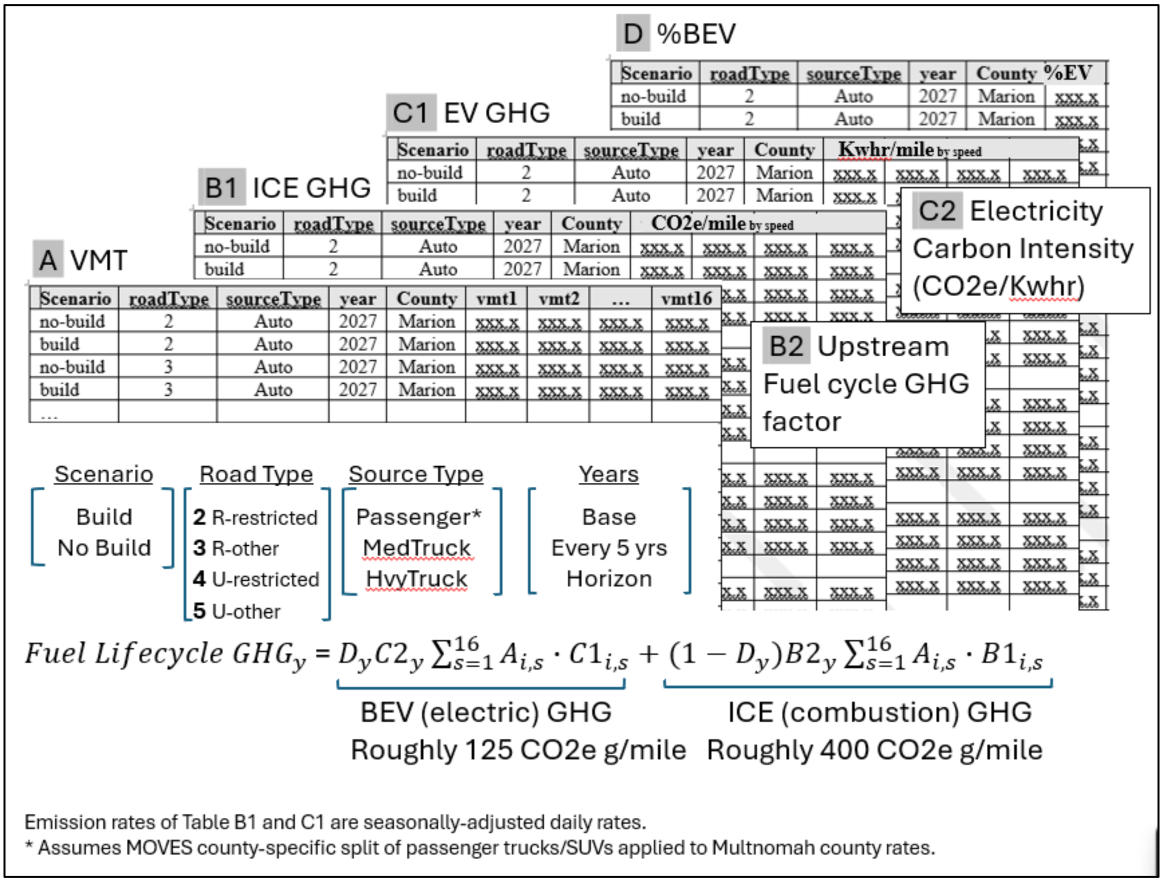
The method follows the steps summarized in Figure 16-21 below (highlighted in gray boxes) to estimate fuel cycle lifecycle emissions from a project. Table A (VMT) data for each yearly build and no-build scenario comes from the travel demand model and is developed following the quantitative MSAT methodology minus the link screening portion shown in Section 16.4.3. Tables B (ICE GHG)-D (%BEV) including the related B2 & C2 factors come from ODOT's Air Quality Unit in coordination with ODEQ. Table A data is multiplied by emission rates for combustion vehicles developed from Table B1

and the B2 upstream fuel factor and for electric vehicles from Table C1 and the C2 local electricity carbon intensity factor, and the share of EVs (Table D).
Table A would be generated by the traffic analyst starting with travel demand model data and ending with aggregated VMT to the dimensions indicated. This MOVES data is broken down by:

- **Scenario** – build versus no-build, or alternative future scenarios
- **Road typ**e –MOVES type 2-5; rural and urban with restricted/unrestricted access.
- **Source Type** (vehicle classification) – Automobiles, medium and heavy trucks; typically based on project/regional traffic counts as this is not available from a travel demand model. HPMS data and related counts can also be used for full regions.
- **Years** – base (existing) year and future years, and five-year increment linear interpolation between base and future year. Interim years are used to estimate the accumulated GHG impact on the environment over the life of the plan.
- **Speed** – VMT is split into 16 speed bins, so this requires use of RITIS to obtain existing year, forecasting to obtain future no-build (or model post-processing), and model post-processing of speeds to obtain future build years.

See Section 16.4.3 for the overall VMT development process, data needs, and examples. Section 16.5.7 has additional detail on developing and formatting the VMT data for MOVES-based analyses. Exhibit 16-22 has more details on the VMT dimensions needed.

Figure 16-21 Summary of "Emission Rates" Method for Fuel Lifecycle Emissions



The Table B1 and C1 emission rates per mile are generated from the EPA MOVES model by the air quality analyst. The Table D estimate of on-road share of EVs are included in the default advanced vehicle and fuel technology (AVFT) data in MOVES5. MOVES5 is the better representation of Oregon vehicle and fuel regulations, as one of the California Clean Air Act exception states, while Oregon data in the MOVES4 (most recent past version) model is more representative of national vehicle standards. For the latest EV adoption assumptions contact ODOT and/or ODEQ MOVES staff.

Because the impact of GHG on the environment is due to its accumulation in the atmosphere, it is important to move from tailpipe from internal combustion engines for a single year to fuel lifecycle emissions of all vehicles. This requires adding in emissions from electric vehicles (C1 and C2) and the upstream emissions for extraction of fuel (B2). Fuel lifecycle emissions is consistent with Oregon's Emissions Website, including the Statewide Transportation Strategy (STS) roadmap for GHG reduction progress towards state targets of ground transportation sector. Metropolitan GHG targets (OAR 660-0020/0025) are pulled from this statewide strategy (for more information see ODOT's Metropolitan Transportation Planning website and Appendix 17B for the VMT per capita calculation process). Infrastructure emissions estimated using the ICE tool (see Section 16.5.4) can be added to this lifecycle fuel emissions.

To fully capture the accumulated GHG impact on the environment, the method should be repeated for interim years, and emissions (fuel, infrastructure, and vehicle-if using) summed across the design life of the project or plan. Interim years are required to capture the non-linear adoption of electric vehicles (Table D) and associated change in emission rates over time (Table C1). VMT (Table A) can be assumed to increase in a more linear fashion between base and future year, allowing linear interpolation for interim years. Guidance on developing the VMT for this methodology is included in Section 16.5.7.

The "Emission Rates" method can be applied to a build vs. no-build scenario of a single project (summing associated VMT from impacted link segments in the designated project area) or a system level (e.g. aggregating links within a regional or city boundary for an RTP or TSP, or set of project locations, like a statewide STIP project list).

Example 16-15 is a recent application of the method at the system-level for ODOT's STIP. The system-level application also aligns with the Oregon Transportation Plan's Key Performance Targets for safety, equity, and climate by providing a methodology to evaluate the emissions impact of investments in a project prioritization process.

Example 16-15: 2024-27 STIP GHG Quantification

The GHG impact of the Agency's Statewide Transportation Improvement Plan (STIP) was quantified, in response to a Governor's directive, i.e., the accumulated GHG estimate from all ODOT-led or administered construction phase projects through 2050. This included the fuel (operational) and infrastructure (construction) lifecycle GHG impacts. Many projects were unable to be modeled given small changes to VMT and operational GHG, while nearly all the projects included construction GHG.

This system-level analysis had the fuel cycle GHG calculated with the MOVES Emission Rate method. It relied on the partnership coordination between ODOT and DEQ regarding available data, particularly as it attempted to capture Oregon vehicle and fuel regulations that had just passed, in advance of MOVES5. This effort was fed by data from travel demand models and supplemented with sketch-level tool methods for selected projects and bicycle/pedestrian elements that were not well estimated in these tools. The MOVES assumptions reflected recent Oregon vehicle and fuel regulations and added upstream fuel emissions as well as electricity emissions for a more complete estimate of lifecycle emissions. Infrastructure cycle emissions (construction) were also estimated but are not discussed here.

The methodology involved coding specific STIP projects into TPAU's Highway Economic Reporting System (HERS) software (now phased out of use) and/or the Statewide Integrated Model (SWIM) as applicable and then running the tools to produce outputs in a format compatible with the MOVES model (i.e. VMT by speed bin by vehicle class fraction). Using both tools allowed capturing a wider range of project types. HERS was a segment-based analysis tool using HCM-consistent planning methodologies with each segment being independent, whereas SWIM is a travel demand tool in which upstream links have influence on downstream links.

The first step required that the possible project types needed to be matched to the HERS and SWIM analysis tools for evaluation. Adding/removing through lanes, new turn lanes, new signals, wider shoulders, lane width changes, and median barrier additions-type projects could be analyzed directly in HERS. New roadway segments and lane additions/removal-type projects could be done in both SWIM and HERS. Turn restrictions and projects that re-route or modify demand (i.e. future tolling) or projects under congested conditions required that they were processed first with SWIM to get the capacity-constrained volumes and related latent demand shifts set before exporting into HERS for the final analysis. The HERS SHRP2 reliability post-processor was able to generate more-detailed VMT speed distributions, which is important since emission rates are highly speed sensitive. Other project types in the STIP list that could not be evaluated with SWIM and /or HERS, were evaluated by sketch-level methods (see Exhibit 16-17), which were mostly the simpler CMAQ tools. Some, like curb ramp projects, prompted the development of new custom sketch-level methods.

Once each project was matched to a corresponding tool, the necessary input data was gathered to properly code each tool with the project build and no-build condition details. Generally, at the STIP scoping level, the project descriptions provided did not have enough detail to code the specific projects which required contacting project staff to provide the remaining details.

Projects that modified roadway capacity either by enhancement (e.g. widening, longer auxiliary weaving lanes) or reduction (e.g. roadway reconfiguration) were coded into SWIM before running in HERS. A crosswalk script was written to automate the linking of the SWIM network to the HERS dataset which enabled model data to be transferred back and forth. After all the network changes were completed, the SWIM assignment is run based on the 30-yr period.

The results of the no-build and build SWIM runs were reviewed for reasonableness regarding road segment VMT and speed changes, especially where volume shifts occurred outside of project extents. These external to the project changes were identified and noted. Since HERS receives its VMT exogenously, it is important to pull in any travel model link changes into the corresponding HERS segments. For example, sometimes only a specific project section saw a decrease or increase in VMT. However, other times-adjacent links exhibited diversion-impacted VMT, leading to more comprehensive VMT changes in HERS.

After all the extra roadway segments were noted in HERS, the horizon year (i.e. 2050) no-build and build AADTs from SWIM were transferred to the HERS segments. Non-SWIM projects (i.e. the ones that did not have potential for diversion through latent demand shifts), had the same volumes for both the no-build and build conditions. The HERS software was executed, and the output files containing VMT by class and average speed for each five-year period were passed to a post-processor to calculate the VMT by the different speed bins. The HERS SHRP2 reliability post-processor created a summary of each project with VMT by speed bins for automobiles (FHWA Class 1-3), medium/single-unit trucks (FHWA Class 4 & 5), and heavy/combination trucks (FHWA Class 6-13) in five-year increments over the 30-year period between the base and 2050 horizon years.

The VMT data was then combined with MOVES and lifecycle factors (essentially Tables B-D of Exhibit 16-21) by ODOT's Air Quality Unit to produce the initial set of fuel lifecycle GHG outputs and accumulated emissions. This included a lookup table developed from prior MOVES runs for Multnomah County and estimates of electricity rates, statewide upstream fuel cycles, and electricity carbon intensity factors. Both VMT and GHG results were run through a quality control review to make sure that the overall trends lined up (e.g. if VMT increased for a section then it would be expected that GHG would also rise), magnitudes of change, and direction of changes were reasonable. In some cases GHG changes were the result of speed changes and/or vehicle mix changes alone, with no change in VMT across these segments.

The change in fuel lifecycle (operational) GHG from each project (build vs. no build) was summed and added to selected additional impacts evaluated in sketch tools, such as bike/ped CMAQ work and estimates of GHG reductions from EV chargers. A separate exercise estimated the infrastructure cycle GHG emissions of these same projects. The accumulated fuel and infrastructure lifecycle emission change from the projects was then estimated by summing across all interim years out to 2050.

16.5.7 MOVES Inventory Method (CO_{2e})

The MOVES Inventory Method is the second of the two primary emission computation methodologies. In this method, in contrast to the emission rates, the project specific data is processed before running MOVES.

Full project-level VMT broken down by roadway type, speed, and vehicle classification (i.e. MOVES-compatible traffic data) would be produced by the traffic analyst following the quantitative air quality MSAT analysis covered in Section 16.4.3 with two main exceptions. First, there is no regional link screening process and related AADT thresholds as any project could be evaluated with this method, and second, the analysis will need to be repeated at five-year intervals to support the computation of lifecycle emissions. Once completed, this information will then be passed off to the air quality analyst for running in MOVES and eventual GHG calculations. In comparison with Exhibit 16-20, running MOVES for this method would replace the Table A-B1-C1-D workflow and factors B2 & C2 would be applied to the MOVES output.

16.5.8 Developing and Formatting VMT Data for MOVES-based Analysis

Prior sections have discussed how to properly estimate project level volume and VMT data. To obtain GHG and other AQ measures, such as in the GHG MOVES Inventory and the Air Quality MSAT analysis methodologies, the VMT data must be processed into the input format that MOVES requires.

There are five key dimensions that the project must "bin" the VMT data into. Those dimensions are listed and described as follows:

- Project Scenario – This will typically be a comparison of two scenarios:
    1. No-build
    2. Build
- Road Types – MOVES uses four road type codes or categories (each project segments/links must be assigned or cross-walked via lookup tables to these designations):
    1. 2 – Rural Restricted (highway / access controlled)
    2. 3 – Rural Unrestricted (arterial, or no access control)
    3. 4 – Urban Restricted (highway / access controlled)
    4. 5 – Urban Unrestricted (arterial, or no access control)
- Vehicle Types – This level of MOVES analysis uses three vehicle (source) types:
    1. Light Vehicles – All light passenger vehicle types (Motorcycles, Passenger cars and other two-axle four-tire vehicles; FHWA Class 1-3)
    2. Medium Truck (Single Unit Trucks (SUT) or Two-axle six-tire trucks; FHWA Class 4 & 5)
    3. Heavy Truck (Multi-Unit Trucks (MUT) or Three-axle and greater single-unit trucks and all combination tractor-trailer trucks; FHWA Class 6-13)
- Speed bins – the VMT needs to be assembled into 16 different speed bins:
    1. Speed < 2.5 mph
    2. 2.5mph ≤ Speed < 7.5mph
    3. 7.5mph ≤ Speed < 12.5mph
    4. 12.5mph ≤ Speed < 17.5mph
    5. 17.5mph ≤ Speed <22.5mph
    6. 22.5mph ≤ Speed < 27.5mph
    7. 27.5mph ≤ Speed < 32.5mph
    8. 32.5mph ≤ Speed < 37.5mph
    9. 37.5mph ≤ Speed < 42.5mph
    10. 42.5mph ≤ Speed < 47.5mph
    11. 47.5mph ≤ Speed < 52.5mph
    12. 52.5mph ≤ Speed < 57.5mph
    13. 57.5mph ≤ Speed < 62.5mph
    14. 62.5mph ≤ Speed < 67.5mph
    15. 67.5mph ≤ Speed < 72.5mph
    16. 72.5mph ≤ Speed
- Year – Years need to start at the opening or base analysis year and then include each five-year increment for an approximate 25 to 30-year period to cover for the accumulated impacts of the project. Accumulated horizon years, for example, are

currently set at 2050 in this time of writing in 2023. If the opening year of the project is 2027, then the required years would be 2027, 2030, 2035, 2040, 2045, and 2050. Most projects do not include specific analysis for every five years into the future, so these values will commonly need to be linearly interpolated, which is discussed further below.

After the project has assembled all this information, it needs to be processed into the correct format for MOVES. The format consists of rows of data, where each row contains the 16 VMT speed bins for each unique scenario, road type, vehicle type, year, and county as shown in Exhibit 16-22.

Exhibit 16-22: MOVES Data Format Sample Table Excerpt

Scenario	roadType	sourceType	year	County	vmt1	vmt2	…	vmt16
no-build	2	Light Veh	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	2	Light Veh	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
no-build	3	Light Veh	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	3	Light Veh	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
…								
no-build	2	Med Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	2	Med Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
no-build	3	Med Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	3	Med Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
…								
no-build	2	Hvy Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	2	Hvy Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
no-build	3	Hvy Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	3	Hvy Truck	2027	Marion	xxx.x	xxx.x	xxx.x	xxx.x
…								
no-build	2	Light Veh	2030	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	2	Light Veh	2030	Marion	xxx.x	xxx.x	xxx.x	xxx.x
no-build	3	Light Veh	2030	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	3	Light Veh	2030	Marion	xxx.x	xxx.x	xxx.x	xxx.x
…								
no-build	2	Light Veh	2035	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	2	Light Veh	2035	Marion	xxx.x	xxx.x	xxx.x	xxx.x
no-build	3	Light Veh	2035	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	3	Light Veh	2035	Marion	xxx.x	xxx.x	xxx.x	xxx.x
…								
no-build	4	Hvy Truck	2050	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	4	Hvy Truck	2050	Marion	xxx.x	xxx.x	xxx.x	xxx.x
no-build	5	Hvy Truck	2050	Marion	xxx.x	xxx.x	xxx.x	xxx.x
build	5	Hvy Truck	2050	Marion	xxx.x	xxx.x	xxx.x	xxx.x

Note that the final resulting table is much longer than this; two scenarios x four road types x three source types x six year bins = 144 rows of information with each row containing 16 columns of VMT by speed bin data.

As mentioned above under the "Year" description, most to all projects will not have a VMT analysis for each five-year increment between the opening (build) year and future analysis (design/horizon) year. Possibly, a project may have an interim mid-point year in addition to the base and future bookend years most likely because of a need for an additional phase or scoped support for needed noise/air-quality/GHG data. The current recommended practice given the huge amount of complexity in assembling all needed inputs and factors for the existing and future horizon years is to linearly develop (i.e. interpolate) the VMT by speed bin for years in between these end points. As with other environmental traffic data development, the resulting math is relatively simple but repeated many times which adds overall complexity.

Example 16-16: VMT Data Interpolation

Using Exhibit 16-20 (Table A) and Exhibit 16-21 above as the start, assume that the starting year (opening year/build year) in the analysis is 2027 and the horizon year is 2045 (18 years apart). Under this assumption, the analyst could populate 2 scenarios x 4 road types x 3 vehicle types x 2 years = 48 of the rows required but would still need 4 years of information (96 rows).

To develop year 2030 (24 needed rows), the VMT cells from the 2045 years are compared to the VMT cells for the 2027 years as follows starting with the first VMT speed bin, "vmt1":

Scenario	roadType	sourceType	Year	County	vmt1
no-build	2	Light Veh	2027	Marion	10

Scenario	roadType	sourceType	Year	County	vmt1
no-build	2	Light Veh	2045	Marion	28

2030 vmt1 = ((Future Year VMT – Base Year VMT) / # Years between Future and Base * # of Years from base to new year) + Base Year VMT

2030 vmt1 = ((28 – 10) / 18 * 3) + 10

2030 vmt1 = 13

Scenario	roadType	sourceType	Year	County	vmt1
no-build	2	Light Veh	2030	Marion	13

This can similarly be done for 2050 (just extrapolation for the five years out past 2045)

Scenario	roadType	sourceType	Year	County	vmt1
no-build	2	Light Veh	2050	Marion	33

This interpolation calculation needs to be done for each of the 16 VMT bins, scenario bins, road type bins, and vehicle type bins independently. It is recommended that an Excel spreadsheet analysis or scripting should be used to greatly automate and simplify the task of building all the interim years.

If the project had a midpoint year available, this would shorten the interpolation ranges. For example, if 2037 was available then both 2027 and 2037 would be used as the base and future years, respectively, to develop the 2030 and 2035 interim years. Developing the 2040 interim year and the 2050 horizon year would use 2037 and 2045 as the data basis.

16.5.9 Coordination & Review

Coordination

Any project GHG analysis **requires** initial communication and ongoing coordination with all parties (e.g. ODOT Environmental Section, project staff, consultants). After the responsible parties produce the VMT traffic data estimates, it is passed to the ODOT Environmental Section's Air Quality Unit (or applicable consultant for an active project) to create the GHG emission values from the supplied inputs. The GHG emission estimates would then need to be reviewed along with the traffic data inputs (i.e. VMT, speed, etc.) inputs to determine if overall trends and comparisons were consistent with expectations.

> *It is important to allow enough time to allow for coordination between the analyst and regional project team/leader/planner contacts, in addition to any additional staff that will be running tools (e.g. TPAU-only tools such as SWIM) to avoid making any wrong project assumptions in the* model *coding process.*

Timing

For system-level planning evaluations, like the STIP assessment, it will take considerably longer and have a higher error-potential across multiple steps as more assumptions and "reverse-engineering" will be needed if the GHG analysis is left to do after the project is closed. Retroactively assessing projects for their GHG impact would limit available information which would require document searches and assorted staff inquiries to re-build an understanding of the construction and impact limits of each project. For some evaluation efforts, there may not be time to do the full level of direct project coordination required to cover all the project details without substantial assumptions. If possible, GHG analyses should be done of projects when they are active (i.e. in project development/scoping stages with project activities occurring, etc.)

Projects are part of a complex system and changes to one project may affect others along with user's responses to those changes. Ideally, impacts should be assessed on an accumulated basis (e.g. coding projects into a travel demand model to capture impacts of shifting demand) when time allows although not all project types are capable of being assessed this way.

Review Considerations

Regardless of the underlying methodologies and tools used, all the inputs to be used and the resulting traffic-based outputs need review. Section 19.5.3 contains considerations and elements that should be reviewed.

Sketch-level Method Reviews

For sketch-level methodologies, the inputs should be reviewed including data sources, basis of assumptions, and interim input calculations. Many of the required inputs such as volumes, heavy truck percentages, number of peak hours, delays, and speeds require substantial calculations and assumptions and need to follow other APM methodologies or RITIS best practices. Errors in input data may result in output data not making sense or being of the correct magnitude.

While the deterministic sketch-level CMAQ/ICE tools produce CO_2 emissions and related performance outputs such as speed and travel time, effort needs to be made to ensure that the resulting emission change makes sense with the change of performance data. For example, if delay and vehicle travel decrease, then it would be expected that emissions would also decrease.

Caution should be taken in combining GHG from different sources. ODOT GHG requirements report the full fuel lifecycle GHG (See Exhibit 16-14), which is ideally the accumulated GHG over the project design life. Sketch tools are built from air quality methods that only capture tailpipe elements of fuel cycle emissions. The travel demand model-based MOVES methods instruct on how to add in lifecycle. The ICE tool allows adding the "infrastructure cycle" GHG emissions of a project as well.

MOVES-based Emission Rate and Inventory Method Reviews

Each project requires traffic data review by the traffic data reviewer to ensure that the VMT total and by each vehicle class, speed bin and road type for both No-Build and Build conditions make sense. Input data such as calculated volumes, vehicle classifications, travel demand model scenario assumptions, and speed profile/RITIS information should be checked. The resulting VMT fractions should also be checked to make sure that they sum properly to the total (e.g. 100%) across all the major input categories: road type, vehicle class, and speed bin. Since these efforts involve many data elements, where possible, reasonableness checking should be automated.

Traffic reasonableness checks:

- Model limitations should be documented. Are there key relationships, feedback, or effects that limit the overall completeness? Is there bias in the direction and magnitude that prevent certain results from being used?
- Does the trend based on the comparison between the no-build and build conditions reflect the expectation from the project? If not, check that the analysis process was followed correctly, investigate further, and consult with other staff or project/local contacts
- Is total VMT increasing over the years for both automobiles and trucks? More lane-miles will increase VMT, reduced lane miles will decrease VMT.
- Within each vehicle class category, do the VMT and speed trends make sense? Are the changes the same magnitude and direction across all classes?
- Relative magnitude of VMT increase/decrease – The largest VMT change should reflect the largest capacity or travel time change. Mainline lane-mile changes should be larger than auxiliary lane change which in turn are larger than operational travel-time-only changes.

The results of the traffic review must be documented. Ideally, the traffic review portion would be documented in a technical memorandum clearly indicating what was checked and any changes that were post-review. This could be done in a table or checklist as part of an appendix.

After the traffic review is complete, the VMT file is passed to the ODOT Environmental Section's Air Quality Unit for MOVES analysis. The air quality analyst will provide traffic data (typically done by the traffic analyst) to calculate emission rates by VMT/vehicle class, speed bin and road type to the consultant. The resulting GHG values should be compared with the VMT, speed and travel time changes to make sure changes are consistent and reasonable.

GHG reasonableness checks:

- Does the GHG impacts require the use of a combination of methods (e.g. sketch-level and the Inventory MOVES-based) to get a more complete picture?
- Are the methods capturing the same "cycle" emissions? Do some methods need to be extended to "lifecycle" emissions? Should the analysis report accumulated emissions over project life or plan horizon?
- Transfers between tools, initial results, and computed emission rates should be checked for reasonableness.

VMT & GHG reasonableness checks:

- Does the VMT and resulting GHG changing in the same direction and magnitude? Tolling assumptions, different impacts on higher emitting trucks vs. lower emitting automobiles, and toll diversion onto other roadways of different speeds may create inconsistencies.
- Is the difference between the no-build and build scenarios an actual change discernable beyond versus model random variation (i.e. noise)?
- After GHG emissions are applied, VMT and GHG may not change in the same direction and magnitude, reflecting higher emissions by trucks and speeds. Does the analysis approach miss key relationships, feedback, or effects that limit the completeness of the results that should be noted?
- VMT and GHG results should be compared and reconciled with existing/current project work and messaging

Like with the traffic review, the results of the VMT-GHG review also need to be documented showing what was checked and any inconsistencies noted. This is needed so the traffic analyst and supporting staff can review specific data elements, assumptions, or scenarios to either fix or explain through discussion on why the results are correct. Any project that has inconsistent VMT – GHG trends must be double-checked through all the analysis steps especially for any coding, assumptions, and defaults used. Each project should have the GHG changes (e.g. from no-build to build) for each project documented on whether they appear reasonable (or not because of limitations in the modeling, or data, etc.).

APPENDICES

Appendix 16A – Noise Traffic Data Request Form

Appendix 16B – Air Quality Traffic Data Request Form

Appendix 16C- Sample MOVES Traffic Data Input

Appendix 16D- Western States Guidebook Project Types & Elements